

**DEVELOPMENT, IMPLEMENTATION AND EVALUATION OF A
COMPUTER PLUS TALK TEACHING SEQUENCE TO IMPROVE
STUDENTS' UNDERSTANDING OF CHEMICAL RATE OF
REACTION: A UGANDAN CASE STUDY**

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**Submitted in accordance with the requirements for the degree of Doctor of
Philosophy**



School of Education

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I confirm that the work submitted is my own and that appropriate credit has been given
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DEDICATION

This thesis is dedicated to my parents

George Henry Odongo, 1930-2010

Joyce Akao Odongo

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ABSTRACT

This study is the first attempt to develop, implement and evaluate a computer plus talk teaching sequence with the purpose of enhancing 15-16 years old students' understanding of chemical rate of reaction concept in Uganda. A total of 247 students aged 15-16 years from two High Schools participated in the study. The experimental class (C&TA) consisted of 108 students, 51 males and 57 females while the comparison class (NTA) consisted of 139, 73 males and 66 females.

Based on recommendations in the literature that chemical rate of reaction is a difficult topic to teach and learn, I developed a research-based teaching sequence on chemical rate of reaction using a computer and talk approach, implemented this teaching sequence in Uganda and evaluated this teaching sequence by making comparisons with 'normal' teaching. Research-based teaching is a novel approach to pedagogy in Uganda, so I had to train the experimental teacher for two weeks. The trainings were very important in ensuring that the teacher acquired working knowledge about C&TA prior to the actual implementation in the classroom.

The study investigated whether the students who followed the C&TA had better understanding of the difficult areas (also called learning demands): (1) rate of reaction, (2) proper orientation of reacting particles, (3) the relationships between activation energy and chemical rate of reaction, (4) the effect of temperature and (5) the effect of concentration of reactants on chemical rate of reaction. I undertook a quasi-experimental study to assess the C&TA's impact. I analysed classroom interactions to inform discussion of what influenced its effectiveness, and inform decisions about whether the C&TA sequence was implemented consistently with its design.

The statistical analyses of the post-test scores show that the experimental class (C&TA) students demonstrated better understanding across all the five difficult areas compared to the comparison class (NTA) students. The findings indicate that female students benefited (a little) more from the intervention than male students. The results show that the C&TA intervention had an effect of the same magnitude across the ability range. Further findings show that C&TA support teaching large classes and that it is possible for a teacher in Uganda to teach in a more interactive/ dialogic way with relatively little training on the communicative approaches.

Evidence shows that aspects of the C&TA teaching sequence that were effective in supporting students' learning of chemical rate of reaction were: computer simulations and modelling, teaching goals, worksheets, social constructivist perspective on teaching and learning along with the communicative approaches.

Further findings show varied benefits and challenges from using C&TA. The teacher and students perceived C&TA as a good method of teaching and learning. Indicating that the use of a computer and talk approach (C&TA) is a feasible alternative teaching approach to didactic teaching in science classrooms in Uganda. It also suggests that C&TA could be adopted for teaching and learning other subjects.

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LIST OF ABBREVIATIONS

BERA: British Educational Research Association

CA: Communicative approach

CAI: Computer-Assisted Instruction

CAnI: Computer-Animated instruction

CLI: Conventional Lecture Instruction

C&TA: Computer and Talk Approach

CVI: Content Validity Index

I/A: Interactive/ Authoritative

I/D: Interactive/Dialogic

MoE&S: Ministry of Education and Sports

NCDC: National Curriculum Development Centre

UCE: Uganda Certificate of Education

UNCST: Uganda National Council of Science and Technology

NI/A: Non-Interactive/ Authoritative

NI/D: Non-Interactive/ Dialogic

NTA: Normal Teaching Approach

ZPD: Zone of Proximal Development

CHAPTER ONE

1 BACKGROUND OF THIS STUDY

1.1 Introduction

The purpose of this chapter is to present the background problems addressed in this study, the Ugandan context in which the study has taken place, and to give general descriptions of the thesis chapters.

This study centres on the innovative teaching and learning of the chemical rate of reaction concept supported by the use of computer simulations and modelling, along with talk approaches in a Ugandan context. This study is the first attempt in Uganda to develop, implement and evaluate a computer plus talk teaching sequence with the purpose of enhancing 15 to 16 year old students' understanding of the chemical rate of reaction concept. Following my experience as a high school chemistry teacher, the chemical rate of reaction concept poses challenges to students because of its abstract nature for a whole variety of reasons which will become apparent throughout this thesis. Previous studies also show that chemical rate of reaction is a difficult topic to teach and learn (see Chapter Two for a detailed discussion). The design of the teaching sequence draws upon research evidence and theories about science learning.

This thesis, therefore, describes the development, implementation and evaluation of a computer plus talk approach (C&TA) teaching of six lessons which covers content on chemical rate of reaction for Ugandan students, aged 15 to 16. The teaching sequence draws on the social constructivist perspective of teaching and learning science, as well as empirical studies of students' understanding of the rate of chemical reaction, and their responses to teaching rate of reaction (including the use of computers).

1.2 The context of the study

The study was conducted in Uganda, a country with little past history of science education research. The country is a presidential republic and is governed by a democratic constitution. It has three arms of government: the executive, judiciary and legislative. The President and the Cabinet are the executive heads of the country, and the parliament is endowed with legislative powers. It is a country that is home to many different ethnic groups, none of whom form a majority of the population. Around 40 different languages are regularly and currently in use in the country, but in school the language spoken is English.

The selected high schools for the research are from the central region of Uganda (Kampala and Luwero districts), and are approximately 32 kilometres from each other.

The central districts are the economic hubs of the country and therefore have well equipped school computer laboratories compared to schools in other less developed and poorer regions of the country.

1.2.1 Educational system in Uganda

The formal educational system in Uganda has a structure of seven years of primary education, six years of secondary education (divided into four years of lower secondary and two years of upper secondary school), and three to five years of post-secondary education. The system has existed since the early 1960s.

The education system lays much emphasis on students' academic abilities, but most schools focus on the quantity of the content covered, rather than the quality of the students' learning.

1.2.2 Perspective of teaching in Uganda

Drawing from my experience, generally teaching styles in Uganda are guided by behaviourist theories of learning, emphasised during teacher training in colleges and universities. The lesson objectives are spelled out in terms of what the learner is expected to perform at the end of each lesson. Teaching is portrayed as a process where the teacher is responsible for presenting the teaching materials, with no recognition being given to the role of learners in coming to understand the material. I use the term 'didactic' to refer to such teaching.

The teaching process is therefore didactic and involves large classes with teachers controlling learning contents and the entire class session. Normally learning is passive and less interactive in science classrooms. From my experience as a science subject teacher, this method of teaching is advantageous in the sense that it enables more subject content to be covered within a short period. On the other hand, because the teacher controls the entire class, change in activity which underpins active teaching and learning science are rarely implemented. Thus, in the classroom environment, the teacher is the 'guru' of all knowledge, a source of all the information, making points, writing ideas on the chalkboard and conducting scientific demonstrations. The students are given little room to respond to factual questions posed by the teacher and in return receive positive reinforcement or rewards according to the behaviourist theory of learning. A limited number of practical activities are conducted by students to provide an opportunity for drill and practice, with individual students required to make observations, and in most cases there is no sharing of results or holding discussions. As such, small group teaching within a large class, which allows students to learn

activity through interaction and discussion within their groups, has not been used to benefit teaching and learning science in Uganda.

These are some of the reasons why I was compelled to conduct a study on teaching which is more interactive, and draws more on the learners' prior ideas about the scientific concept as such students' ideas are often "resistant to change" (Driver, 1989, p.481).

1.3 The aims of the study

My focus in this study is to explore the use of a computer and talk approach (C&TA) as an alternative teaching approach to didactic teaching in science classrooms. I developed a research-based teaching sequence on chemical rate of reaction using a computer and talk approach (C&TA), which was implemented in Uganda and evaluated by making comparisons with 'normal' teaching.

This teaching sequence involved the use of computers to simulate and model behaviours of molecules during chemical reactions, and provided a platform for classroom discussions as students interacted with the learning materials.

The lessons involved both children and teachers talking freely about the chemistry concept, chemical rate of reaction. In this way the designed teaching sequence was based on the reviewed literature on the importance of 'talk' in making the meaning of learning contents in a classroom (see Chapter Two for a detailed discussion). The aims of C&TA were to enhance understanding of chemical rate of reaction by high school children aged 15 to 16 in Uganda. If successful, the selected topic and the developed teaching scheme ought to serve as a teaching model upon which future design sequences for teaching science concepts using computer programs can be adopted.

1.4 Research questions

Building on the general aims, the study addresses four research questions:

1. Does the computer and talk approach improve the students' level of understanding of chemical rate of reaction in this Ugandan high school context in comparison with students following 'normal' teaching?
2. Which parts of the teaching sequence are effective in supporting learning, and which are less effective?
3. What are the major benefits and challenges of the implementation of a computer and talk approach in the Ugandan context?
4. What are the teacher and students' perceptions of the computer and talk approach?

1.5 The study in outline

The study was constructed through three phases:

Phase 1: Design of the C&TA teaching sequence (see Chapter Four)

Phase 2: Implementation of the teaching sequence (see section 3.6)

Phase 3: Evaluation of the impact of the teaching sequence (see section 3.7)

The design phase involved analysing the Ugandan chemistry curriculum to identify the target concepts to be taught, and how they relate to each other. This was followed by reviewing empirical evidence about students' characteristic ways of thinking when introduced to teaching about chemical rate of reaction. The next step was to identify the difficulties that learners appear to have in understanding teaching about rate of reaction by comparing the two in terms of the concepts used to generate explanations, their epistemology and ontology, which give 'the learning demands'. Finally, I drafted computer plus talk teaching instructions to address each aspect of the identified learning demands. Computer simulations were used to simplify the understanding of microscopic behaviour of atoms during chemical reaction while computer modelling (spreadsheets) was used to provide a virtual environment for the students to perform investigations (testing their theories and hypotheses) on the relationship between temperature, concentrations and chemical rate of reaction. This was to enhance students' understanding of how a change in temperature or concentration affects the chemical rate of reaction.

The design phase of the study, together with the rationale for the implementation phase, is presented in Chapters Two, Three and Four of the thesis.

Chapter Two presents reviews of literature related to the study. The first section presents reviews of literature on students' understandings of the basic ideas of collision theory, as related to chemical reactions. The second section presents reviews of literature on the theoretical perspectives on learning: sociocultural approach, constructivist approach including the importance of talk in teaching-learning science, and drawing on all these perspectives, a Social Constructivist Approach was taken in this research. The third section presents reviews of literature on the capabilities of computer simulations and modelling (spreadsheets) to facilitate science education; research evidence from teaching chemistry concepts; implications for teaching chemical rate of reaction, and the conceptual framework designed for this study.

Chapter Three presents the research methodology, including research aims, research questions, the design of the study, sample selection, data collection methods, validity and reliability of research instruments, data analysis procedures, ethical

considerations, the timeline of the study and methodological issues concerning the approaches to data analysis.

Chapter Four presents the design and development of the C&TA teaching sequence which includes the design of the teaching, analysis of chemistry syllabus for ordinary level and text books, teaching goals, identification of learning demands and drafting instructional design suitable for computer simulations and modelling (spreadsheets) along with talk approaches to support the teaching and learning of the chemical rate of reaction.

The implementation phase was conducted in Uganda as a case study. It was a quasi-experimental study intended to discover whether the designed teaching approach (in this case, C&TA) would make significant enhancements to students' understanding, compared to what students might otherwise reasonably have been expected to achieve. Therefore, one school was selected to serve as an experimental class, and a comparison class with similar academic ability who followed normal teaching approaches (NTA) was selected from another school for comparison purposes.

The evaluation phase involved the use of a base-line test before the teaching, as a diagnostic test to establish equivalence levels of understanding of the students from the selected sample schools. After the teaching, a post-test was used to compare students' performance in the class that followed the C&TA teaching sequence, with the class that followed the normal classroom teaching (NTA).

Analyses of the results of the base-line test and post-test were conducted by comparing group mean scores using independent t-test. Also, correlation (Pearson r) tests were conducted within the groups to ascertain if the students' initial understandings had a statistically and practically significant influence on their final post-test scores after the intervention. General Linear Model (GLM) procedures to model the post test scores were conducted based on base-line test, group and gender, to determine if their effects predicted the final students' achievement levels.

The classroom observations (interactions) data were collected in order to allow for comparisons to show how different the experimental and comparison teaching actually were, with regard to the design features in C&TA (for example, dialogic talk). This would enable advancement of hypotheses about the likely potential causes of any differences noted in the post-test results.

For the C&TA to be useful across schools in Uganda, science teachers must see it as feasible to implement, and their students must view it as productive. Therefore, in the study, the interview data were also collected to explore students understanding immediately after each teaching and also to gather the teacher's and students'

response to the benefits and challenges, as well as their perceptions about C&TA compared with NTA, to teach and learn chemical rate of reaction concepts.

The evaluation phase of the study is presented in Chapters Five, Six, Seven and Eight of the thesis.

Chapter Five presents coding schemes developed for analysing students' responses in the base-line test, post-test and classroom interactions. The coding schemes for classroom analysis were developed based on a sociocultural framework to gather information on the teaching purposes, content, and approach, forms of teacher intervention and patterns of interaction from the classroom interactions, coding schemes of the interview data are also presented.

Chapter Six presents the base-line test and post-test analysis of total scores then items scores. Chapter Six compares the performance of students who followed the computer and talk approach (C&TA), to the performance of students who followed the normal teaching approach (NTA) in science classrooms in a Ugandan context.

Chapter Seven presents an analysis of classroom interactions. This chapter compares the actual teaching process in the C&TA and NTA classes.

Chapter Eight presents an analysis of the C&TA teacher's and students' interviews. This chapter covers the teacher and students' perceptions after each lesson and at the end of the intervention. The C&TA teacher and students' perspectives on major benefits, challenges, perceptions, comparison between C&TA and NTA teaching approaches are presented.

Chapter Nine presents discussions on findings regarding the main research investigation and broader aspects of the C&TA teaching sequences; its benefits, challenges and perceptions of the teacher and students. Thus, the first section will consider the extent to which students who receive C&TA understand better the concept of chemical rate of reaction, in comparison to students who follow the NTA. The second section will deal with the effectiveness of C&TA in enhancing students' understanding of chemical rate of reaction in comparison to NTA. The third section will cover aspects such as the benefits, challenges and perceptions of the teacher and students about C&TA teaching sequence.

The thesis concludes in Chapter Ten with brief summary of the full study, the contributions of the study to science education, limitations of the study, implications for science education and further research, and the final reflections on what I have gained from the research process.

In the next chapter, I present what the international literature tells us about students' understanding when learning the chemical rate of reaction concept in high schools.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

In this chapter, I present reviews of literature related to the study. The first section presents reviews of literature on students' understandings of the basic ideas of collision theory, as related to chemical reactions. The second section presents reviews of literature on the theoretical perspectives on learning: sociocultural approach, constructivist approach including the importance of talk in teaching-learning science, and drawing on all these perspectives, a Social Constructivist Approach was taken in this thesis. The third section presents reviews of literature on the capabilities of computer simulations and modelling (spreadsheets) to facilitate science education, research evidence from teaching chemistry concepts, implications of teaching chemical rate of reaction, and the conceptual framework designed for this study.

2.2 Review of literature on students' understandings of chemical rate of reaction

This section offers a review of the literature on students' understandings of the basic ideas of collision theory as related to chemical reactions. It also looks at the effects of temperature, activation energy and concentration of reactants on chemical rate of reaction. I will begin by making the general statement that students, in my experience, often find it difficult to understand and explain in terms of collision theory how activation energy, temperature and reactant concentration changes affect chemical rate of reaction. In the literature, the number of studies related to students' ideas of chemical rate of reactions is limited, with many dating back to the late 1980s, and just a few from recent studies. For example, Gorodetsky & Gussarksy, 1986; Cachapuz & Maskill, 1987; Van Driel & De Vos, 1989a; Justi & Ruas, 1997; Chuephangam, 2000; Bozkoyun, 2004; AlgebraLAB, 2010; Cakmakci et al., 2006 and Cakmakci, 2005, 2010. All of these studies indicate that throughout this period of time from the 1980s to recent day, students often continue to develop views on chemical rate of reactions which are not consistent with the scientific point of view.

2.2.1 Insights into students' understandings of the collision theory of rates of reaction

This sub-section presents students' understandings of the basic ideas that chemical reactions are caused by collisions between particles of reactants.

In a broad review of chemical education, Gilbert et al. (2002) refer to a study by Cachapuz and Maskill (1987) on chemical kinetics - the idea of collision. The study focused on the ability of students (aged 15 to 16 years old) to explain the term 'collision'. The students' ideas about collisions were investigated by means of word association tests. The results obtained indicated that the majority of students with high achievement abilities associated words such as 'reaction', 'atom', 'speed', and 'molecule' to the stimulus word 'collision', only 50% of the low achieving students associated 'molecule' with collision. In the group of low achievers, the words associated mainly originated from *everyday* meanings: 'accident', 'crash', 'bang', and 'car'. According to the Gilbert et al. (2002) review, Cachapuz and Maskill argued that such a "difference may be explained by the very abstract nature of collisions of atoms in sub-microscopic level, abstract entities in explaining the real and visible changes in reaction rates" (p. 297-298). Gilbert et al. (2002) further explained that:

"low achieving students may be able to understand the occurrence of changes in reaction rate due to changes in the physical dimensions of solid reactants or the concentrations of dissolved reactants, but only using superficial, inconsistent, everyday less relevant terms instead of a sub-micro level 'collision' mode" (p.298).

Gilbert et al. (2002) also refer to a study by Justi and Ruas (1997) of 16 year old students' ideas about the nature of matter, the concept of chemical reaction and how a reaction occurs. The study focused on which ideas students use to explain why chemical reactions take place at different rates. The results indicated that half of the student sample (n=42) expressed a continuous view of the matter, 38% believed a chemical reaction is a result of particle interaction, while 80% of the students did not express any ideas concerning the dynamic nature of particles. The results meant that students did not use any ideas of the particles being constantly in motion (particulate model).

"Thus, when asked to explain why different chemical reactions occur at different rates, 59% of the students did not use the ideas of the particles being constantly in motion / energetic (particulate model) to explain why chemical reaction takes place at different rates. On the other hand, when the students were asked to explain how reactant concentration, temperature, and catalysts influence the rate of chemical reactions, the majority did use the collision particle model in an appropriate manner" (p.297).

In this study, it seemed the students did not have ideas or an understanding of the particulate nature of matter which explains that matter composes of large molecules consisting of small particles or atoms which are in constant motion. Students should have used the idea of such particles in explaining why chemical reactions take place at different rates. Say for example, in the gaseous state the particles are completely separate, they move very fast and collisions are more frequent which results in more

chemical reactions and the rate of reaction is higher. While in liquid, because of weak forces between particles, movements of particles are slower, the collisions are not as frequent as in gaseous states and therefore chemical reaction rates are moderate. In solid, because of stronger forces that hold the particles, the particles are fixed in position they do not move apart from vibrating, collisions tend to be less frequent and so chemical reaction rates are lower.

Chuephangam's (2000) investigation of misconceptions in the chemical rate of reaction of Mathayom Suka five Grade 11 students (age 16 to 18) using a test in Thailand, revealed that 11.7 - 21.5% of the students' answers were misconceived. A total of 177 students in the public secondary schools during their second semester of the academic year participated in the study. The results of the study indicated that most common misconceptions (21.5%) were about explanations of factors which affect chemical rate of reactions; 6.2 - 18.9% of the misconceptions were on the meaning of the chemical rate of reactions. Unfortunately no further details were provided in this study about the nature of the misconceptions.

Cakmakci, et al. (2005; 2006; 2010) investigated the understandings of 108 high school students (SS) (aged 15 to 16 years old), 48 university first-year students (UF) and 35 university third-year (UT) students' conceptions of chemical kinetics in Turkey. Students' ideas were obtained through interviews and written responses after formal classroom teaching of chemical kinetics. The results indicated that:

“Around 33, 29, and 3% of SS, UF, and UT students respectively, believed that reaction rate is the period of time taken for a reaction to occur, reaction rate increases as the reaction progresses (23, 13, and 3% of SS, UF, and UT, respectively), reaction rate is constant (19, 6, and 6% of SS, UF, and UT, respectively), reaction rate increases up to a maximum value, and remains constant at this value (8, 25, and 54% of SS, UF, and UT, respectively), or the reaction rate increases up to a maximum value and from this level decreases gradually to zero when the limiting reactant is consumed (2, 10, and 9% of SS, UF, and UT, respectively) were quite common among both secondary school and undergraduate students” (2010:450-451).

The results of this study indicated that students have difficulty in understanding that chemical rate of reactions are normally higher at the beginning of the reaction and decrease as the reaction comes to completion or a stop. In fact, this study further highlights the need to address students' learning difficulties of the chemical rate of reactions at the secondary level, as it is evident that a number of students from the secondary school showed a slightly higher percentage of misconceptions about chemical rate of reaction.

Furthermore in the US, Mainland high school AlgebraLAB Project, an online learning environment that focuses on building links between science and basic mathematics in their project report (AlgebraLAB, 2010), the point is made that students hold basic ideas that chemical reactions are caused by the collision of particles. It further explained that “many students have the misconception that every collision leads to the formation of product, when the truth of the matter is that many collisions do not go anywhere”. It is cited in this project that “a huge percentage of molecules within a sample may collide without ever turning into products, and when creating a mental picture of a successful collision, students must envision molecules that possess both proper orientation and a sufficient amount of energy”. Proper orientation means reacting atoms must be aligned in such a way that they bond together. For example, consider the chemical reaction between NO_3 and CO to produce CO_2 and NO_2



In this reaction, an atom of O is transferred from an NO_3 molecule to a CO molecule. The collision orientation most favourable for these to occur is that the O atom from NO_3 must be near a C atom from the CO molecule at the moment of collision. This is illustrated in the diagram below. The first pair of diagrams shows that even with the correct orientation, colliding molecules with low energy do not result in the formation of the chemical product. The second diagram shows that even with enough energy, molecules with incorrect orientation bounce back without reacting and forming the chemical product. The third diagram shows that molecules with enough energy and correct orientation react and form a new product on collision.

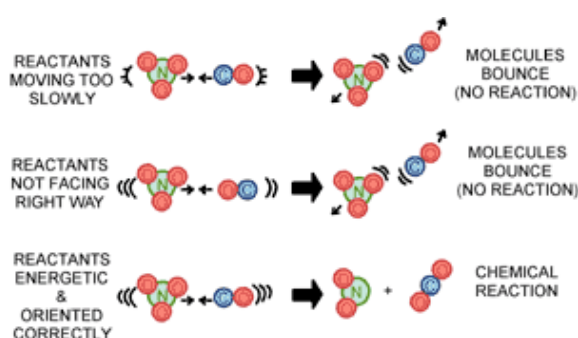


Figure 2-1: Proper orientation of reacting molecules (John, 2002)

2.2.2 Insights into students' understandings of the effect of temperature on the rate of reaction

In this sub-section, I present students' understandings of the effect of temperature on chemical reactions from research studies conducted in late 1980s, as well as a recent study.

In the literature Van Driel and De Vos, 1989a as cited in Gilbert et al. 2002, investigated how students aged 15 to 16 used a collision model to explain chemical rate of reactions after they have performed experiments. When asked to explain the increase of reaction rates at higher temperatures, most students relate 'faster moving particles' with 'more collisions' or 'a higher probability of collisions'. This is consistent with the scientific point of view. Most students also reasoned that when fast moving particles collide with each other, it is very likely that these particles will bounce back without a change or reaction occurring. Some students added that the molecules would not have enough time to exchange atoms. In the review by Gilbert et al. (2002), it is not clear whatever numbers of students were represented by the above ideas.

A further study from around this time was carried out by Gorodetsky and Gussarksy (1986). This examined 12th Grade (aged 17 to 18 years old) high school students' misconceptions in a related area chemical equilibrium reaction. The students were assessed on the taught concept of factors influencing chemical equilibrium reactions; effect of catalyst, temperature and activation energy. The test was composed of multiple choice questions mixed with correct answers and a distracter, 'I do not know', designed to reveal a particular misconception was then administered. The results indicated that 25% of the students had misconceptions about temperature, and perceived the "mediating concept 'temperature' as giving more products by increasing the rate of the reaction" (p.438). In other words, these findings suggest that more products are formed with an increase in temperature. This reasoning misses the point that increasing temperature means the molecules gain kinetic energy and move faster. Thus, increasing frequency of collisions and increased collisions means more chances of reactions, so reaction takes place quicker. This is a kinetic theory which forms the basis for the scientific view for the effect of temperature on chemical reactions.

In the study outlined earlier, Cakmakci (2005, 2010) found that 5% of the students believed that the rate of an exothermic reaction is not affected by a rise in temperature. It was noted that most of these students believed that increasing temperature

increases the rate of endothermic reaction. According to Cakmakci, students reasoned that:

“Since the reaction gives out heat, a rise in temperature would not affect the reaction rate. However, if a reaction took heat (from its surroundings); the reaction rate would increase with temperature. Because a rise in temperature increases the rate of a reaction that takes in heat” This alternative conception mostly arose because students tried to interpret the reaction rate and extent of the reaction by using Le Chatelier's principle and thus confused the concept of reaction rate and chemical equilibrium” (Cakmakci, 2010, p. 452).

In fact, the scientific view is that for chemical equilibrium reactions, since endothermic reactions occur with absorption of heat from the surrounding, the forward reactions are favoured by an increase in temperature and for exothermic reactions, since the forward reactions occur by release of heat to the surrounding, increasing temperature favours backward reactions.

2.2.3 Insight into students' understandings of the effect of activation energy on rate of reaction

This sub-section presents students' understandings of activation energy and its relationship to chemical reactions. In review, limited studies have been conducted on students' understandings of the effect of activation energy. In the few articles I have come across, the evidence shows that students have difficulty in defining and explaining how activation energy affects chemical rate of reaction. For example, the literature of Bozkoyun (2004), as cited in Calik, (2010) listed two students' alternative ideas about activation energy (E_a), as follows:

- Activation energy does not affect the rate of reaction.
- Activation energy is the highest point in number of molecules and kinetic energy graph.

Similar students' ideas were also reported in the same study of Cakmakci (2010) as outlined earlier, in which the results revealed that:

“A few secondary school students had difficulties in interpreting an energy profile diagram for a reaction and associating it with theoretical models. Such students interpreted the diagram based on surface features of the diagram; for example, they simply stated that “activation energy is the highest point on the diagram” or “activation energy is the peak of the energy profile diagram” (p.453).

These ideas apparently develop in students since the term 'activation energy' is usually explained using an energy graph or diagram below.

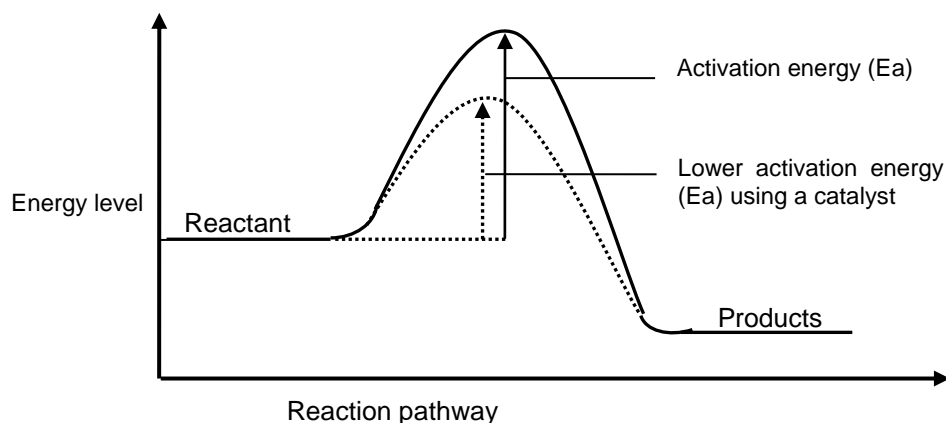


Figure 2-2: Energy level diagram for chemical reaction

Students easily misinterpret the graphical symbolic representation of activation energy and they often have difficulties in explaining the energy profile diagram for a reaction and linking it with theoretical representation. In fact the concept of activation energy is mainly presented at the symbolic level (drawing upon an energy profile diagram), and also the particulate level (the transition-state). At the peak of the activation energy hump, the reactants are in the transition state, halfway between being reactants and forming products. On an energy diagram, this is the difference in energy levels between the reactants and the transition state.

According to Bozkoyun (2004) as cited by Calik (2010), students believe that activation energy is heat energy. Bozkoyun argued that such confusion may be due to the students' misunderstanding about heat and temperature. Similar results were reported by Cakmakci (2010), who reported that students show a lack of understanding of activation energy and its connection to the rate of reaction.

According to Cakmakci, secondary school students think that:

“Activation energy is the energy released after a reaction. ...The second reaction (with a higher Ea) is faster, because more energy is released. The faster a reaction is, the more energy is released” Cakmakci (2010: 453).

However, according to chemistry concepts the activation energy is the minimum kinetic energy that reactants must go through to form products, and activation energy can be thought of as a barrier that reactants must overcome in order to reach the transition state. From a scientific point of view, the activation energy barrier can be lowered when a catalyst is present. Thus, catalysts provide an alternate energy pathway in which the potential energy barrier between reactants and products is lowered. For a chemical

reaction to proceed at a reasonable rate, the reacting molecules should possess energy equal to or greater than the activation energy.

2.2.4 Insights into students' understandings of the effect of concentration on rate of reaction

This sub-section presents students' understandings of the effect of reactant concentration and its relationship to chemical reactions. In the study outlined earlier, Van Driel and De Vos (1989a) found that students held various explanations of the effect of concentration. For example, to explain the effect of concentration, students most commonly and correctly reasoned that "fewer particles (per unit of volume) would lead to fewer collisions (per unit of time)". Other students emphasised that in a dilute solution particles are far apart from each other, but did not develop this line of argument further.

In the study outlined earlier, Cakmakci (2005, 2006, and 2010) students' conceptions of the relationship between concentration and the rate of reaction showed that:

"The majority of the SS, one-half of the UF, and around one-third of the UT responses included scientifically incorrect ideas. For instance, they argued that, there is a linear relationship between the concentration of reactants and reaction rate, and they did not anticipate the order of the reaction or the role of the solid catalyst" (p.1806).

Firstly, this reasoning is only true for elementary reactions where reaction occurs in one step. However, it is not informed by scientific collision theory which is used to explain chemical rate of reaction. Scientifically, increasing the concentration of a reactant simply means there are more particles which may collide and so react. More collisions mean a faster reaction.

Secondly, in this case, the students attempted to answer the question based on a rate equation, but they did not consider some of the variables in the rate equation, i.e., the reaction order. Reaction order is defined as the power of concentration in the rate law expression. The rate law is an expression indicating how the rate depends on the concentrations of the reactants and catalysts. The relationship between rate and concentration and the order of a reaction are experimentally determined and in this study, "students were not aware" (Cakmakci, 2010, p.454). These aspects of reaction will not be dealt with in this study, since I will basically be looking at the elementary reactions.

Students also assume that mixing chemicals results in a constant reaction rate. He argued that students largely do not understand the importance of concentration. His results also indicated that students believed that when the concentration varies there is no visual change, such as colour changes or bubbles that accompany it and are surprised to see the speed of the reaction change each time.

2.3 Summary of students' understandings of chemical rate of reaction

From the above review four key aspects about students' understandings of chemical rate of reaction have been identified as follows:

2.3.1 Aspects students often understand which are consistent with the scientific view

- The particles of a substance move faster when it is heated
- Faster moving particles leads to more collisions
- Faster moving particles lead to a higher probability of collision
- A rise in temperature increases the rate of endothermic reactions

2.3.2 Common misconceptions/difficulties in this area:

- Problems with using kinetic theory to explain behaviour of atoms at the molecular level and relating these to macro and symbolic levels
- Every collision leads to formation of a product
- Fast moving particles may lead to particles bouncing off each other without a reaction occurring: collision is too quick and energetic
- Rate of reaction is constant throughout a reaction
- Activation energy is the energy released after a reaction
- Activation energy is the peak of the energy profile diagram

Common student thinking not informed by collision theory

- Increasing temperature increases the amount of product
- The rate of a reaction is directly proportional to the concentration of reactants

For the purpose of this study, students' misconception about equilibrium reactions (endothermic and exothermic) was not dealt with as emphasis was laid on the students' alternative conceptions of the rate of reaction in section **2.3.2** at the lower level of high school.

2.4 Why understanding chemical rate of reaction is challenging

From the review, it is clear that students often do not understand the sub-microscopic representations which relates to collision theory and the behaviour of the reacting atoms during the chemical reaction. Refer back to the earlier example in section 2.2.1.

For that reason, to understand this concept, Johnstone (1982; 1991) suggested a theoretical model explaining that teaching chemistry requires an understanding of the behaviour of molecules at a molecular level, which is subsequently explained at macroscopic and symbolic levels.

Johnstone's theoretical model provides a primary framework for the representation of chemical matter and understanding of chemistry. This representation can be illustrated as shown in the **Figure 2-3** below.

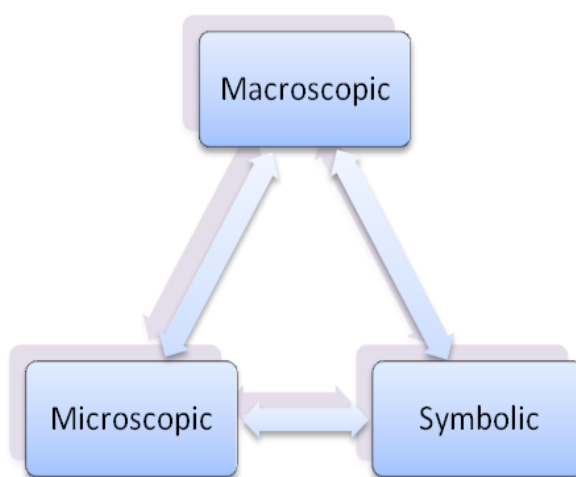


Figure 2-3: Conceptual understanding of chemistry: A model for learning (Johnstone, 1982/1991)

These are frequently referred to as the macroscopic (physical phenomena), microscopic (particles or atoms), and symbolic levels (chemical symbols, equations and formulae).

In light of Johnstone's theoretical model above, Nahum et al. (2004) have argued that students normally operate in the macroscopic level of matter, and do not simply follow links between the macroscopic and microscopic levels. They further explained that, because of this, chemical concepts become "very abstract and students find it difficult to explain chemical phenomena" (p.302).

Such a similar line of argument is held by Gabel (1996):

"The complexity of chemistry has implications for the teaching of chemistry today. We know that chemistry is a very complex subject from both the research on problem solving and misconceptions ...and from our own experience...Students

possess these misconceptions not only because chemistry is complex, but also because of the way the concepts are taught” (p. 43).

Gabel (1996) argues that classroom teachers often move without knowing from one level (microscopic, macroscopic and symbolic representation) to another during teaching. The different teaching approaches often applied do not help students to understand the relationship between the three levels, and yet each level may be subject to more than one interpretation. This makes students easily confused about the chemistry concepts (Nahum et al., 2004).

In relation to this, understanding the chemical rate of reaction requires the students to conceptualise what happens at the microscopic level in order to link it to the macroscopic level through proper symbolic representation. In doing so, students are expected to envision and interpret symbolic representations for the chemical rate of reaction in order to gain a proper understanding of the concept.

2.5 Teaching approaches adopted for chemical rate of reaction

In this section, I present the different approaches that have been used in attempts to improve the teaching and learning of chemical rate of reaction.

Many authors and researchers have proposed ways of remedying students' learning difficulties of the chemical rate of reaction. For example, Van Driel (2002) used laboratory work; Tezcan and Yilmaz (2003) reported the use of computer aided instruction with commercial software (Akademedia 99), but their study did not take the students' alternative conceptions into consideration. Likewise, Fortman (1994) used a pictorial analogy to facilitate students' understanding of the effect of concentration on 'rate of reaction'; however, he did not investigate its effectiveness.

Bozkoyun (2004) as cited by Calik (2010) examined the effectiveness of conceptual change using text oriented instruction, accompanied with analogies over traditionally designed chemistry instruction on 10th Grade students' understanding of rate of reaction concepts, and attitudes towards chemistry as a school subject. The study showed that conceptual change using text oriented instruction accompanied with analogies led to a better understanding of rate of reaction concepts, and was also better in the elimination of students' misconceptions than traditional chemistry instruction. This research also indicated that conceptual change texts and discussion about the texts addressed the students' misconceptions. Conceptual change text oriented instruction accompanied with analogies provides alternative strategy to clarify students' misconceptions in chemistry concepts.

Van Driel (2002) used small group discussion and hands-on experiments with students in the first year of chemical education (aged 14 to 15 years). The students performed and discussed the experiments in small groups (three to four students per group), guided by questions in the course material, in order to facilitate the process of explaining the observations. The students observed the appearance of iodine, resulting in a brown colour, under various conditions (i.e., temperatures ranging from 5°C to 60 °C; different initial concentrations of the peroxodisulphate solution). The students were then invited to explain their observations in corpuscular terms.

Van Driel argues that the corpuscular conceptions in the context of chemical kinetics seem to have the potential to move students from primitive corpuscular views towards more scientifically acceptable views. Although he was quick to recognise the limitations of young students' abilities to reason in corpuscular terms, which requires them to argue from a hypothesis which is not based on empirical observations, saying he was convinced that these students could gradually learn to become more proficient in using corpuscular models as explanatory tools. He further argued that the students' explanations at this level contained deficiencies from a scientific perspective, and also argued that he would prefer this approach in chemistry courses in secondary school to an approach which merely leads to rote learning.

My argument is that in this approach of corpuscular conceptions, Van Driel (2002), seemed to have ignored the importance of the teacher in helping the students to gain meanings of the scientific ideas of chemical rate of reaction. This point in this study was addressed through the dialogic teaching and the communicative approaches.

Chairam et al. (2009) used inquiry-based experiment for chemical kinetics that incorporated the use of the *prediction–observation–explanation* (POE) sequence to enhance Thai students' learning of chemical kinetics. Students with an age range of 18 to 19 years were asked to design the experimental procedure themselves, in order to investigate the reaction of acids and bases. A number of variables were investigated here by changing each separately, while maintaining all others constant, including solid surface area, concentration, temperature and type of acid. Overall, the research findings suggest that most students had a good understanding of chemical kinetics. They were able to explain the changes in the rate of a chemical reaction, and also developed a better conceptual understanding of chemical kinetics, both qualitatively

and quantitatively. Whereas this study claimed an improved understanding of chemical kinetics, I would argue that it actually said very little about what actually happened during the chemical reaction at the sub-microscopic level, which is impossible to observe in the reaction solutions. In addition, the nature of the method chosen, inquiry-based though supported by a *social constructivist approach*, lacked the teachers' support in working through the students' misconceptions. That is why in this study, I used computer simulations and modelling which not only provided opportunity for the students to discuss their ideas, but also visualise what actually occurs during the chemical reactions. This was also supported by a *social constructivist approach*, using dialogic teaching and communicative approaches to ensure that the students' misconceptions were dealt with by the teacher.

Gilbert et al. (2002) observed one common issue across all the types of proposals that have been made for the improvement of students' learning of the chemical rate of reaction. That is, "there has been no systematic research into the use and evaluation of such proposals. Sometimes, it seems that the authors have actually implemented their proposals, but there has been no accompanying inquiry into their effectiveness in promoting students' meaningful learning". He then noted that, assuming a constructive view of learning, in which teachers create situations for an active engagement with students' prior knowledge, computer simulations may help students in learning several aspects of the chemical kinetics (rate of reaction). Computer assisted learning programs have been suggested as ways to present teaching models (see Reid et al, 2000).

Following on from his early study, Calik et al. (2010) used computer animation and guide sheets to make abstract concepts or phenomena 'concrete', create an interactive learning environment, foster individual learning, boost engagement with the learning of chemistry and make connections among macroscopic, microscopic and symbolic levels of representation. The study used a base-line test and post-test non-equivalent comparison group design approach and the sample consisted of 72 Turkish Grade 11 students (aged 16 to 18 years old) selected from two intact classrooms. The '*Rate of Reaction*' Concept Test comprising of 9 lead and 10 sub-questions (total 19 items) was employed.

First, the teacher handed the student guide sheets out with questions that sought to promote curiosity and draw out their prior knowledge to activate students' pre-existing

knowledge and enhance their attitudes towards chemistry education. Second, students were asked to use *computer animations* and conduct a small group discussion of three to four students by tracking the given directions in each student guide sheet. The purposes of these activities were to help students identify their own pre-existing knowledge, produce new ideas, and negotiate agreement on any disputes. They were asked to write on the student guide sheets what they discussed in groups based on the animations. Third, the teacher directly introduced the concepts and processes of rate of reaction to students. In this stage, the students attempted to develop their understanding of the concept and track their correct and incorrect knowledge claims. Through this process, the teacher led students to a deeper understanding of the concepts. Fourth, to elaborate students' conceptual understanding and skills, students used animation and attempted to extend their newly structured knowledge to obtain a deeper and broader understanding of the concept by following the given directions on each student guide sheet. They also tried to apply their understanding of the concept to additional activities. In the final phase, the teacher assessed the students' comprehension by means of questions at the bottom of each student guide sheet.

Calik et al's (2010) theoretical perspective and methodological aspects were identical to my research study but the only significant difference is that while their intervention involved the use of *computer animation*, my research intervention employed both the computer simulations and modelling, and the geographical scope (context) may be useful to researchers interested in making a comparison between the two very similar ICT tools in terms of effectiveness to improving the learning.

By drawing from Calik et al (2010)'s recommendation for the need to utilize more than one intervention model to effectively eliminate student alternative conceptions, my study made use of a combination of computer simulations and modelling supported by classroom talk in which the teacher interacts with students through interactive/dialogic or interactive/authoritative, non-interactive/authoritative approach as the teacher works with students to develop ideas in the classroom (Mortimer and Scott, 2003).

2.5.1 A review of the teaching approaches: points arising from the literature

From the review, the following key teaching strategies have been identified from the literature as approaches so far that have been employed to improve the teaching and learning of the chemical rate of reaction:

- use of computer aided instruction

- small group discussion and hands-on experiments
- use of a pictorial analogy
- use of conceptual change texts oriented instruction accompanied with analogies
- use of inquiry-based experiment
- use of computer animations

Further explorations of ICT intervention to effectively eliminate students' alternative conceptions have been recommended (see for example, Cox, 2000; Hennessy, et al. 2007; Calik et al. 2010).

In review, I have not come across any study carried out on students' learning of chemical rate of reaction using computer simulations and modelling supported by classroom talk in which the teacher interacts with students through interactive or non-interactive and dialogic or authoritative approach, to make the scientific point of view available to them, and to support them in being able to understand and apply it. I therefore used computer (simulations and modelling) and talk approach in this study. The details of this approach are outlined in **Chapter Four** of this study.

2.6 The theoretical underpinnings of the study: learning and teaching

In this section, I situate the present study within the relevant literature to provide the rationale behind the research aims, research questions and also to inform the issues presented in the discussion chapter of the thesis. The focus of the review is on the theoretical perspectives on learning, including the importance of talk in teaching-learning science, starting with socio-cultural points of view.

2.6.1 A socio-cultural perspective on learning - Vygotsky's approach

The current idea of sociocultural theory of learning comes from the work of Vygotsky (1978). The advocates for this view of learning argue that learning takes place in a social setting when a group of people collectively discuss ideas, and the individuals participating make sense of what is being discussed (see for example, Driver et al., 1994; Wells, 1999; Wertsch, 1991 & Howe, 1996). According to Tharp and Gallimore (1988):

"The sociocultural perspective has profound implications for teaching, schooling, and education. A key feature of this emergent view of human development is that higher order functions develop out of social interaction" (pp. 6-7).

Vygotsky (1978) argued that learning involves a passage from social contexts to individual understanding. Thus, we first meet new ideas in social situations where those ideas are rehearsed between people, drawing on a range of modes of

communication, such as talk, gesture, writing, visual images, and action (Lemke, 1990). Vygotsky referred to these interactions as existing on the social plane. As ideas are discussed during the social gathering, each participant is able to reflect on and make individual sense of what is being communicated. The words, gestures, and images used in the social exchanges provide the very tools needed for individual thinking. Thus, there is a transition from social to individual planes, whereby the social tools for communication become internalized and provide the means for individual thinking.

Vygotskian theory has been directly drawn upon by a number of researchers in their development of an account of science learning (see, for example, Driver et al. 1994; Hodson & Hodson, 1998; Scott, 1998; Leach & Scott, 2002, 2003; Mortimer & Scott, 2003). Sociocultural accounts of learning can be thought to be “social” in nature on two counts: first, in the sense of specifying the social origins of learning, through the interactions on the social plane, and second in recognizing the social context of the scientific community for the development of scientific knowledge. The view of scientific knowledge as a product of scientific community maps into Bakhtin’s notion of social language. That is, a social language is “a discourse peculiar to a specific stratum of society (professional, age group) within a given system at a given time” (Bakhtin, 1934/1981, p.430). Thus, science can be construed as the social language that has been developed within the scientific community. From this point of view, learning science involves learning the social language of “school science” (Leach & Scott, 2002; Mortimer & Scott, 2003).

Wertsch (1991) recommended that the different social languages that we learn represent the ‘tools’ of a meditational tool kit, “which can be used for talking and thinking as the situation demands”. Furthermore, Wertsch suggested that “children do not stop using perspectives grounded in everyday concepts and questions after they master scientific discourse” (1991, p.118). Thus, everyday or spontaneous (Vygotsky, 1934/1987), ways of talking and thinking make up an “everyday social language”. According to Scott, et al (2007) Wertsch saw the learner developing disciplinary social languages alongside these everyday ways of talking and thinking.

Following this line of argument, Mortimer and Scott (2003) view learning science in the school setting as “being introduced to the tools and practices of a school science language, and coming to see how these might be applied to diverse social,

technological and environmental contexts” (p.16). Driver (1989:482) makes the same point:

“Learning science...is seen to involve more than the individual making sense of his or her personal experiences but also being initiated into the ‘ways of seeing’ which have been established and found to be fruitful by the scientific community. Such ‘ways of seeing’ cannot be ‘discovered’ by the learner - and if a learner happens upon the consensual viewpoint of the scientific community he or she would be unaware of the status of the ideas”.

Following this point and the earlier argument, Bakhtin’s notion that scientific knowledge is the product of the science community, it is clear that scientific knowledge is not there to be discovered through close individual scrutiny of the natural world. Furthermore, the scientific perspective is not necessarily the same as everyday ways of talking and making sense of the natural world (Hodson & Hodson, 1998). For example, the common ideas that ‘plants get food from the soil’ (common in everyday social language), differs from the scientific point of view where plants synthesize carbohydrates from water and atmospheric carbon dioxide. Thus, alternative ideas referred to about photosynthesis map into the Vygotskian notion of everyday or spontaneous ways ordinary people talk about such things, and in this respect there is a very real sense in which the scientific point of view (based on the concept of photosynthesis) offers an alternative perspective.

In making the transition from Vygotskian views of learning to perspectives on teaching, Mortimer and Scott (2003) argue that any science teaching must involve three fundamental parts or phases. The details of these phases shall be elaborated in the next section under the role of the teacher.

2.6.2 A sociocultural perspective: The role of the teacher

Following on from the ideas introduced in the previous section, Vygotskian theory emphasises that it is the job of the teacher to make scientific facts available on the social plane of the classroom, supporting students as they try to make sense of it. Vygotsky refers to the role of the teacher as being that of supporting student progress in the zone of proximal development (ZPD). The ZPD is a concept developed by Vygotsky that brings together the progress in learning of the individual student with the key role of the teacher in assisting that learning. Mortimer and Scott (2003) explained that as “the teacher is engaged in these linked processes of monitoring and responding, he or she is probing and working on the ‘gap’ between an individual student’s existing understandings and their potential level of unassisted performance”. They are working with the student in the ZPD. Therefore, drawing from Mortimer and Scott (2003), it is possible to identify three fundamental phases of science teaching.

In the **first phase**, the teacher must make (staging the scientific story) the scientific ideas available on the social plane of the classroom. The aim of the staging process is, to make the scientific point of view, or scientific story, available to students and to support their learning of it. Mortimer and Scott (2003), Ogborn et al. (1996) and Sutton (1992; 1995) have all suggested that the fundamental way in which the teacher develops the scientific story is that it must be 'persuasive' in character as the teacher seeks to convince the students of the reasonableness of the scientific story, which is being staged on the social plane of the classroom.

In the **second phase** (supporting students' internalisation); the teacher needs to assist students in making sense of, and internalizing, those ideas. The teacher acts to support students as they gradually develop meanings for new scientific concepts, and gain expertise and confidence in using them.

In the **third and final phase** (handing over responsibility to students); the teacher provides opportunities for students to try out and practice the scientific ideas for themselves, to make those ideas their own and gradually take responsibility for their independent working. As the students gain in competence and confidence, the teacher gradually hands responsibility over to them (Wood et al., 1976), recognizing their increased capability for unassisted performance. This concept of handover follows directly from the Vygotskian conceptualization of learning, as moving from assisted performance (Mortimer and Scott, 2003) to competence and confidence performance.

2.6.3 Sociocultural perspective: review

In review, it is clear that the sociocultural perspective on learning set out here emphasises the importance of social starting points for learning (the social plane). On this social plane language provides the most important tool for communication. Furthermore, according to the sociocultural perspective, the role of the teacher is central in introducing scientific ideas to the learner and dialogue, interaction and argument become internalised to form the basis for reflection, logical reasoning and the formation of new concepts.

2.6.4 Constructivist perspectives on learning

We now turn our attention to a second perspective on learning which some claim has been the most influential perspective in the last three decades. In literature, (Jenkins,

2000 as cited in Bennett, 2003) comment ‘... it has become almost impossible to escape any reference to constructivism among the papers published in the research journals’. Jenkins goes on to suggest that research work within science education draws more from constructivist perspectives. Bennett (2003) goes on to add that “whilst it is arguable that constructivism has evolved to produce something close to an underlying theory (a paradigm), it is undeniable that work in the area forms the largest research programme in science education” (p.25).

Lorsbach and Tobin (1992) have argued that constructivism is an epistemology, a theory of knowledge used to explain how we know what we know. Thus, for the constructivist, knowledge is constructed by the learner by drawing on prior knowledge and personal experience, and lies in the mind of the beholder. According to Lorsbach and Tobin, in an article explaining the implications of constructivism for practising science teachers:

“The constructivist epistemology asserts that the only tools available to a knower are the senses. It is only through seeing, hearing, touching, smelling, and tasting that an individual interacts with the environment. With these messages from the senses the individual builds a picture of the world. Therefore, constructivism asserts that knowledge resides in individuals; that knowledge cannot be transferred intact from the head of a teacher to the heads of students. The student tries to make sense of what is taught by trying to fit it with his or her experience” (Lorsbach and Tobin, 1992, p.5).

Alessi and Trollip (2001) concur and they add “constructivism holds that the only reality (or the only one that matters) is our individual interpretation of what we perceive and that knowledge is not received from outside, but that we construct knowledge in our head”. By this argument constructivists suggest that all knowledge is constructed from prior ideas. They draw their accounts from the notion that children’s minds are not a ‘blank slate’ or ‘empty vessel’ to which knowledge is simply poured into without the child making sense of it according to their current ideas.

Consequently, constructivism can be understood as presenting a learning perspective where learners through interaction with phenomena construct knowledge, develop and share meaning of a phenomenon during interactions within a social context. In the case of the school the social context is that of the classroom. Although the ideas of constructivist focused learning theory have been contested among science educators (Matthews, 1993; Phillips, 1995, Osborne, 1996; Suchting, 1992), it is generally agreed (Fensham 1992; Bentley, 1998, p.244) that constructivism has had considerable influence on curriculum thinking in science and clarifying the nature of scientific knowledge. Thus, students learn through experience with phenomena as they make

sense of them, evaluate their merits, and try to make sense of them within a socially acceptable environment (the classroom) using their prior ideas. Some constructivists (Mortimer and Scott, 2003) stress the role of social interactions in this process, while others do not. For example, the work of Driver et al (1985) focuses on the individual alternative conceptions of students and has no link to the social interactions which might underpin those individual understandings. However, most constructivists have the opinion that learning occurs when individuals incorporate new information into existing mental ideas of the concept, build new mental models that can hold both old and new ideas gained from the experience. Furthermore, all constructivists would agree that knowledge construction requires the student to be actively engaged in learning the process. Wheatley (1991) concurs and offers virtually the same argument of the epistemological core of constructivism, saying:

“The theory of constructivism rests on two main principles....Principle one states that knowledge is not passively received, but is actively built up by the cognizing subject....Principle two states that the function of cognition is adaptive and serves the organisation of the experiential world, not the discovery of ontological reality....Thus we do not find truth but construct viable explanations of our experiences” (p.10).

This second principle introduces to further the idea that actually constructivism cannot be ‘certain’ if the external world which teaches are not socially constructed. From my point of view, reality can only be understood through clear, viable explanations and discussions within a socially acceptable environment (the classroom) using prior ideas. Furthermore, Lorscheid and Tobin (1992), argued that in the constructivist classroom, students should be given opportunities to make sense of what is learned by agreeing to meaning, comparing old ideas to new knowledge, and deciding on the difference between old ideas and what seems to be meant by new knowledge.

They argued that agreeing on the difference leaves the learner satisfied about new knowledge in relation to old ideas. They further argued that negotiation is also possible in a classroom through discussion, attentive listening, and making sense of the views of others, and comparing individual understandings to those embedded within the theories of peers.

2.6.5 Constructivist perspectives: The role of the teacher

Agreeing with a constructivist perspective on learning does not lead directly to a specific approach to teaching (Millar, 1989). For example, Lorscheid and Tobin (1992) argue that the constructivist viewpoint suggests that teaching science should be like

the science that scientists actually do - it should be active and social to allow making sense of knowledge, as opposed to what we now call 'school science'. This is not a view that I would agree with, since the role of the teacher seems to be overlooked if the students are expected to work like scientists. The key point is that the teacher must introduce scientific ideas to the students and guide the learning as individual students makes sense of the scientific point of view.

Nevertheless, it is possible to make more general statements about teaching which follow from constructivist perspectives on learning, considering the characteristics of the constructivist form of learning being more learner-centred, the teacher plays the role of planning the learning task and being a knowledge facilitator. It is the teacher who sets up the classroom environment to enable learners' to gain new knowledge. It is the teacher who encourages learners to share ideas with one another through discussions. It is the teacher who probes and guides the learner by posing thoughtful, factual questions rather than just providing learners with answers.

Accordingly, teacher participation and guidance, which bring out challenges and build upon learners' own ideas (Mercer, 1995), are considered significant for learners' understanding of more abstract, general and explanatory knowledge frameworks (Driver, et al, 1994). The nature of scientific ideas and processes means that opportunities for talking and teachers' explanations are very important for knowledge construction.

2.6.6 Constructivist perspectives: review

The key message which comes from the constructivist perspectives on learning relates to the individual responsibility of the learner in making sense of new ideas, relating new knowledge to existing understandings. In this way, the constructivist perspectives take a similar point of view to the sociocultural approach in agreeing that meaning making occurs within an individual as they think and reflect on what is being communicated.

2.6.7 Combining social and individual points of view: The perspective on learning adopted in this study

In the preceding sections, I have outlined perspectives on learning: socially focused (Vygotsky), and individually focused (Constructivism). Each has its strengths and here I argue that the approaches are complementary.

By drawing attention to the social origins of learning, Vygotsky also emphasized the role of the individual in the learning process through the process of internalisation. The process of internalisation, as envisaged by Vygotsky, does not involve the simple transfer of ways of personal sense making. Leontiev (1981), one of Vygotsky's contemporaries, made the point in stating that "the process of internalisation is not the transferral of an external activity to pre-existing 'internal plane consciousnesses'. It is the process in which the plane is formed" (p.57). Leontiev's argument is that an individual makes sense of ideas being discussed during social interaction and relates these talks to their prior ideas.

Leach and Scott (1995) strongly supported this view, arguing "that individual learners must make sense of the talk, which surrounds them on the social plane, relating that talk in a dialogic way to their existing ideas and ways of thinking" (p.44). In this way the internalisation process of sociocultural theory reflects the basic sense making step of constructivism, and so the two points of view fit together and are complementary. Dialogue, interaction and argument become internalised through individual sense making to form the basis for reflection, rational reasoning and the formation of new ideas.

Therefore the approach taken in this thesis is to draw on both perspectives, taking what has been referred to as a *Social Constructivist Approach* (Leach and Scott, 2002). In the last decade, this approach has advocated for an account of individuals as they function in social contexts with an emphasis on the role of the teacher being that of making the scientific point of view, or scientific story, available to students and to support their learning as they gradually develop meanings for new scientific concepts, internalize and gain expertise and confidence in using them (also see, Mortimer & Scott, 2003).

2.6.8 Different theory alerts us to different aspects of teaching and learning:

A sociocultural view highlights the importance of language, scaffolding, conversation, and interaction on the social plane which provides the opportunity for each participant to reflect on and make individual sense of what is being communicated. The key point here is that the student's learning is conceived as being directly connected to, and dependent upon, the supporting activity of the teacher on the social plane.

Constructivist views highlight the importance of individual sense making, alternative conceptions of scientific views.

2.6.9 Approaches to teaching: The perspective adopted in this study

In considering the approach taken to teaching in this study, three different but related perspectives were considered. The first consists of a series of theoretical points derived from social constructivist theory. The latter two consist of more practical perspectives relating to 'Dialogic teaching' and the 'Communicative approach'.

2.6.10 Implications for teaching: Derived from social constructivist theory

Building on the social constructivist perspective on learning as set out above, there are some implications for the design of teaching.

First of all, effective teaching involves bringing together every day and scientific views, examining differences in students' alternative views of science ideas and scientific viewpoints.

Secondly, effective teaching is language based: talk is fundamental as it does not simply imply talking about science. It means using language as a medium of teaching and learning science. Lemke (1990) argues that:

“talking science means observing, describing, comparing, classifying, analysis, discussing, hypothesizing, theorising, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalising, reporting, writing, lecturing and in teaching and through the language of science” (p.1).

Thus, language is a system of resources for making meanings.

Thirdly, teachers provide access to scientific knowledge (no discovery possible). This point is supported by Mercer (1995) who argues that students must be guided. Driver et al. (1994) made a similar argument stating that participation and guidance which brings out challenges and builds upon learners' own ideas is significant for learners' understanding of more abstract, general and explanatory knowledge frameworks.

Last but not least, students need an opportunity to talk science for themselves (Lemke, 1990). That is, science teaching being seen as a social process which brings students virtually close to a community of people who 'talk science', and that the individual

learner must make sense of the talk, which surrounds them on the social plane, relating that talk in a dialogic way to their existing ideas and ways of thinking.

Bearing these general points in mind, the following approaches to conceptualising teaching were developed in this thesis:

2.6.11 Implications for teaching: Dialogic teaching and other talk-based approaches

The theoretical points discussed in the previous section about the importance of talk have been investigated in practice by Alexander (2008, 2008b). In his work on dialogic teaching, a talk approach was used to encourage pupils to think, learn and understand ideas. This approach differs from the traditional question-answer, teacher-centered and informal discussion.

Alexander et al. (2004, p.26-7) argues that dialogic teaching is “grounded in the principles of collectivity, reciprocity, support, accumulation and purposefulness.” He argues that dialogic teaching is a collective process in a sense that teachers work together with learners to solve learning tasks, paying attention to each other and sharing ideas; reciprocal because both the teacher and students listen and consider each other’s views; supportive because learners are free to discuss their answers in an environment where no answer is ‘wrong’; cumulative because teachers and students develop on their own and each others’ ideas, chaining them into logical lines of thinking and enquiry; and purposeful in a sense that teachers plan and guide classroom talk with specific learning goals in view.

These ideas have links to constructivist perspective because it recognises that in the teaching and learning processes, the learners are active participants. On the other hand, the actions of the teachers’ and students’ are linked to Vygotsky’s socio-cultural and Bakhtin’s notion of social language which can be used to mediate classroom discussions.

Sociocultural researchers (Leach and Scott, 1995; Mortimer and Scott, 2003; Alexander, 2001; and Mercer, et al. 2004/2007) have all argued that the learning of science is a discursive process, with scientific ideas and ways of understanding being learned through engagement in practical investigation and social interaction, as well as individualized activity. According to this viewpoint, students are presented with

alternative views and required to engage with each other's ideas in ways that test and broaden their own theoretical understandings.

Sociocultural researchers have frequently described science teaching as a discursive process, whereby students are introduced into a system of using language and other representational means by teachers (Mercer, et al. 2004). In this line of argument, Lemke (1990) proposed that science teaching should enable students to become "fluent speakers of science" (p.24), while Leach and Scott (1995) have suggested that "students should be helped by their science teacher to make sense of the talk which surrounds them, and in doing so, relate it to their existing ideas and ways of thinking" (p.44).

Mercer, et al. (2004) argued that modern sociocultural theorists (Wertsch, 1991; Wells, 1999 and Daniels, 2001) have all followed Vygotsky (1978) in stressing the importance of language use and social interaction for the development of making sense of the world, such as scientific ideas. For example, Barton (2004) argues that:

"I always felt that pupils would learn the concepts and ideas more effectively if there was more opportunity for them to talk about their ideas with the teacher and if there was more time for the teacher to provide the 'bridge' between their experiences during practical work and the abstract concepts they related to" (p.37).

These ideas of encouraging talk to support the learning process are consistent with the social constructivist perspective to learning. Driver, et al. (1994) strongly supported this view and suggested that scientific knowledge constructions involve both social processes and individual understanding. Drawing from all these views, it is clear that 'talk' is an important factor in learning science, and in the next section we will be looking at a broad framework of classroom talk, the communicative approach and its implications for teaching which this study adopted in the design of the teaching sequence.

2.6.12 Implications for teaching: The communicative approach

In the previous section we have emphasised the importance of talk. Mortimer and Scott (2003) provide a useful framework in thinking about the talk in the classroom between the teacher and students. This framework involves moving along two dimensions; dialogic or authoritative and interactive or non-interactive, which can be represented as in **Table 2-1** below.

Table 2-1: Four classes of communicative approach

	Interactive	Non-interactive
Dialogic	Interactive / dialogic	Non-interactive / dialogic
Authoritative	Interactive / authoritative	Non-interactive / authoritative

Source: Adopted from Mortimer and Scott (2003, p. 35)

In planning the teaching, the framework provides the perspective of thinking about different kinds of talk in which teachers can work with their students to develop specific ideas in the classroom. For example, Alexander (2008) talks in general terms of dialogic teaching while Mortimer and Scott (2003) identify four possibilities through which the teacher can interact with the students “taking turns in the discourse” (p.33), with the focus of making sense of the specific view point. In the classroom, these different kinds of talk may take the following form of interaction.

- Interactive / dialogic: is an approach whereby the teacher asks, probes, elaborates, supports and prompts the pupils’ ideas about the specific subject concept.
- Non-interactive / dialogic: the teacher considers various points of view, exploring and working on a range of students’ ideas.
- Interactive / authoritative: the teacher leads students through a sequence of questions and answers with the aim of reaching one specific idea (e.g. scientific ideas).
- Non-interactive / authoritative: the teacher presents one specific point of view and makes a review. In this teaching approach, the teacher controls the entire session and the subject content. There is no room for teacher-student interaction.

The different communicative approaches outlined above have been drawn upon to design the computer and talk approach (C&TA) teaching sequence for this study. The detail of the design teaching sequence is provided in **Appendix 7**.

2.6.13 Overall theoretical conceptualisation of teaching

In summary, overall in terms of theoretical perspectives, the literature suggests that there is a strong link between sociocultural theory, constructivist theory, social constructivist theory, dialogic teaching and the communicative approach. The representation of the link can be illustrated as shown in **figure 2-4** below:

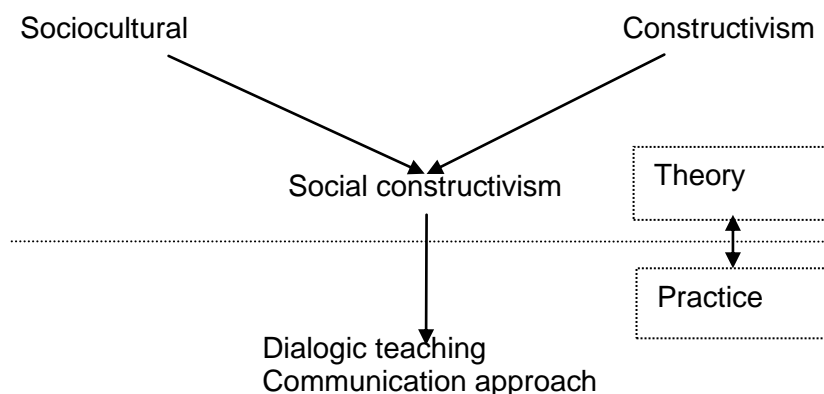


Figure 2-4: Perspectives on teaching and learning: Theory and Practice

The link above provides perspectives on teaching and learning which can be drawn upon to inform the design of the teaching, because it recognises that teaching is cumulative over time, in that it involves bringing together every day and scientific views (social constructivism theory); using talk to make meanings; teachers guiding and providing scientific knowledge, and students talking science for themselves relating to their ideas and ways of thinking. All of these, as we have seen, help in supporting students' understandings of scientific ideas.

It is with these ideas in mind therefore, that I found it reasonable to draw on both sociocultural theory and constructivist theory, taking what has been referred to as a social constructivist approach (Leach & Scott, 2002) along with the different communicative approaches to provide theoretical perspectives for this study. In **section 2.8**, the theoretical perspectives and communicative approach (talk approaches) adopted here were used to develop the conceptual framework for the implementation of a computer and talk approach (C&TA) teaching sequence to improve students' understanding of the chemical rate of reaction. Before this, I present a review of literature on computer simulations and modelling in education.

2.7 Review of literature on computer simulations and modelling in chemistry education

In this section, I outline the capabilities of computer simulations and modelling to facilitate science education; research evidence from teaching chemistry concepts and application to teaching chemical rate of reaction. I will begin with the definitions and benefits of computer simulations and modelling in teaching science subjects in general.

2.7.1 Computer simulations and modelling

Thurman, (1993) and Rieber, (1994) defined simulation as a form of a real world environment, with the feature for the user to interact with the phenomena. While Sauvé et al. (2007) have defined it as a simplified, dynamic and accurate model of reality, that is, a system used in a learning context to illustrate occurrence of phenomena. In science teaching computer simulations are used to replicate dynamic systems of objects in a real or imagined world (Akpan & Andre, 1999). Johnson et al. (1998) argued that simulations are mostly appropriate in creating such an environment because they provide high-level interactivity; strengthen ideas and theory acquisition within the heart of learning. Thus, interactivity inherent in simulations allows learners to see immediate results as they try out their theories about the concepts modelled (Rieber, 1992; 1994). Simulations have been described by Alessi & Trollip (1991) as:

“Powerful techniques that teaches about some aspect of the world by imitating or replicating it. Students are not only motivated by simulations, but learn by interacting with them in a manner similar to the way they would react in real situations. In almost every instance, a simulation also simplifies reality by omitting or changing details. In this simplified world, the student solves problems, learns procedures, comes to understand the characteristics of phenomena and how to control them, or learns what actions to take in different situations.”

Alessi and Trollip (1991) further argued that, computer simulated instruction offers opportunity to learners to observe and interact with a real world experience. They explained that simulations allow virtual experiments and inquiry to be conducted in the school science laboratory and that problem-based simulations allow students to experiment with new models, monitor experiments and can help to improve the understanding of difficult concepts.

Modelling software, as its name implies, encourages pupils to create, use and test their own models (Scaife & Wellington, 1993; Jackson, et al. 2000). In science teaching the

use of models has been linked to the importance of modelling activities and interactive learning environments that associate constructivist learning with computer applications, which allows students to interact with dynamic representations of models (Jackson, et al. 2000). Following on from these two descriptions of simulations and modelling, Dalgarno (1996) has argued that there is no clear difference between simulations and modelling (also called microworlds) because both share similar features regardless of which definition is chosen. In this study, therefore, simulations and modelling were treated synonymously.

2.7.2 Benefits of using computer simulations and modelling in science education

In the literature, simulations and modelling have been recognised as promoting critical thinking; developing problem solving skills and the ability to ask ‘what if?’ questions (Mellar and Bliss, 1994), as well as improving cognitive understanding (Yildiz and Atkins, 1993); bettering students’ concept retention (Parush et al. 2002); helping pupils to understand and gain experience of phenomena which are potentially hazardous and not easy to replicate in the school science laboratory, where the time scale does not permit and when used for ‘virtual’ experiments immediate outcomes are obtained and thus allows more inquiry (Baggott and Nichol, 1998; Bennett, 2003; Boyle, 2004; Linn, 2004; and Hennessy et al., 2007); increase the salience of underlying abstract ideas—helping students to visualise processes more clearly, and support the analysis of trends and exploration of relationships between variables at sophisticated levels (Bennett, 2003; Hennessy, 2006).

Thus computer simulations and modelling can be used to support teaching and learning science content knowledge and processes.

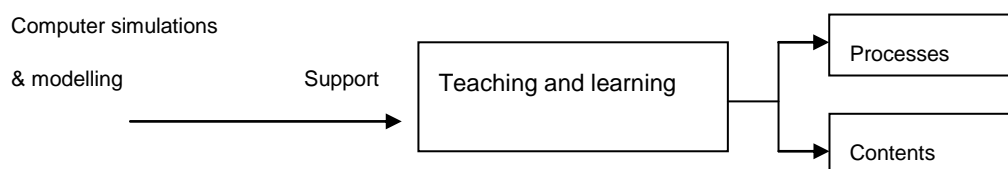


Figure 2-5: Using computer simulations and modelling to support teaching science processes and contents

2.7.3 Use of simulations and modelling in teaching chemistry concepts:

Research evidence

In this section, I present the use of simulations and modelling in teaching chemistry practical activities and abstract concepts. I begin by looking at the studies which have explored the use of simulations and modelling in chemistry laboratory processes, and then look at other studies which have dealt with applications of simulations and modelling in teaching abstract chemistry concepts.

2.7.4 Use of simulations in teaching chemistry processes

Research suggests that computer simulations and modelling can help students to investigate and understand complex models and processes which they cannot investigate in a school science laboratory (Osborne et al. 2003). Such benefits of simulations and modelling have been reported in other subjects, for example the use of the simulated package, 'Crocodile Physics', to teach electric circuits in physics (Hennessy, 2007); use of simulation software to investigate the effect of temperature on enzyme activity in biology (Hennessy, 2007); investigation of growth curve of micro-organisms in biology (Huppert, et al. 1998 / 2002), were found useful and a comparative investigation into the effectiveness of simulated laboratory instructions 'digital electronics circuitry', versus traditional laboratory instructions in physics (Pyatt, 2007; Taghavi & Colen, 2009).

However, little has been reported on teaching chemistry processes. Rodrigues (2007) reports on a project based on constructivist perspectives and simulated practical experiments which depicts microscopic chemical interactions; acid-base neutralisation. The project was piloted with three male pupils, age 15 to 16 years old, and a main study was conducted with 21 pupils, age 14 to 15 years old. Working in pairs, the pupils used simulations for up to five minutes. The pair approach was to allow pupils' thinking "as some 'thought aloud' as they sought clarification from the peer or as they reacted to screen shot" (p.4). The results indicated that vividness, logic, instruction and prior knowledge played an important role in determining the pupils' participation and improved understanding of acid-base neutralisation reactions concept. This study suggests that 'talk' was important in understanding the practical concept among the pupils as they responded to the screen shot, an opportunity which was provided for by computer simulations. Drawing from Rodrigues et al. (1999) there is still little available use of simulations reported on practical work, more especially in teaching chemistry subjects in secondary schools. In my opinion, since 1999 many researchers and

instructional designers have had ideas about the use of computer simulations in teaching science but actual implementation in the classroom and research are still at infant stages.

The laboratory process requires students to perform experiments and coordinate their results with theory in order to explain the underlying theory of chemical reactions. Usually, students have to take measurements of volumes of reactants, mix and record the time taken for the reaction to come to a stop. All these processes, from my experience as a chemistry teacher, do not give students adequate time to focus on relating the practical phenomena to the underlying theory of chemical reaction at the sub-microscopic level to macroscopic level where understanding occurs. Simulations and modelling, as we have already seen, can help students to have a clearer understanding of what actually happens at sub-microscopic level during chemical reaction. Understanding these enables students to map up the sub-microscopic level to macroscopic level, thus improving their understanding of the chemical rate of reaction concepts. However, for this particular study, I used simulations and modelling to enhance students' understanding of the chemical rate of reaction.

2.7.5 Use of simulations and modelling in teaching chemistry concepts

As mentioned in **section 2.7.2**, simulations and modelling can be used for visual representation of abstract molecular interactions and therefore provide the students with the opportunity to observe molecular interactions alongside graphical representation and chemical reaction formulae (Bodner, 1992). It has been argued that the use of computers in chemistry lessons makes traditional molecular symbols visible and clearer to the learner (Stieff & Wilensky, 2003). Stieff and Wilensky (2003) further argued that using computers in chemistry lessons contrasts with the "traditional chemistry lectures that rely almost entirely on verbal explanation of concepts meaning students have little opportunity to 'observe' molecular interactions" (p. 286). Furthermore, the use of computers in teaching is seen to encourage critical thinking, conceptual understanding and discourages rote memorisation and algorithmic problem-solving (Garnett & Kenneth, 1988). For example, Stieff and Wilensky (2003) hold that using simulations and modelling to teach chemical equilibrium helped students to shift from memorising ideas to explaining chemical equilibrium reaction concepts.

Literature also suggests that computer simulations and modelling facilitate the teaching and learning of not only difficult concepts in chemistry, but chemistry as a whole. For example, Oloruntegbe and Odutuyi (2003) have suggested that the often perceived

difficult and abstract concepts in chemistry such as radioactivity, mole and stoichiometry, electrochemistry, organic chemistry can be encoded or programmed into computer software that teachers and students could utilize to make their teaching and learning better.

At this point we will shift our attention to studies which have employed computer simulations, modelling and other related tools such as animations, and see how such interventions have enhanced teaching and students' learning of chemistry concepts. I will attempt to show how such studies have informed my study.

Papageorgiou et al. (2008) investigated the effect of simulations in supporting pupils' understandings of particulate explanation for melting and evaporation below boiling point. The study involved two Grade 6 pupils (aged 11 to 12 years). Computer simulations were used to help pupils understand microscopic behaviours of particles of substances undergoing melting and evaporation processes. Simulations were found to be useful in illustrating "particulate nature of substance in the three states (solid, liquids & gas) and the events of melting and evaporation below boiling point" (p.169). The experimental class was taught using simulations and the control class followed the traditional instruction. The experimental class were supported and guided by the teacher as they made predictions and observations along with group discussions. The study was evaluated through individual interviews of pupils before and after (pre and post interviews). The findings indicated that simulations helped pupils understand the ideas of particles holding together and also the distribution of energy, especially during evaporation. These ideas in my experience as a chemistry teacher are abstract, difficult to understand and comprehend.

This study has given a clear application of simulations to engage pupils through initiations of prior ideas by making predictions, drawing attention and discussions in the group. This can help the teacher to address pupils' misconceptions as they are being supported by revealing nature of microscopic behaviours of particles under different states of matter, as displayed by simulations. In this way pupils are able to envision 'bonding' and the 'energy distribution' thus bettering the pupils' understanding. The strategy of using predictions and observations is core in my design teaching sequence for this study. We shall return to this later in Chapter Four.

In another study, Arcdac and Ali (2002) conducted a comparative study on relative effectiveness of guided versus unguided computer-based instruction (simulations and modelling) with respect to regular instruction. The study aimed at improving the understanding of 74 Grade 9 students (aged 14 to 15 years) of the chemistry concept 'Boiling point elevation and freezing point depletion' in a secondary school in Turkey. Two classes received computer-based instruction under guided (n=25) and unguided (n=24) conditions, while the third class (n=24) followed regular instructions.

Students in the regular class followed an instructional sequence, which matched the sequence used for the computer-based instruction, with identical concept examples and questions. However, although regular instruction proceeded in a question–answer format, students had limited opportunity to question, and no opportunity to inquire about the factors affecting changes in boiling–freezing point, through direct manipulation of variable attributes. Instead they were guided towards the expected outcome, through teacher directed questioning.

Students in a Computer-Based Instruction class completed the instruction in the computer laboratory. Each student worked on a separate computer individually. In one group, students received computer-based instruction under unguided conditions, and covered the topic by themselves. The teacher gave a short introduction and merely presented the contents after which the students were left to work independently, with the teacher only intervening to answer individual questions from students.

In the second group, students followed computer-based instruction under guided conditions, projected on to a screen as well as from the students' computers.

The initial screens that displayed pictorial and graphical representations concerning the boiling and freezing of pure water were presented to the whole class with subsequent questions that were answered collectively. Representations of phase changes corresponding to a solution (water C glycol) were observed, and related questions were completed on an individual basis. The exploration phase was opened by the teacher through the presentation of factors that affect boiling point elevation and freezing point depletion. The students were given direction on how to manipulate the variable values and calculate the resulting change in boiling-freezing point. No clear instruction was given with regard to the control of variables during the inquiry process. Students came up with individual designs and determined how solute-solvent characteristics affect the changes in the boiling-freezing point of a solution.

The final phase of instruction that consisted of five 'fill-in-the-blank' type questions were completed by individual students and was then reviewed by the teacher through whole class participation.

Students in the three study groups were assessed using the "Test on Boiling Point Elevation and Freezing Point Depression" and "Test on Identification of Variable Attributes in a Controlled Experiment", prior to and following instruction.

The results indicated that the effectiveness of computer-based instruction increases when learning is supported by teacher-direct guidance. They found that computer-based instruction (with or without guidance) was observed to be more effective than normal instruction in improving process skills, mostly for high level chemistry achievement students. However, it was also found that, although the students who received regular or guided computer-based instruction showed significant gain in content knowledge, students under unguided conditions failed to construct the content knowledge.

The point here is that, when computer-based instruction is supported by teacher guidance, students' understanding of the concept is greatly enhanced. This idea is what my study is set to follow when using simulations and modelling in the teaching and learning of the chemical rate of reaction.

In another study, Ozmen (2008) reported an investigation into the effect of computer-assisted instruction (CAI) on conceptual understanding of chemical bonding and attitudes towards chemistry. The study involved 50 students from Grade 11 (aged 14 to 15 years) of a secondary school in Turkey. The experimental class of 25 students followed CAI, while the control class of 25 students were taught following the normal teaching approach (talk and chalk), the dominant teaching method in Turkish high schools. The students in the CAI class were supported through regular classroom instruction and PowerPoint presentations. The teaching intervention was then evaluated using an Achievement Test, administered as base-line test and post-test. The results indicated that the experimental class performed better than the control class, and showed slight improved conceptual change.

I would suggest that helping students overcome their alternative conceptions requires the teacher supporting students through dialogic talk as they work with CAI to support their learning, as they gradually develop meanings for new scientific ideas, internalise and gain knowledge (see for example, Papageorgiou et al. 2008).

In another study, Stern et al. (2008) investigated the effect of interactive simulations in improving Grade 7 students' understandings of the kinetic molecular theory at two middle schools located in the Northern Israel. The study involved three teachers and 133 students. Students were randomly assigned. Both the experimental and control classes were first taught the topics: 'heating and cooling, expansion and contraction' from the matter and molecules, for seven periods. The students in experimental classes were given three additional lessons using simulations to study the behaviour of particles in the three phases of matter. Their study focused on the effect of temperature change on the particles in gaseous phase, liquid phase and solid phase. The dynamic representation of molecules took place during the computerised simulation. Three lessons were selected and were structured in order to minimise the difference between the teachers. Each lesson was accompanied by computerised worksheets with questions to guide students' observations. Students were able to receive feedback on their responses.

The results of the post test revealed that the students in the experiment group scored significantly higher than those in the control group. Their findings suggested that the simulations improved the understanding of the Grade 7 students, though it was acknowledged that interactive simulations were insufficient to promote meaningful learning. I agree with this point on insufficiency, and my argument would be based on the nature of the software implementation. Analysing the process of implementation, it is very clear that the simulations provided the learners with the opportunity to try out their ideas, which perhaps was a good strategy but the teacher's input was overlooked leaving it to the software to provide feedback to students. Arguing from the Mortimer and Scott (2003) point of view on the importance of talk to make meaning of science concepts, students should have been supported by their teacher through dialogic-talk and discussions when working with worksheets as they made their observations, which would have helped them to learn more successfully. This finding re-echoes the fundamental importance of Vygotsky's view (1978) that it is the job of the teacher to make scientific knowledge available on the social plane of the classroom, supporting

students as they try to make sense of it through dialogue, a point which this study is set to investigate.

In their study, Talib et al. (2005) investigated students' conceptual change on electrochemistry using computer-animated instruction. The study consisted of 85 university students. The students were assigned randomly to an experimental class and control class. The students' misconceptions were first obtained using focussed interviews. The teaching method used was based on the constructivist approach with students using interactive computer animated images to test their ideas. The experimental class followed computer-animated instruction (CAI) while the control class followed conventional lecture instruction (CLI). The results indicated that the CAI experimental class had better explanations of the electrochemistry concept, thus had undergone a conceptual change while for the CLI control class the concept "remained unintelligible and implausible even after a series of lectures" (p.41). In my opinion, it is true that using the constructivist approach of teaching, results in some kind of conceptual change as indicated by the results of this study. In my opinion, the approach used however did not take into account the importance of the role of social interaction and classroom talk as a tool for meaning making, and so limited students' conceptual change was realised in this study.

Morgil et al. (2005) conducted a comparative study between computer-assisted learning and the traditional teaching of acids and bases. The study involved 84 students who attended chemistry education classes at Hacettepe University. The experimental class followed computer-assisted instruction while the control class followed traditional instruction. The two classes were evaluated using pre and post achievement tests. The results indicated that on average the scores of the experimental class had increased by 52 %, and for the control class by 32 %. When the results were subjected to an independent test (t-test), it was confirmed that the significant test favours the experimental class. The study pointed out that Computer-Assisted Instruction when combined with the student-centered teaching approach is more effective in terms of student achievement and attitude than traditional instruction.

In the most recent study, Calik et al. (2010) investigated 72 Grade 11 students (aged 16 to 18 years) conceptual change in 'rate of reaction' concepts, using computer animation to illustrate 'rate of reaction' concept and make it understandable by students. The experimental class used computer animations and guide-sheets along

with informal group discussion. The control class meanwhile followed the teacher centred approach - traditional instruction (learners viewed as passive receivers). The results indicated that the experimental class had an increased understanding compared to the control class. The study further revealed that the students who followed the computer animation instruction were able to overcome their misconceptions. The results of this study were significant. Having students to work with computer animation and worksheets to develop their understanding and track their correct and incorrect knowledge claims was a good strategy, but this could perhaps have been made even more effective if the teacher had given a more dialogic approach through teacher lead discussion. For example, by combining teacher led classroom talk while students work in groups provides powerful instruction and support which ultimately result in the reduction of students' alternative conceptions. I have found this study useful because Calik (2010) recommends that further studies need to be conducted in combination with other approaches, such as argumentation. Therefore, this study further supports my research on improving students' understanding of chemical rate of reaction using computer simulations and modelling along with 'talk approaches', in a Ugandan context.

In all these studies as we have seen, working with computers in teaching chemistry concepts can be very useful but could be even more effective if they are accompanied with more quality talk (Mercer, 1994) which includes good science talk. Those studies which have included the use of talk tend to have shown better results (see for example, Papageorgiou et al. 2008; Arcdac & Ali, 2002).

2.7.6 Using simulations and modelling for teaching chemical rate of reaction

In reference to the reviewed work in the above section and particularly on the use of computer simulations and modelling, it is clear that few studies on the use of simulations and modelling using computer and talk approaches have been reported. I have decided that it merits carrying out a teaching intervention with simulations and modelling using computer and talk approaches (C&TA).

Being highly interactive (Johnson et al. 1998) and increasing the salience of underlying abstract ideas and allowing exploration of relationships between variables (Bennett, 2003; Hennessy, 2006), simulations and modelling provide a learning environment in which learners can hold meaningful discussion as they interact with the learning phenomena supported by the teacher as they make meaning of the learning concepts.

As mentioned above, the attributes of simulations and modelling which simplify the understanding of abstract ideas and relationships between different variables, form the bases for the choice to be used in this study. These attributes will allow abstract representations of reacting molecules during a chemical reaction. The concept of reacting molecules being abstract requires that students have to envision particles undergoing collisions, having proper orientations and subsequently combining to form a new product. Using simulations and modelling to demonstrate the collisions might help students to have a clearer understanding of what actually occurs during a chemical reaction.

Another benefit of simulations and modelling is its potential to allow learners to try out their ideas, for instance how temperature or concentration change might affect rate of reaction.

In relation to this study, where students are required to conduct laboratory experiments to determine rate of reaction, using simulations and modelling allows students to focus their attention on the graphical interpretations of rate against temperature and rate against concentration, as they manipulate the temperature variable or concentration variable within the virtual laboratory experiment. It also helps students in testing their theories and hypotheses thus, enhancing their understanding of how change in temperature or concentration affects rate of reaction.

In the final section of this chapter, we shall look at the conceptual framework for the integration of computer simulations and modelling along with 'talk approaches' derived from the theory adopted for this study.

2.8 Conceptual Framework of the study

In this section, I present the overall conceptual framework for this study, bringing together the social constructivism theory adopted in this study, chemical rate of reaction concept and computer simulations and modelling in the teaching. Chemical rate of reaction has been documented as a difficult topic in chemistry (see for example, Gilbert et al, 2002). Other studies from the review reported students' various misunderstandings of the rate of reaction concepts, for example, 'every collision leads to a product', 'fast moving particles may lead to particles bouncing off each other without a reaction occurring: collision is too quick and energetic' and 'rate of reaction is constant throughout a reaction' (see **section 2.2.2**). All these misconceptions arise as

the result of the abstract nature of the relationships between activation energy, temperature, concentration of the reactants and chemical rate of reaction as explained by the kinetic theory-ideas of collisions. Students tend to explain the scientific phenomena involved in the chemical rate of reaction using their own words in order to make meaning of their own perspectives and understandings; in other words, by using their everyday language (Vygotsky, 1978).

By drawing from the *social constructivist approach* (Leach and Scott, 2002), the theoretical perspective adopted for this study, such students misconceptions can be addressed through effective teaching involving bringing together the everyday and scientific views, examining differences in the students' alternative views of science ideas and the scientific view point. Having children talk in the science classroom has been recognised as vital in this process as it does not simply mean talking about science but doing science through the medium of language (see Lemke, 1990; Leach & Scott, 1995 p.44; Leach & Scott, 2003).

All these views as we have seen, suggest that 'talk' is an important factor in learning science and will have significant impact on the teaching of chemical rate of reaction where students tend to have misconceptions. However, talk or dialogue alone in science classrooms is not sufficient to make abstract concepts understandable where there is need for the learners to visualise, create a mental model and build on the acceptable scientific knowledge. Research in science education (Bennett, 2003) has shown that science lessons are dominated by teacher talk and few opportunities are provided for pupils to engage in small group discussions. This is where the computer can play a role. In this study, the teaching involves the teacher using computer simulations and modelling along with "talk approaches" (Mortimer and Scott, 2003, p.35) to support students' understandings of the relationships between activation energy, temperature, concentration of the reactants and chemical rate of reaction as explained by the kinetic theory or ideas of collisions.

In structuring the broad framework for this research study therefore, emphasis was placed on the concept presentation levels (macroscopic-moles of molecules, sub-microscopic-atoms taking part in the chemical reactions and symbolic-reactants symbols & equations) and learners interaction with the computer simulated chemical rate of reaction designed to improve the students' understanding of the chemical rate of reaction concepts.

To effectively achieve the learning outcomes, emphasis was also placed on dialogic teaching and a communicative approach providing a perspective on how the teacher works with students to develop ideas in the classroom (Mortimer and Scott, 2003, p.33). Below is an illustration of the interplay of all these aspects.

2.8.1 The Conceptual Framework

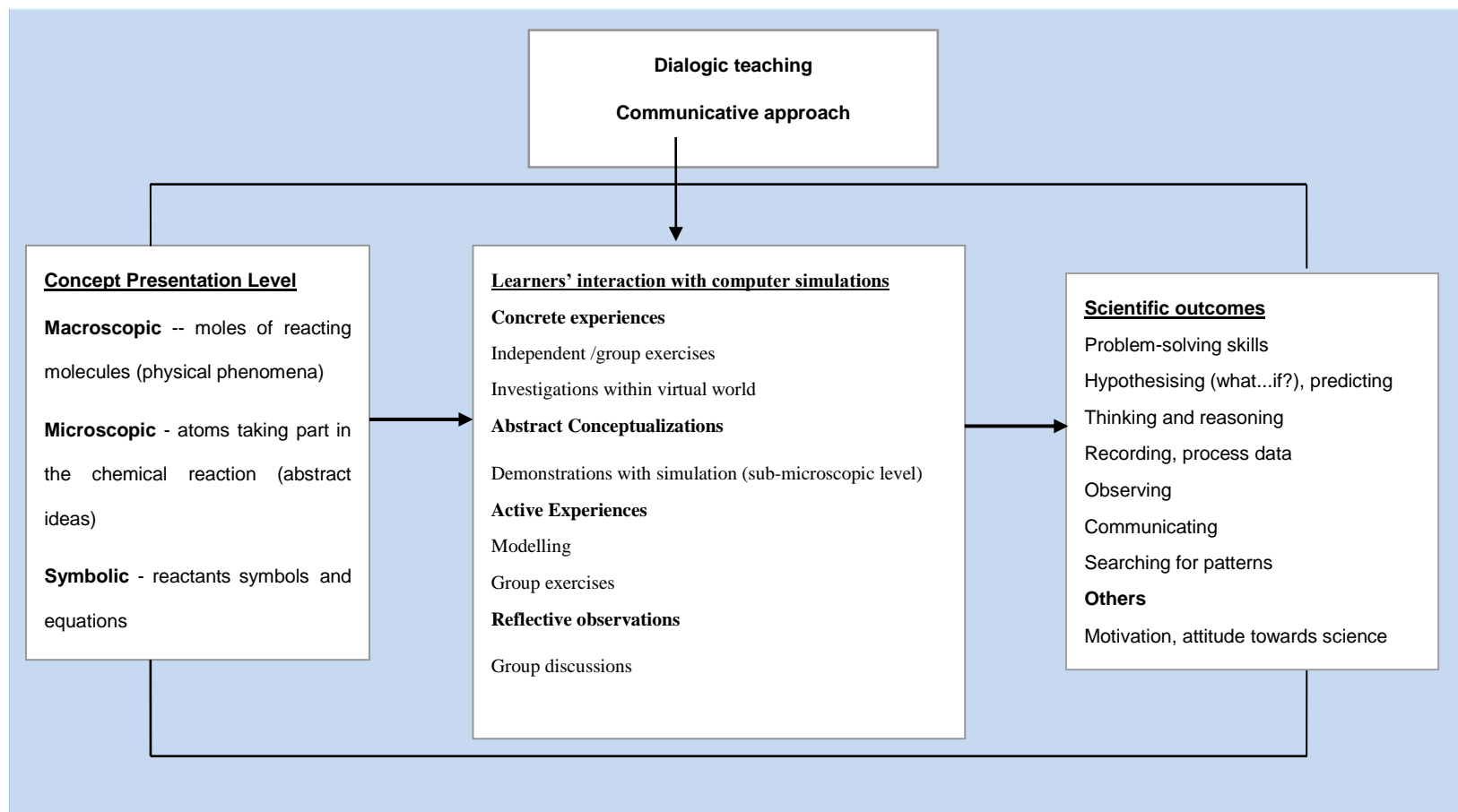


Figure 2-6: A school-based model of a computer and talk approaches for teaching school science subjects

The above framework can be used to provide ideas of thinking about how computer tools along with the theoretical perspectives and communicative approach (talk approaches) can be employed in teaching science concepts. It draws attention to the analysis of concept presentation levels. For example, chemistry teaching as we have seen takes place on three levels: sub-microscopic (abstract ideas), macroscopic level (physical phenomena) and symbolic level (using equations, formulae and mathematical representation). In this study, computer simulations and modelling along with talk approaches are used to simplify abstract ideas at sub-microscopic level and even to teach macroscopic and symbolic concepts. This framework was used to develop the design of the teaching sequence implemented in this study (see **Appendix 7** for further detail). In the next chapter, I present the methodology used in this study.

CHAPTER THREE

3 METHODOLOGY

3.1 Introduction

In this chapter, I present research aims, research questions, the design of the study, sample selection, data collection methods, validity and reliability of research instruments, data analysis procedures, ethical considerations, the timeline of the study, and methodological issues concerning the approaches to data analysis.

3.2 The aims of the study

Earlier in the background (Chapter One) of this study, I indicated concerns with didactic teaching, passive and less interactive learning in science classrooms in Uganda. The purpose of the study is to explore the use of a computer and talk approach (C&TA) as an alternative teaching approach to didactic teaching in science classrooms. In order to achieve this, I developed a research-based teaching sequence on chemical rate of reaction using a computer and talk approach (C&TA), which was implemented in Uganda and evaluated by making comparisons with 'normal' teaching.

This teaching sequence involved the use of computers to simulate and model behaviours of molecules during chemical reactions and provided a platform for classroom discussions as students interacted with the learning materials.

The lessons involved both children and the teacher talking freely about the chemistry concept, chemical rate of reaction. In this way the designed teaching sequence was based on the reviewed literature on the importance of talk in making meaning of learning contents in a classroom (Chapter Two). The aims of C&TA were to improve the understanding of chemical rate of reaction by high school children aged 15 to 16 years in Uganda. If successful, the selected topic and the developed teaching scheme ought to serve as a teaching model upon which future design sequences for teaching science concepts using computer programs can be adopted.

3.3 Research questions

To remind the reader, the study addresses four research questions:

1. Does the computer and talk approach improve the students' level of understanding of chemical rate of reaction in this Ugandan high school context in comparison with students following 'normal' teaching?

2. Which parts of the teaching sequence are effective in supporting learning, and which are less effective?
3. What are the major benefits and challenges to the implementation of a computer and talk approach in the Ugandan context?
4. What are the teacher and students' perceptions of the computer and talk approach?

3.4 The design of the study

To outline, the study involved three phases:

Phase 1: Design of the C&TA teaching sequence (see Chapter Four)

Phase 2: Implementation of the teaching sequence in Uganda (see section 3.6)

Phase 3: Evaluation of the impact of the teaching sequence (see section 3.7)

A total of about 247 students and two teachers participated in this study. The participants for this study were students aged 15 to 16 years from two similar graded high schools in the Central region of Uganda (Kampala and Luwero districts), which were approximately 32 kilometres from each other. The selections of the schools were based on the national intake grade points for the ordinary secondary education (O level). The selected schools admit students with similar grades obtained in the Primary Leaving Examinations (PLE). Therefore, the two schools and classes were matched to allow for comparison between the experimental class and the comparison class. Having two separate schools ensures that there is no leakage between the experimental class and the comparison class. In addition, it helps to avoid complaints among students when only one school is used in the study.

Designed teaching sequence of C&TA (Chapter Four) was used in the experimental class, while the comparison class in a different school followed the 'normal' teaching approach (NTA). The two teaching sequences were covered at the same time, each using almost concurrently a set of six timetabled teaching sessions, covering a total of 240 minutes of contact time.

3.5 Research approaches and methods employed

The research approach used was a quasi-experimental design since I did not have control over which students to assign to each class, as this is normally determined by academic heads at schools (see also Johnson & Christensen, 2004), and I was not able to make a complete random allocation of students. In review of the relevant literature on the use of computers in science education, studies on the effects of

computer tools on learning science are mostly conducted using quasi-experimental design or true experimental design (see for example, Calik, 2010). However, the experimental designs are rarely used due to difficulties in randomly assigning participants to single groups, such as students in a classroom (Johnson & Christensen, 2004). In my study, since it involved students who make up a group, Johnson and Christensen (2004) recommended that in such a situation “researchers must use quasi-experimental and single-case research design” (p. 300). In order to ascertain effects of C&TA on learning chemical rate of reaction, quasi-experiments provided an opportunity to compare post-test results of students from classes that are not randomly selected (Margoluis et al., 2009) whilst controlling for baseline differences.

The study employed mixed methods (qualitative and quantitative methods). Firstly, research question 1 in **section 3.3** is best answered quantitatively. The use of quantitative results alone would be of limited value in showing the characteristics of either the C&TA or NTA which made the difference of enhancing the students’ understanding. Therefore, a qualitative analysis of the classroom talk was used to supply information about the nature of teaching (research question 2) in order to provide an in-depth complementary analysis (Bryman, 2006; Kelle, 2006). Qualitative analysis also provided evidence for research questions 3 and 4 about the teacher and students’ opinions about the benefits, challenges and perceptions of C&TA.

Secondly, another key point was the opportunity to be able to use the quantitative method to provide insight for possible further exploration of the research findings. For example, if in a comparison between two schools we found out that the scores of the experimental class are significantly greater than the comparison class, then it would be reasonable to assume that in a similar school in Uganda the same results would apply. That is, we would get the same level of performance elsewhere when the study is replicated (Punch, 1998: 247).

3.6 Implementation of the study

This section present implementation process: piloting the C&TA teaching sequence, sample population and teacher training

3.6.1 Piloting the C&TA teaching sequence

Before the actual implementation of the study, an informal pilot teaching using the C&TA to teach chemical rate of reaction concept was conducted at Centre for Studies in Science and Mathematics Education (CSSME), School of Education, University of

Leeds, United Kingdom. The teaching presentation was carried out to show how the actual teaching would be implemented in Uganda. To establish the validity of the C&TA teaching sequence, the lessons were conducted in the presence of a Professor of Science Education for his review, since face or content validity can be determined by expert judgement (Gay, 2009). He commended that the C&TA teaching sequence was adequately developed but made suggestions that the intervention teacher be trained on dialogic approach of teaching and social-constructivist approaches to science teaching, a theoretical framework adopted for the design of C&TA teaching sequence (Chapter Two). I will outline the training of the teacher later in **section 3.6.3**.

3.6.2 Sample population

A purposeful sampling method (typical case study approach) was used to select two high schools. Consideration was made based on background information about the schools with more computers and a teacher-student level of computer knowledge. The selected schools were then randomly assigned through the 'simple tossing of a coin' to the experimental and comparison groups in order to minimise selection bias and risk of confounding which possibly would have influenced the results of the study.

A total of 247 students aged 15 to 16 years from two high schools in central Uganda participated in the study. The experimental class consisted of 108 students (51 males and 57 females) while the comparison class consisted of 139 (73 males and 66 females). Two teachers aged in their early 30s with similar qualifications and experience of eight years in chemistry teaching were involved in the study. Below is the summary table showing the students sample population.

Table 3-1: Percentages of student sample population

Class	Gender		Total
	Male	Female	
Experimental	51 (47.22%)	57 (52.77%)	108 (100%)
Comparison	73 (52.52%)	66 (47.48%)	139(100%)
Total	124 (50.20%)	123 (49.80%)	247(100%)

Out of the 247 students, not all were available at the time of administering either the base-line test or post-test. Full participation of the students in the base-line test and post-test were affected by either the student being out of school due to financial issues or sickness. The table below shows the number of students with complete data on both the base-line test and the post-test.

Table 3-2: Percentages of student sample with full base-line test and post-test data

Class	Gender		Total
	Male	Female	
Experimental	48 (47.06%)	54 (52.94%)	102 (100%)
Comparison	53 (53.53%)	46 (46.47%)	99 (100%)
Total	101 (50.25%)	100 (49.75%)	201 (100%)

3.6.3 Teacher training

The teacher for the experimental class underwent staff development training (SDT) for two weeks. During this time, I conducted mini teacher training workshops on the different communicative approaches (Chapter Two), learning problems associated with chemical rate of reaction drawing from research evidence, C&TA teaching sequence, computer simulations and its usage in teaching chemical rate of reaction. The training sessions were attended by four chemistry teachers in the experimental school. However, only the teacher who was teaching chemistry in the selected class carried out the teaching intervention. It was important to have other teachers on standby in case of sickness or unforeseen circumstances that would interrupt the implementation. Training on each aspect mentioned above lasted for two hours per day (see **Table 3-3**).

The teacher training was conducted in January, 2011 during school holidays, one month before the schools opened. The timetable was designed bearing in mind that teachers normally have spare time during holiday periods. The training sessions were very important in ensuring that the teacher acquired working knowledge about C&TA prior to the actual implementation in the classroom.

In addition, I held meetings during the intervention with the C&TA teacher as often as necessary to listen and provide feedback as a colleague on how best to apply C&TA in teaching chemical rate of reaction.

In the experimental class, the teacher was specifically intended to guide students to recognize and resolve everyday scientific views (misconceptions) and think with new scientific meanings, in groups or in whole-class situations and individually using the computer and talk approach.

The teacher for the comparison class did not receive any form of teacher training linked to this study. The only information provided to the comparison teacher was that the

exercise was about students' understanding of chemical rate of reaction. In fact, there was no clue given to him about his class being compared to another class following a different approach of teaching. Effort was made to ensure that the comparison teacher taught according to the traditional teaching approaches that he was accustomed to. Alerting him of the intention would perhaps have made him change his teaching methods, which would compromise the actual aim of comparing the C&TA and NTA. Thus, in the comparison class, students were instructed with traditionally designed chemistry textbook contents approved by the Ministry of Education and Sports (MoE&S). During the classroom instruction, this teacher used the 'normal' teaching approach (practical, talk and chalk). Both groups received an equal amount of instructional time and the same instructional content.

Also, both experimental and comparison classes were observed during the implementation of the C&TA teaching sequence of chemical rate of reaction.

Table 3-3: Summary of C&TA Teacher Professional Development Programme

January 2011	Modules	Monday Time: 2 hours	Tuesday Time: 2 hours	Wednesday Time: 2 hours	Thursday Time: 2 hours	Friday Time: 2 hours
WEEK 1	Concepts students find difficult to learn in chemical rate of reaction	Why understanding chemical rate of reaction is challenging	Students' basic ideas of collision theory What international studies say.	Students' basic ideas of: Collision orientation Activation energy What international studies say.	Students' basic ideas of temperature What international studies say.	Students' basic ideas of: concentration What international studies say.
WEEK 2	Social constructivist theory, Communicative approaches Dialogic approaches	Vygotsky accounts of children's learning	Social constructivist perspective	Communicative approaches/ dialogic e.g. Interactive / dialogic; Non-interactive / dialogic; Interactive / authoritative & Non-interactive / authoritative	Illustration with example	Review of communicative approaches Dialogic approaches
WEEK 3	Computer simulations and modelling	What simulations & modelling are	advantages	Working through the teaching sequence design	Working through the teaching sequence design	Working through the teaching sequence design
WEEK 4	C&TA for chemical rate of reaction	Overview of the teaching sequence	Working through computer simulations & modelling	Activation energy Working through ...	Temperature Working through ...	concentration Working through ...

3.7 Evaluation of teaching approach: Data collection methods

In order to address research question 1, measurements were made of the students' learning in experimental and comparison classes. This was achieved through the use of base-line and post-tests. Research question 2 was addressed through use of classroom observations and research questions 3 and 4 through interviews.

3.7.1 Base-line test

A base-line test was used as diagnostic test¹ to establish equivalence levels of understanding of the students from the selected sample schools. A base-line test on a related (but not identical) knowledge domain was administered followed by a post-test focused on the specific topic which had been taught. The base-line test consisted of closed and open ended questions based on prior concepts of states of matter and kinetic theory of matter covered in the lower secondary level (Form Two). The base-line test questions were derived directly from chemistry textbooks (Atkinson, 1979; Holderness & Lambert, 1986).

3.7.2 The administration of the base-line test

The base-line test was administered to students at the start of the implementation process during **lesson one**, so as to assess students' understanding of states of matter and kinetic theory of matter. Students were expected to demonstrate understanding of what the molecules of solid, liquid and gas look like and to explain the relationship between the kinetic energy of molecules and heat, and collision theory. Testing the understanding of ideas on the above concepts is fundamental in teaching and learning chemical rate of reaction. The base-line test consisted of 11 open-end items (questions) and 6 closed ended items (questions).

3.7.3 Post-test

In order to address research question 1 (**RQ1**) a post-test² was designed to focus on the concept of chemical rate of reaction as stated in the chemistry syllabus and textbooks (Atkinson, 1979; Holderness & Lambert, 1986). The post-test consisted of 21 open-end items (questions).

¹ See appendix 8: Your understandings of particles and matter

² See appendix 9: Your understandings of chemical rate of reaction

This was done in accordance to Treagust (1988) who asserted that designing test questions should involve identification of the content through analysis of contents in textbook; school science syllabus, literature review and reference books.

3.7.4 Aspects considered in designing the post-test questions

The post-test was designed in line with questions related to the concepts students find difficult to understand as discussed in Chapter Two, the national curriculum (chemistry teaching syllabus) and the content of the textbooks. The questions were designed in an open ended format in order to allow the students to explain their ideas in as much detail as possible. The aim was to gather an in-depth insight into students' understandings of the concepts of chemical rate of reaction after the intervention.

3.7.5 The administration of the post-test

The post-test was administered 'under examination conditions', to obtain individual student's scores after the intervention. The aim was to measure students' levels of attainments and compare performance between the C&TA and NTA students, and also to evaluate the two teaching methods, in order to make judgement about the effectiveness of the C&TA teaching intervention in supporting students' understanding of chemical rate of reaction compared to the NTA. According to Leach et al. (2006), post-test results also allow ascertainment of 'the extent to which students' learning gains were consistent with the aims of the teaching (p.81)'. In order to ensure that the questions were not in favour of the students who followed the C&TA class, the post-test questions were designed to match the national curriculum (chemistry teaching syllabus) and the content of the textbook(s) for ordinary level secondary school (see **Appendix 9**).

3.7.6 The validity of base-line and post-tests

Before administering the tests, both the experimental class and comparison class chemistry teachers were asked to evaluate the items on the base-line test (diagnostic test) and post-test for relevance to the stated chemistry concepts and the research objectives. The content validity index (CVI) (Amin, 2005) for the instruments were computed after the rating of the items in the base-line test (diagnostic test), and post-test. The CVI is the proportion (s) of the highly ranked items in the questionnaire regarded as relevant to address the research objectives.

The CVI of each test was obtained by drawing up the objectives which guided the construction of the tests. Each test with its objectives was given to the experimental class and comparison class chemistry teachers who were asked to independently give a thorough critique of the items which specifically:

1. Linked each item with respective objective,
2. Assessed the relevance of the items to content addressed by the objectives,
3. Judged if the items adequately represented the content in the subject under study.

They rated each item on a four-point scale as:

1. Not relevant. 2. Somewhat relevant. 3. Quite relevant. 4. Very relevant.

CVI for base-line test and post-test were obtained using the following formula:

$$\text{CVI} = \frac{\text{Number of items rated as relevant}}{\text{Total number of items in the questionnaire}}$$

The content validity indexes (CVI) for base-line test and post-test computed were as 0.75 (75%) and 0.80 (80%) respectively.

The following results were obtained:

Table 3-4: Validity of the base-line test and post test

Instruments	Not/ somewhat relevant	Quite/ Very relevant	Total items	CVI value
Base-line test / Equivalence Test	4	14	18	0.75
Post-test	4	16	20	0.80

For an instrument to be considered valid, Amin (2005) argued that it should have a CVI of at least **0.60 (60%)**. In this case, the CVI for pre and post tests were well over **0.60 (60%)** and therefore considered valid to address the research question 1 (**RQ1**).

3.7.7 Reliability of base-line and post-tests

The reliability of research instruments has been discussed and defined differently by different authors. For example, in a review by Hammersley (1987), he cited the following definitions:

“...The reliability of a measuring instrument is defined as the ability of the instrument to measure consistently the phenomenon it is designed to measure” (Black & Champion, 1976: 222 and 234)

or

“... Reliability refers the capacity of the instrument to yield the same measurement value when brought into repeated contact with the same state of nature. Thus, this meaning of reliability is concerned with the stability of measured values under constant conditions” (Johnston and Pennypacker, 1980: 190 and 191).

The above definitions have one thing in common, that is the idea of repeated measurement to produce similar results or to put it differently, the consistency, truthfulness or correctness of a measure instrument.

3.7.8 The piloted base-line and post -tests

As the base-line test and post-test questions had not been tested in any study before, it was necessary to find out whether the structuring of the questions was appropriate for students. It was intended to see whether students understood the questions asked, and whether the questions were answered accordingly.

The base-line test and post-test were piloted in November 2010 before the main study in two different classes in two schools for senior four students (S.4). The senior four (S.4) were selected because the topic of chemical rate of reaction is covered in the final year of ordinary secondary school.

The piloted tests were administered in school by a teacher who is also a personal friend of mine. The students were given 40 minutes to complete each test and in each set they were advised to write as much as they wanted, and were allowed to ask questions if they did not understand the instructions.

The scores of 20 students were used in the pilot sample to answer the base-line and post- tests. Their scores were subjected to a Cronbach Alpha Coefficient reliability test, using SPSS version 19.

The reliability of Cronbach’s Alphas was established as **.52** for the base-line test and **.75** for the post-test. For the base-line test, the reliability was small because the base-line test had few items (shorter) and was used to establish that the groups were comparable before the teaching. According to Amin (2005), for research purposes, a

minimum reliability of 0.7 and above indicates high reliability of the research instrument. However, some items showed that they did not contribute well to the alpha scale because their α -values were higher when omitted. This was more evident with base-line test items; possibly because this test has fewer items (see **Appendix 13**) for details.

Furthermore, from the results of the piloted samples, the responses show that students did have difficulty with the explanations for the chemical rate of reaction, although according to the teacher involved in administering the questions, the items in the post-test were comprehensible and within the content required in the curriculum.

3.8 Analysis of base-line and post-tests, interview and classroom talk:

Overview

This section provides a summary of the analysis, and procedures for the base-line test and post-test scores of students from both the experimental and comparison classroom observations and interviews. It begins with presentations of scoring (for marking) of base-line test and post-test coding of classroom talks.

3.8.1 The data scoring, coding scheme and inter-rater reliability conformity / agreement

This sub-section present scoring, coding schemes and inter-rater reliability conformity, analysis descriptions of base-line test, post-test and interviews.

3.8.2 For base-line test and post-test scripts

The data analysis followed similar criteria suggested by Abraham et al. (1994) for scoring and coding student responses. Students' responses to test items were classified as: Correct response (3 points) for responses that included all components of the validated answers; partially correct response (2 points) for responses that included at least one of the components of a validated response, but not all the components; incorrect response (1 point) for responses that included illogical or incorrect information, unclear information and no response.

Inter-rater reliability decision to assign scores to the student responses were agreed by four (4) experienced chemistry teachers based upon the appropriate scientific explanations or answers for the questions. I (the researcher) scored draft data

responses separately and negotiated the classification. There was a high agreement with 90% for post-test items. All disagreements were resolved by negotiation.

3.8.3 Analysis of items in the base-line test and post-test

The effectiveness of the teaching sequence was analyzed by comparing students' performances on base-line test and post-test items. Students' base-line test and post-test item-level scores were entered into SPSS version 19 for processing and analysis. Inferential statistics was used to compare the mean scores or achievement levels of high school students who received computer and talk teaching instruction, with students who received normal teaching instruction.

An analysis of the results of the base-line test and post-test was conducted by comparing group mean scores using an independent t-test.

The results from the t-test were then used to explore if there was a statistically (and practically) significant difference between the mean scores of the experimental and comparison groups in terms of level of understanding of chemical rate of reaction.

Also Correlation (Pearson r) tests were conducted within the groups to ascertain if the students' initial understandings had a statistically and practically significant influence on their final post-test scores after the intervention. Further analysis was conducted using the General Linear Model (GLM) procedure to compare the post-test scores based on base-line test, group (experimental or comparison), gender, group and gender interaction to determine the extent to which their effects predicted the final students' achievement level, the post-test outcomes.

This analysis ensures that any significant difference (or level) of students' understandings of chemical rate of reaction is treated purely as due to the design teaching intervention.

3.8.4 Semi-structured interview

In this study, semi-structured interviews were carried out with the students and the teacher in the C&TA class as they offered some flexibility within the prepared questions (also see Drever, 2003).

According to Wilkinson and Birmingham (2003) an interview is a method which entails a researcher asking questions and receiving answers from people. The interview is one of the most widely used methods of data collection and is a resource intensive method, as the researcher is required to elicit information from respondents on a one-to-one basis. According to Kvale (1996) the interview is defined as a specialised form of communication between people for a specific purpose associated with some agreed subject matter.

The purpose behind interviewing the students was to investigate their understanding after each lesson, at the end of the intervention, and to find out their perceptions of the teaching. According to Verma and Mallick (1999), the interviews can explore in greater detail and depth some particularly important aspects covered by the post-test (the content of teaching) while according to Fraenkel and Wallen (1993), the interviews are used to discover what respondents think or how they feel about something in this case, the teacher's and students' perception on the use of C&TA teaching.

3.8.5 Interview with the teacher

The purpose of the teacher's interview was to gain views on using computer simulations and modelling along with talk approach (C&TA) to teach and learn chemical rate of reaction concepts.

As one of the aims of the study is to explore the effectiveness of the C&TA, it was important to obtain the teacher's perceptions and views on its implementation in order to determine whether or not the C&TA has the potential to be used as an alternative approach to NTA in classroom teaching and learning.

The questions asked are presented in **Appendices 10 and 11**.

The interviews with students are divided into the following:

1. Interview with the target group (follow up group) during intervention stages.
2. Interview with the focus group at the end of the intervention.

3.8.6 Interview with the target group

A semi-structured interview lasting for about ten minutes was conducted with each of the same target students (five students) after each lesson in order to establish their

understanding. For example, after Lesson 1, the students were asked about some of the taught content and were also asked about their perceptions of the teaching.

Thus, there were six interviews with this target group.

3.8.7 Interview with the focus group

20 minute semi-structured interviews were conducted in the experimental class (C&TA class) with a focus group (eight students) at the end of the intervention in order to obtain information regarding their perceptions of the use of C&TA teaching.

The structured questions asked are presented in **Appendix 11**.

It worth mentioning that because of limited time, it was not possible to conduct interviews with individual students as a follow up on individual understanding during the course of the intervention and after the post-test.

The interviews with the teacher and students were audio recorded for data analysis and were carried out immediately after each lesson interview. There was one final overall interview focussing on the benefits and challenges, as well as the perceptions of the teacher and students about C&TA as compared with the NTA. The interview results were used to provide evidence to answer **RQ2** (after each lesson interviews were used), and to address **RQ3** and **RQ4**. The findings are presented in Chapter Eight.

3.8.8 Analysis of interviews

The data obtained from the interviews were analyzed thematically, identifying common similarities and differences in responses (Merriam, 1988; Yin, 1994). The thematic analysis process was straightforward as the purpose was to explore students understanding immediately after each teaching, and also to gather the teachers and students' response on the benefits, challenges and perceptions about C&TA, as compared with the NTA to teach and learn chemical rate of reaction concepts at the end of the intervention.

3.8.9 Classroom observations

The classroom observations (recordings) were conducted in order to gather evidence of classroom talk as well as to compare both classes (C&TA and NTA) and judge to

what extent the C&TA actual teaching patterns / interactions were consistent with the design of C&TA teaching patterns / interactions.

The C&TA teaching sequence is six (6) lessons long and all six (6) lessons were video and audio recorded. Also six (6) lessons were video and audio recorded from the comparison class (NTA). This is normally the time allocation for this content in Uganda. This provided classroom data which allowed evaluation of the teachers' and students' actions when working on learning activities matched to those intended in the design of teaching (Millar, et al. 1999). The evaluation of results of the teaching process and the extent to which the teaching sequence was successful in meeting its aims, was conducted to address research question two (RQ2).

3.9 Analysis of classroom observations (classroom talk)

The data were collected in order to assess how different the experimental and comparison teaching actually were, with regard to the design features in C&TA (for example, dialogic talk). This would enable the advancement of hypotheses about the likely potential causes of any differences noted in the post-test results. Analysis of which part of the teaching sequence worked and why; or which part did not work and why it has not worked, were considered in the analysis.

Video recordings of classroom interactions collected were transcribed and patterns of interaction were analysed to provide information on whether the recommended teaching sequence was followed by the classroom teacher (Mercer, 1992: 1994b).

3.9.1 The framework for analysing the classroom talk

As the second aim of the study was to evaluate the effectiveness of the C&TA teaching sequence, a conclusion could only be made by looking at the aspects of the teaching activities and their staging by the teacher that were influential in promoting students' learning.

To address this aim, an analytical framework based on socio-cultural perspective of teaching and learning was considered appropriate in providing such detailed evaluation of teaching sequences. The framework is based on five linked aspects, which focus on "the role of the teacher in making the scientific story available, and in supporting students in making sense of that story" (Mortimer & Scott, 2003, p.25). The five aspects

are - purpose of teaching, teacher interventions, and content of the classroom interactions, communicative approach and pattern of the talk.

Purpose of teaching: Mortimer and Scott, (2003, pp. 25-26) identified six teaching purposes commonly employed by teachers at different phases of a lesson

- opening up the problem
- exploring and working on the students' views
- introducing and developing the scientific story
- guiding students to work with scientific ideas and supporting internalisation
- guiding students to apply, and expand on the use of, the scientific view, and handing over responsibility for its use
- maintaining the development of the scientific story

In this study, I chose to refer to the purpose of teaching as teaching aim drawn from the curriculum. As the purpose of the talk is to be the learning aim the teacher will focus the students' understanding through the form of interventions outlined in the next paragraph.

Teacher interventions: Scott, (1997) as cited in Mortimer and Scott, (2003) identified six forms of teacher intervention; shaping ideas, selecting ideas, marking key ideas, sharing ideas, checking student understanding and reviewing. Alexander et al. (2004, p.26-7) supports this argument (see **Chapter 2, section 2.6.11**). This aspect is key in carrying out this analysis because it allows us to identify the teacher's supporting moves during teaching.

Content of the classroom interactions: in Mortimer and Scott, (2003) framework, the analysis of the classroom interactions covers a range of content matter, which include the scientific concept being taught, procedures of conducting science experiment and classroom management (e.g., giving instructions). In carrying out analysis of the content, specific focus has been given to three categories (Mortimer & Scott, 2003, p.26):

- every day-scientific
- description-explanation-generalisation
- empirical-theoretical

Fundamental to these three categories is their relationship in explaining the nature of knowledge the teacher and students are talking about during classroom interactions (see Mortimer & Scott, 2003, p.26 for more details). This aspect is important in this analysis as it helped in the collection of evidence of talk to support the effectiveness of the intervention which was talk based approach of teaching.

However, I adopted a broad approach taking into account all the aforementioned range of classroom interactions. The decision taken allows a comparison to be made between C&TA and NTA which is didactic and characterised by less talk.

Communicative approach: In Mortimer and Scott, (2003), this concept lies at the heart of the framework; it focuses on the ways in which the teacher works with his students to address the different ideas that emerge during the lesson (p.27). Mortimer and Scott, (2003) identify four classes communicative approach (**refer to section 2.6.12**).

Patterns of talk: the patterns of interaction that develop in the discourse as teacher and students take turns in classroom talk includes the moves as Initiation, Response or Follow-up (whether evaluation, comment or elaboration).

According to Sinclair and Coulthard (1975) educational classroom discourse (pattern of talk) consists of an exchange structure which is identifiable by initiation and closure of discourse in a dialogic situation, particularly between the teacher and student classroom talk. Building on the early work of Halliday's (1961) model which consists of five ranks: lesson, transactions, exchange, move and act, Sinclair and Coulthard (1975) argued that exchange structure involves acts of five types of 'move'. These are framing and focusing moves used by the teacher to indicate that one stage of the lesson has ended and another is beginning. These are indicated by a limited number of markers such as 'right', 'okay', 'well', 'now' and 'good'. This is often followed by opening, responding and follow-up moves which combine to make the teaching exchanges. They argued that a number of exchanges combine to make transactions, which combine to make the lesson. The moves are used to elicit, inform and direct in classroom discourse.

An **Initiation (I)** is realized as an opening move which causes others to participate in an exchange. Initiation may refer to a question from the first speaker to the second speaker and requires the second speaker to use their memory to produce some response. Initiation may also be a verbally given directive to the second speaker. As argued by Andre (1979), instructional directions from the first speaker that do not require an overt response from the second speaker are not characterised as a question. It is important to note that not all questions asked by either the teacher or students are initiations, some are considered as a type of follow up move. However,

whenever a second question is asked, the first question is categorised as an initiation and the second as an elaborative follow-up (to be explained later on) and not initiation.

A **Response (R)** is realized by an answering move, the function of which is to be an appropriate reply to the opening move. In the classroom setting, response may take two forms; the verb and non-verb reaction supplied by either the student or the teacher to answer a certain question. This can be an initiation or an elaborative follow-up move. Any statement uttered which does not answer a query of the questioner is not categorised as a response but rather a second type of follow-up move, called a 'comment'.

A **follow-up move** is realized as feedback (**F**) given to the second speaker. It is used to let a learner know how well they have performed (as an evaluation). In some incidents it actually follows the first speaker's initiation (I-F), for example in talk initiated by the students, but does not, in itself, provide a clear response to that initiation. Moreover, each turn can enclose two types of follow-up (for example, *the teacher comments on a pupil's answer and then elaborates on it*) which means that a follow-up move can be defined also as a statement spoken by the same speaker, following and complementing their first, but of different-types of follow-up.

Richard (1998:184) argues that classroom feedback from the teacher to the students' responses is either an acknowledgement that the answer is acceptable (for example, by echoing, or, by a comment such as 'fine').

Sinclair and Coulthard (1975 pp.24-27) argued such classroom exchanges together make up a transaction, and a series of transactions make up a lesson which is the highest level of classroom discourse. The next section presents an approach to analysis classroom discourse.

3.9.2 Analysis of transactional exchange structure / patterns of talk

According to Sinclair and Coulthard (1975), in carrying out the transactional analysis or patterns of talk, the exchange is viewed as the smallest unit which can stand alone and still make sense. For example, an exchange may consist of statement and counter-statement, question and answer, or offer and acceptance.

Sinclair and Coulthard (1975) described such exchange in educational classroom as consisting of I-R-F (initiation-response-feedback) discourse chains in which the teacher

initiates the chain (normally by asking a question), a student responds, and the teacher then gives feedback to the student (e.g. 'good'), before initiating another chain with another question.

Richard (1998:184) argues that the structure of the IRF pattern (discourse) is usually characterised by good deal of echoing of the student's statement by the teacher. While Mortimer and Scott (2003) assert that teachers instead of evaluating the student's response may give feedback or elaborate on the student's answer so as to support the student in developing their own point of view. They argued that in 'this pattern of discourse, the teacher initiates the chain, followed by the student's response, and then the teacher's elaborative feedback (F) from the teacher is followed by a further response from the student (R) and so on' (p.41). In this case the pattern of interaction is **I-R-F** (F standing for feedback), rather than an **I-R-E** form.

According to Mehan (1979) the **I-R-E** form is a pattern of interaction characterised by initiation-reply (response)-evaluation interaction in which the teacher initiates the chain (typically by asking a question), a student responds, and the teacher then gives evaluative feedback to the student before initiating another chain with another question. Evaluative feedback may take the forms of appraising (e.g. 'very good'), affirming, agreeing/disagreeing with, approving/disapproving students' responses.

I-R-F patterns of classroom interactions are common because teachers and students regard question and answer routines as appropriate behavior for the classroom (Musumeci, 1996). Walsh (2011) supports this arguing that students are socialized right from an early age to answer questions and respond to prompts. Musumeci (1996) pointed out that continuity of I-R-F use in classrooms is due to the teacher's control power in a classroom. While Chaudron (1988) asserts in the exchange structure model that the teacher has two statements to one from the pupil (initiation and follow-up).

However, in applying such approach to analysis of the classroom talk, Pilkington (1999) argued that the transactional analysis does not help to capture details of the characteristics of the classroom talk or moves in terms of education functions, intentions (purposes) and content.

Therefore, in order to ensure that detailed evidence is collected on classroom interactions and activities that are influential in promoting students' learning, a socio-cultural perspective described above was adopted in this study. Furthermore, the

framework was also adopted so as to allow evaluation of the extent to which the teacher followed the C&TA teaching sequence that was designed based on the communicative approach framework.

The framework includes the teaching purposes, content, and approach, forms of teacher intervention and patterns of interaction as illustrated in **table 3-5**. The categorization of the patterns of talk includes the moves as Initiation, Response or Follow-up (whether Evaluation, comment or elaboration). Here, I follow the different moves for each lesson and put them in their order of occurrence in what is called the patterns of talk or interaction.

Table 3-5: Summary of a Socio-cultural Framework for Analysing Classroom Talk

Teaching Purposes	Content	Forms of Teacher intervention	Categories of talk	Patterns of classroom talk/discourse	Communicative approaches
Exploring and working on students' views, guiding students to apply, and expand on the use of the scientific view, and handing over responsibility for its use	For example, Definition of rate of reaction	The teacher and students (or student pairs or group) exploring ideas, generating new meanings, <i>posing genuine questions</i> and <i>offering, listening to</i> and working on different points of view (e.g. by Echoes—to emphasize the point/reinforce the correct answer/acknowledge an answer as acceptable)	I -Initiation, R -Response, F -Feedback	I-R-F chain	Interactive/dialogic I/D
Introducing and developing scientific story	For example, proper orientation of reacting particles , activation energy (Ea)	The teacher leads students through a sequence of questions and answers with the aim of reaching one specific science point of view / intervenes to work on alternative conception (through <i>shaping, selecting and marking ideas</i>) some aspect of the content, with a view to developing further the scientific ideas	I -Initiation, R -Response E -Evaluation	I-R-E chain	Interactive/authoritative I/A
Maintaining the development of the scientific story; reviewing progress	For example, effect of temperature on rate of reaction	The teacher introduces, <i>reviews or summarizes</i> key scientific points and looks ahead to the next steps	I – initiation	I	Non-interactive/authoritative NI/A
Exploring and working on students' views	For example, effect of concentration on rate of reaction	The teacher considers various points of view, setting out, exploring and working on the different perspectives	N -Neutral	N	Non-interactive/dialogic NI/D

Source: Developed from Mortimer & Scott, (2003)

The next section describes the patterns expected to be illustrated by the analysis.

3.9.3 Characterisation of the talk in C&TA teaching sequence

Building on the socio-cultural framework, the patterns expected to be illustrated by the analysis will entail a mix of all four types of communicative approaches as demonstrated by Mortimer and Scott (2003, pp.35, 105).

- Interactive/dialogic-I/D (I-R-F pattern): The teacher seeks to elicit and explore students' ideas about a particular issue with a series of 'genuine' questions.
- Non-interactive/dialogic-NI/D (N pattern): The teacher is in presentational mode (non-interactive), but explicitly considers and draws attention to different points of views (dialogic), possibly in providing a summary of an earlier discussion.
- Interactive/authoritative-I/A (I-R-E pattern): The teacher typically leads the students through a sequence of instructional questions and answers with the aim of reaching one specific point of view.
- Non-interactive/authoritative-NI/A (I-pattern): The teacher presents a specific point of view.

In **Chapter Seven**, I have selected episodes to illustrate each of these teaching purposes and to characterise the classroom talk along the communicative approach.

3.10 Analysis codes for classroom interactions

To collect evidence on teaching activities (purposes, content, and approach, forms of teacher intervention and patterns of interaction) presented in **section 3.9**, coding schemes were adopted from suggestions made by Mortimer and Scott, 2003, pg. 69; Edwards and Mercer, 1987; Lemke, 1990; Scott, 1998; Alexander et al. 2004, p.26-7 that, the patterns of interactions in a science classroom featured words such as: questions, initiation to (introduce ideas, explore ideas, review ideas, summarise ideas), response to (answer questions), motivation, selecting, marking students key ideas, shaping students ideas and evaluation of students' ideas by the subject teacher.

In addition, at the point of analysing the classroom talk, I first explored excerpts of the classroom teaching in more detail, thereby generating more detailed categories coming from the classroom talks. Thus, I conducted a 'grounded analysis' (Strauss and Corbin, 1998) of the teacher-students interactions to offer insight into the patterns of classroom talk. In this respect, I focused on the transcribed data and inductively generated more categories (featured words) during teacher-students classroom talk. To accomplish this, I was 'flexible' and 'open to helpful criticisms' by my supervisors, whilst showing 'appropriateness, authenticity, credibility, intuitiveness, receptivity, and sensitivity' (Strauss & Corbin 1998:5, p.6). It was a developing and continuous process, or 'evolving process' (Charmz, 2006) which involved finding key phrases or words

statement between the teacher and students as they took turns during classroom talk. The key phrases or words provided codes which were used to identify the teaching purposes, content, and approach, forms of teacher intervention and patterns of interaction. Detailed codes, their meanings and examples are presented in **Chapter Five (section 5.11)**.

3.11 Summary of the research instruments to address the research questions, expected data type and data analysis

Table 3-6 below shows research instruments, the data type and how the research data will be analysed.

Table 3-6: Instruments, data types and data analysis

Research question	Data type	Instruments	Analysis
RQ1 (Quantitative data)	Base-line test and Post-test scores	Base-line test (N=201) and Post-test (N=201)	Content validity index (CVI) Cronbach alpha t-test establish statistically significant difference between mean scores of the experimental and comparison classes correlation (Pearson r) to establish relation between predictor variable and the post-test scores General Linear Model (GLM) to establish relationship between post-test, fixed effects (intervention or not) , groups, gender & base-line test (predictor variable) Analysis of items responses Descriptive statistics (frequencies, percentages, error bars and histograms and) were used
RQ2 (Qualitative data)	Descriptive observation of verbal & non verbal behaviour	Video and audio recording / classroom observation (6 lessons) Interview guide Teacher (N=1) Target group students (N=5)	Video & audio analysis- identification of patterns of interaction (Discourse-analysis)
RQ3 (Qualitative data)	Teacher / students' thoughts, ideas, reasoning	Interview guide Teacher (N=1) Focus group students (N=8)	Thematic analysis- identification of themes / patterns of ideas
RQ4 (Qualitative data)	Teacher / students' attitudes, feelings, motivation, interests	Interview guide Teacher (N=1) Focus group students (N=8)	Thematic analysis- identification of themes / patterns of ideas

3.12 Ethical considerations: Research procedure / Ethical issues

In carrying out this study, I have endeavoured to follow the ethical guidelines for research issued by the British Educational Research Association, BERA (2004). The first step was to seek the approval of the research study from the AREA Faculty Research Ethics Committee, University of Leeds for clearance to conduct the study³. Secondly, I obtained a covering letter of introduction from the School of Education, University of Leeds which I presented to the Uganda National Council of Science and Technology (UNCST) for clearance to conduct the study⁴. UNCST successfully registered and granted the permission for the research to be conducted. Thirdly, I made contacts with identified high schools and permission was successfully sought from the Head of School to allow the participation of the teacher and students in the research study. The informed consent forms were signed by the Head of School, the teacher and students agreeing to take part in the study⁵.

In this study, three main ethical issues were identified, namely; 1) the confidentiality and anonymity of the participants and their schools, 2) informed consent, and 3) protection from harm or benefit.

3.12.1 Confidentiality / anonymity

Protection of the identity of the participants and maintenance of the confidentiality of data/records is general practice by researchers while conducting any research. According to BERA (2004), the confidential and anonymous treatment of participants' data is considered the 'norm' for the conduct of research. In this study, the information obtained has been kept strictly confidential and anonymous. The results of statistical and other analyses of data have been published in a non-attributable and aggregated form. Also, the lessons video and audio recorded to collect data on classroom activities has not been used as classroom teaching films and kept securely. As suggested by Hill, (2005) there has been no identification of students, teachers or schools in research analyses and presentations. Thus, adequate care has been taken to ensure the confidentiality and anonymity of the participant schools in the publishing of the results. I

³ See appendix 1: AREA Faculty Research Ethics Committee, University of Leeds

⁴ See Appendix 2: Uganda National Council of Science and Technology (UNCST) Approval Research Certificate

⁵ See Appendix 4: Participant Consent Form [Head teacher/Teacher Form B] and Appendix 6: Participant Consent Form [Student Form B].

minimised any form of threat to the participants during classroom video and audio recordings and assured the teacher that the recordings were for my personal study, and that analysis may be made accessible by my supervisors in case they wish to see.

3.12.2 The informed consent of participants

According to Cocks (2006) informed consent is a process of provision of information by the researcher, the potential of the participant's understanding of the information, and making a response to it. Clark (1995) argues that informing the participants and obtaining their consent affects their behaviour and the results of the study. My approach for dealing with this ethical issue was to first introduce myself, explaining my institutional affiliation and the intentions of the research study. I then explained how students could benefit from this kind of teaching approach. This openness encouraged the head teacher, teacher and students to respond freely without expectations beyond those I had explained. I then provided the head teacher, teacher and student participants with an information sheet⁶ about the study, and they all consented by signing the consent forms or with written agreements (Gallagher, 2009).

3.12.3 Protection of participants from harm

According to AARE (2009), research design should minimise the risk of significant harm to the research participants. Similarly, Belmont Report (1979) argues that it is the responsibility of the research investigators to maximise benefits for the individual participant and society while minimising risks of harm to the individual. While Amin, (2005) suggested that an honest and thorough risk or benefit calculation (i.e., the ratio of risks to possible benefits) must be performed before any research is carried out. For this study, there were no risks but potential benefits were that students would, or it was hoped that students would, even learn better.

In regards to this, students' normal class lessons were not interfered with in any way. That is, the same concepts were taught as planned in the school syllabus and calendar.

⁶ See Appendix 3: Information sheet [Head teacher / Teacher Form A] and Appendix 5: Information sheet [Student Form A]

To ensure that the comparison class was not demotivated, both the experimental class and comparison class came from different schools. Deprivation of the comparison class of the benefits of C&TA was resolved after intervention through remedial classes for the comparison class. The C&TA teaching sequence, computer simulations and modelling tools were given to the comparison class for use as revision lessons.

3.13 Time and duration of the study

The data collection was conducted between the periods of December 2010 to June 2011, as shown in table below. The period for teaching chemical rate of reaction is 24 periods for the whole content. The total period for chemistry lessons per week is four, each lasting 40 minutes.

Thus, the total time of teaching was 160 minutes per week. The teaching sequences for this study did not cover the whole 24 periods because it focused on - collision theory, activation energy, temperature and concentration of the reactants.

Table 3-7: Fieldwork Timetable (December 2010 to June 2011)

	Week 1 Activity	Week 2 Activity	Week 3 Activity	Week 4 Activity	Week5 Activity
December 2010	Arrival in Uganda	Research permit negotiation of access from UNCST	Contacts with identified schools	Schools visits	
January 2011	Interview of 4 teachers	Interview Transcriptions	Training of teachers	Training of teachers	
February 2011	Schools open (School programs)	Beginning of term 1 examination (School programs)	Diagnostic / Equivalence test	Transcriptions of diagnostic test	
March 2011	Implementation of lesson 1	Implementation of lesson 2	Implementation of lesson 3	Implementation of lesson 4	Implementation of lesson 5
April 2011	Examination periods End of term 1	Examination periods End of term 1	School Holidays	School Holidays	
May 2011	School Holidays	Implementation of lesson 6			
June 2011	Post-test				

Key

UNCST: Uganda National Council of Science and Technology

3.14 Some methodological issues concerning the approaches to the data analysis

In this study, an analysis of the students' response on the post-test items was carried out using three classified criteria specified in **section 3.8.2**, and were coded as correct response (3 points), partially correct response (2 points) and incorrect response (1 point). The analysis of the items presented in Chapter Six does not include students' alternative ideas and reasoning since the major aim of the analysis was to compare students' performance (the mean scores) with important consideration made only to responses which are scientifically correct.

The analysis of classroom interactions did not include student-to-student talk and teacher talk to small student groups during student group discussions since these were inaudible in most lessons.

This is because technically, it was not possible to record a clear exchange of words between students as they shared ideas with their peers during group discussions. The challenge was a lack of audio recorders which would have made it possible to record group discussions.

Therefore, the whole class interactions analysis in Chapter Seven represents the ideas agreed on by group members as each group presented their ideas.

In the next chapter, the approach to designing the teaching sequence is presented.

CHAPTER FOUR

4 DESIGN OF TEACHING SEQUENCE

4.1 Introduction

This chapter presents the design of the C&TA teaching sequence which includes the approach used in the design of the teaching, analysis of chemistry syllabus for ordinary level and text books, teaching goals, identification of learning demands and drafting instructional design suitable for computer simulations and modelling (spreadsheets), along with talk approaches to support the teaching and learning of chemical rate of reaction to senior four students, aged 15 to 16 years.

4.2 Overall Approach

The approach adopted was drawn from a strand of the Evidence-Based Practice in Science Education (EPSE) research project, based at the University of Leeds, UK. According to EPSE, students often hold prior ideas about the phenomena addressed in science lessons which differ from them (see Leach & Scott, 2002). These ideas often differ from the scientific view in many ways, posing difficulties for learners and must be overcome in order to understand the scientific view points. Leach and Scott (2002) characterised them through 'learning demands'. They exist in the following forms:

- a. Conceptual form, for example, the prior understanding of natural world by the learner is different from the scientific one.
- b. Epistemological form, characterized by the difference in the explanation of things between the learner and scientists.
- c. Ontological forms, characterized by the way we talk about things (Leach & Scott, 2002).

To address the learning demands in understanding chemical rate of reaction, I started by identifying likely initial conceptions (and difficulties) of students, around relevant chemistry curriculum content (chemical rate of reaction) in Uganda. I then identified the differences between these two areas in terms of the concepts used to generate explanations, their epistemology and ontology – which give 'learning demands'. I then identified 'teaching goals' to address those learning demands, and finally proposed lessons to address those teaching goals using teaching approaches based upon communicative approach (Mortimer and Scott, 2003), and Leach and Scott's social constructivist perspective on teaching science in formal settings to inform the design of the teaching sequence.

4.3 Implication for design of teaching

Building on the concept of the different forms of learning demands as set out above, I have adopted guidelines outlined by Leach and Scott (2002) to inform the teaching sequence:

- a. Identifying the school science knowledge to be taught.
- b. Considering how this area of science is conceptualized in the everyday reasoning of students.
- c. Identifying the learning demand by appraising the nature of any differences (conceptual, epistemological and ontological) between **a** and **b**.
- d. Designing the teaching intervention to address each aspect of this learning demand:
 - i. Identifying the teaching goals for each phase of the intervention
 - ii. Planning a sequence of activities to address the specific teaching goals
 - iii. Specifying how these teaching activities might be linked to appropriate forms of classroom communicative approach (p.127).

Following these guidelines, the expected school science knowledge about chemical rate of reaction was identified from the national curriculum, school syllabus and text books.

4.4 Analysis of chemistry curriculum

An analysis of the Ugandan national chemistry syllabus for ordinary secondary school level identified the following topics.

Table 4-1: Chemistry syllabus for ordinary secondary school level

Chapter 1: Introduction to Chemistry	Chapter 9: Carbon and its compounds
Chapter 2: States of matter	Chapter 10: Sulphur and its compounds
Chapter 3: Mixtures	Chapter 11: Nitrogen and its compounds
Chapter 4: The periodic table / Bonding & structure of atoms	Chapter 12: Mole concept
Chapter 5: Chemical Formulae & Equations	Chapter 13: Chemical rate of reaction
Chapter 6: Compounds	Chapter 14: Energy changes and chemical reactions
Chapter 7: Oxygen and its compounds	Chapter 15: Applied chemistry-Organic chemistry
Chapter 8: Hydrogen and its compounds	

Source: UCE Chemistry Teaching Syllabus, National Curriculum Development Centre (2008)

From the above list of topics, chemical rate of reaction (Chapter Thirteen) is taught in the final year of the ordinary secondary level. The units covered under Chapter Thirteen; chemical rate of reaction are as follows:

Table 4-2: Chemical rate of reaction concepts

Unit 13: Chemical rate of reaction

13.1 Definition of chemical rate of reaction

- Collision theory
- Proper orientation of reacting particles

13.2 Factors that affect rates of reaction:

13.2.1 Temperature

- ◆ Activation energy, E_a
- ◆ Graphical plot and interpretation of temperature against time
- ◆ Graphical plot and interpretation of temperature against rate

13.2.2 Concentration of reactants

- ◆ Graphical plot and interpretation of concentration against time
- ◆ Graphical plot and interpretation of concentration against rate

13.2.3 Surface area of reactants

13.2.4 Pressure

13.2.5 Catalyst

13.3 Applications of rates of reactions

13.3.1 Preparation of oxygen from H_2O_2 .

13.3.2 In contact process / manufacture of sulphuric acid

13.3.3 Haber process / manufacture of ammonia

13.3.4 Manufacturer on nitric acid.

The units selected as the focus for this study were 13.1, 13.2.1 and 13.2.2. These units were selected to specifically offer scientific explanations to the difficult aspects of chemical rate of reaction, collision theory and proper orientation of reacting particles, temperature, activation energy, E_a and concentration. In the next section, the science knowledge taught in Uganda under this concept is presented.

4.5 Chemical rate of reaction: School science knowledge

According to the Ugandan national curriculum, school syllabus and text books, the knowledge about chemical rate of reaction to be taught in school science can be summarised as:

1. Chemical reactions occur only when the reacting molecules collide with the correct orientation. That is, unless the alignment is favourable, the reaction will not be successful. Of course, as the overall number of collisions increases, it becomes more likely that a collision with a favourable orientation will occur hence the rate of the reaction would increase.

2. A rate of chemical reaction is the amount of products formed per unit of time or the amount of reactants used up per unit time: Rate = amount/time.
In solution, this amount is in moles per litre (or grams per litre). If the time is in seconds, then the units of rate are $\text{mol dm}^{-3} \text{ s}^{-1}$ or $\text{mol l}^{-1} \text{ s}^{-1}$. $\text{mol l}^{-1} \text{ s}^{-1}$ is read as “moles per litre per second”. The amount of products formed in a given time depends on the concentration of the reactants present. At the beginning of a reaction, the concentration of the reactants is high. Hence the reaction is fast. As the reactants get used up, the reaction slows down. Then, when there are no more reactants, the reaction stop.
3. The molecules must collide with enough energy to overcome the activation energy barrier. The activation energy barrier can be lowered when a catalyst is present. Thus, catalysts provide an alternate energy pathway in which the potential energy barrier between reactants and products is lowered.
4. Increasing the temperature gives the reactants molecules more kinetic energy, thus more high energy collisions can occur. Thus, reaction rate depends on temperature because as the temperature increases the reactant molecules are moving more rapidly and coming into contact with each other more often, which increases the reaction rate.
5. Concentration refers to how close together the solute particles are in a given solution. The higher the concentration, the higher the frequency of collision. Thus, as concentration of reactants increases, molecules of the reactants are more likely to come in to contact with each other, which increases the rate of reaction. (Spiers & Stebbens, 1973; Atkinson, 1979; Holderness & Lambert, 1986)

This work was followed by the identification of students' understanding about chemical rate of reaction from the reported literature (see **Chapter Two**).

4.6 Chemical rate of reaction: Students' understandings review

From the review we have seen in Chapter Two, students hold alternative ideas about chemical rate of reaction and such misconceptions / difficulties can be summarised as:

- Problems with using kinetic theory to explain behaviour of atoms at the molecular level and relating these to the macro and symbolic levels
- Every collision leads to a product
- Fast moving particles may lead to particles bouncing off each other without a reaction occurring: collision is too quick and energetic
- Rate of reaction is constant throughout a reaction

- Activation energy is the energy released after a reaction
- Activation energy is the peak of the energy profile diagram

Common students thinking not informed by collision theory

- Increasing temperature increases the amount of product
- The rate of a reaction is directly proportional to the concentration of reactants

A comparison between school science knowledge and students' alternative ideas was carried out in order to establish the learning demands.

4.7 Learning demands

The following learning demands were identified. Learning in this area requires students to:

- Develop abstract scientific concept that particles must collide in the correct orientation for an effective collision to occur leading to the formation of products.
- Understand that particles must have enough kinetic energy to produce an effective collision in the context of explaining the activation energy barrier. That is, for a reaction to occur, the collision needs to be forceful enough to break the existing chemical bonds of the reactant, i.e. the energy barrier.
- Understand that increasing the temperature will cause particles to move faster with more kinetic energy. That the particles therefore collide more often and with greater energy. That these two things mean there are more successful collisions per second and therefore a faster rate of reaction, **NOT** that when particles that move very fast collide with each other, it is likely that these particles 'bounce back' without reacting.
- Understand that increasing the concentration of a reactant simply means there are more particles which may collide and so react. More collisions mean a faster reaction.
- Understand that rate of chemical reaction is the amount of products formed per unit of time. That the amount of products formed in a given time depends on the concentration of the reactants present. That at the beginning of a reaction, the concentration of the reactants is high. Hence the reaction is fast. That as the reactants get used up, the reaction slows down. That when there are no more reactants, the reaction stops, **NOT** for example, that the rate of chemical reactions cannot be altered (as reported in the literature).

I now define the design of the teaching sequence with specified learning goals, teaching activities and classroom discourse aimed at improving students' understanding of chemical rate of reaction.

4.8 Teaching goals

By the end of chemical rate of reaction topic in secondary education, the Ugandan national curriculum specifies that the learner should be able to:

- a. Define the term 'rate of reaction'
- b. Discuss collision theory:
 - i. Particles must have enough kinetic energy to produce an effective collision that leads to a reaction and formation of new product
 - ii. Particles must collide in the correct orientation for an effective collision to occur
- c. Explain the term activation energy and how this affects the number of effective collisions and formation of the products in a reaction
- d. Explain how varying the temperature affects the rate of reaction
- e. Interpret graphically how temperature affects rate of reaction
- f. Explain how varying the concentration affects the rate of reaction
- g. Interpret graphically how concentration affects rate of reaction

4.9 Teaching approaches: review

In order to address students' learning difficulties in chemical rate of reaction, the following teaching strategies have been used in other research to improve students' learning of chemical rate of reaction (refer to **Chapter Two** for details and how these strategies have informed this study).

- use of computer aided instruction (Tezcan &Yilmaz, 2003)
- small group discussion and hands-on experiments (Van Driel 2002)
- use of a pictorial analogy (Fortman, 1994)
- use of conceptual change texts oriented instruction accompanied with analogies (Bozkoyun, 2004)
- use of inquiry-based experiment (Chairam et al., 2009)
- use of computer animations (Calik et al., 2010)

For this study, I developed a teaching sequence to support meaningful learning of chemical rate of reaction using computer programmes (simulations & modelling) and

talk approach (C&TA). The C&TA was intended to enhance students' understanding of chemical rate of reaction, based on the importance of talk as emphasised by social constructivist perspectives on teaching and learning (Mortimer and Scott, 2003).

The teaching sequence involved three key phases described in **Chapter Two, section 2.6.2**: 1) the teacher staging scientific view of chemical rate of reaction during class session; 2) The teacher supporting students' internalisation with help of computer simulations and talk approaches; and 3) the teacher providing the opportunity to students to try out and practice chemical rate of reaction ideas they have learnt. That is, the teacher hands over responsibility to students (See Mortimer & Scott, 2003).

Since the students were required to discuss their ideas in a group around the computer, a set of ground rules for talk and operating the computer was to be followed as outlined below:

4.10 Ground rules for talk

1. Everyone should have a chance to talk.
2. Everyone's ideas should be carefully considered.
3. Each member of the group should be asked:
 - What do you think?
 - Why do you think that?
4. Look and listen to the person talking.
5. After discussion, the group should agree on a group idea.
(Wegerif & Mercer, 1996, p.58)

4.11 Computer and talk teaching sequence for chemical rate of reaction

In this section, I present the teaching sequence that was designed to encourage classroom talk. Students discuss the rate of reaction concept with their peers while the teacher guides them to make meaningful understanding using a computer based and talk approach.

4.12 Overview of the teaching sequence

Overall the teaching sequence involved moving between three key phases: 1) Staging scientific view point; 2) Supporting student internalisation; and 3) Handing-over responsibility to the students (See Mortimer and Scott, 2003).

For collision model (CM) to explain the chemical rate of reaction, the following sub-topics were considered: Temperature (T) and concentration (C), the following steps are to be followed by the teacher.

To ensure continuity, the sequence was designed to allow the teacher to move back and forward between lessons. The first lesson covered an overview on ideas of Collision theory; proper orientation of reacting particles; activation energy; effect of temperature and concentration of the reactants. In dealing with the second lesson, the teacher reviews lesson 1 before tackling lesson 2, and so on when dealing with lessons 3, 4, 5 and 6 to ensure links are created between the previous lessons.

Lessons 1, 2, 4 and 5 are to provide opportunities for the teacher to stage the concept of chemical rate of reaction and also for the learners to internalize the chemical rate of reaction concept before they are left on their own to try out and practice chemical rate of reaction ideas that they have learnt in lessons 3 and 6.

The summary flows of the lessons sequence are as shown in the **figure 4-1** below.

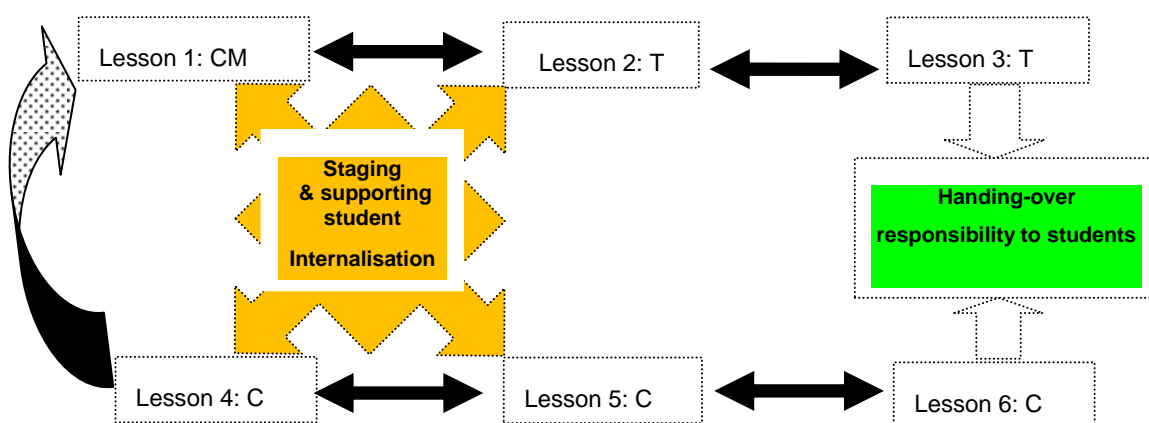


Figure 4-1: Teaching sequence design to ensure continuity links between lessons

4.13 Mode of interaction

The sequence was designed to maximise students learning by incorporating various forms of classroom interaction. The sequence involved:

- Using different modes of interaction between the teacher and students in different episodes. The teacher explores different approaches which included: Interactive/Dialogic; Non-interactive/dialogic; Interactive-authoritative and Non-interactive/ authoritative.
- Opportunities for student-student talk in pairs and small groups.
- Developing the idea of the collision model for describing, explaining and predicting the chemical rate of reaction phenomena under change in temperature and concentration of reactants.

In the next section, I present the outlines of the teaching sequence.

4.14 Outline of the Teaching Sequence

The teaching intervention for this study consisted of six lessons out of an eight lesson sequence. The other two lessons literature show that students often have no challenges in understanding the concepts that are involved within them. This section provides a summary of the teaching plan in broad terms of the content covered and the activities involved through the six-lesson sequence. The school timetable followed during the intervention was divided into 40 minutes, with lesson sessions lasting for one or two periods.

In lesson 1 (episode 1.0); the teacher starts by administering base-line test questions to students to assess their understanding of states of matter and kinetic theory of matter. Students are expected to demonstrate understanding of what the molecules of solid, liquid and gas look like and to explain the relationship between the kinetic energy of molecules and heat, and collision theory. The results of the base-line test are used to provide a measure of equivalence of students' understanding before the intervention between the experimental and the comparison groups.

In lesson 1 (episode 1.1-1.3); the teacher performs precipitation reaction by adding barium chloride solution to dilute sulphuric acid to initiate discussion on how the reaction can be increased or decreased. The teacher introduces the concept of rate of reaction, definition of the term rate of reaction; explanation of collision theory with respect to rate of reaction, factors that affect the rate of reaction to the whole class (social plane of the classroom). This is followed by group discussion where students are engaged using worksheets and share ideas while working with computer simulations. The teacher provides support during group discussion through probing, scaffolding and helping them to make sense of, and internalize, those ideas. The teacher provides support and assists them to see what happens to the rate when temperature changes. Groups share their discussions and explanations with the class. Group discussions and explanations are relayed to the whole class. During the whole class discussion, the teacher emphasizes that for reaction to occur the molecules must possess enough energy and proper orientation of the reacting particles or atoms. *Proper orientation* means atoms must be aligned in such a manner that they bond together.

From collision theory when temperature increases the reactant molecules are moving more rapidly and coming into contact with each other more often, which increases the reaction rate. Thus, increasing the temperature gives the reactant molecules more kinetic energy, thus more high energy collisions can occur. There must be a minimum amount of energy (activation energy) that reacting particles must have to form the activated complex and lead to chemical reaction / form products.

Lesson 2 (episodes 2.1-2.2); starts with revisiting the effect of temperature on chemical rate of reaction. In this session laboratory experiments are conducted. The teacher prepares and conducts an experimental demonstration to show the effect of temperature on the chemical rate of reaction. The students are engaged in groups using worksheets, performing the experiment by measuring volumes, recording temperature change and plotting graph of rate against temperature and drawing conclusions using ideas of collision theory. The teacher provides support during real laboratory experiments. Groups share the results of their discussions with the class. Group results are relayed to the whole class. During the whole-class discussion, the teacher emphasizes that the graph shows rate of reaction increases with increase in temperature - thus, high temperature less time taken, the higher the rate of reaction and that from collision theory, when temperature *increases* the reactant molecules are moving more rapidly and coming into contact with each other more often, which increase the reaction rate.

In lesson 3 (episode 3.1); the teacher substitutes real experiment with computer virtual learning environment using Excel spreadsheets to model the effect of temperature change on chemical rate of reaction. This lesson involves students modelling the effects of temperature change on the rate of reaction. Students make predictions, hypothesizing or asking 'what if?' questions, and discuss and share their ideas in groups. The teacher provides support and assists them in investigating what happens to the rate when temperature changes. The teacher relays students' results to the whole class. The teacher provides opportunities for students to try out their ideas, develop theories and test these themselves, and to make those ideas their own and gradually take responsibility for their independent working.

Lesson 4 (episode 4.1-4.2); other ways of increasing chemical rate of reaction are revisited (review of episode 1), the resulting ideas are shared and the teacher introduces the concept of effects of concentration on rate of reaction to the whole class

(social plane). This is followed by group discussions where students are engaged in groups using worksheets and share ideas while working with computer simulations. The teacher provides support during group discussion through probing, scaffolding and helping them to make sense of, and internalize, those ideas. The teacher provides support and assists them to see what happens to the rate when concentration changes. Groups share their discussions and explanations with the class. Group discussions and explanations are relayed to the whole class. During the whole class discussion, the teacher emphasizes that, increasing concentration of a reactant simply means there are more molecules coming into contact with each other more often, which increases the reaction rate. Thus, the more particles that there are in the same volume, the closer to each other the particles will be. This means that the particles collide more frequently with each other and the rate of the reaction increases.

Lesson 5 (episode 5.1-5.2); starts with a revisiting of the effect of concentration on chemical rate of reaction. In this session laboratory experiments are conducted. The teacher prepares and conducts an experimental demonstration to show the effect of temperature on the chemical rate of reaction. The students are engaged in groups using worksheets, performing the experiment by measuring volumes, recording time taken for the reaction to end, and plotting a graph of volume of thiosulphate against time or rate ($1/\text{time}$), and drawing conclusions using ideas of collision theory. Groups share the results of their discussions with the class. Group results are relayed to the whole class. During the whole class discussion, the teacher emphasizes that rate of reaction increases with increase in concentration. That is, high concentration less time taken, the higher the rate of reaction and that from collision theory increasing concentration of a reactant simply means there are more molecules coming into contact with each other more often, which increase the reaction rate.

In lesson 6 (episode 6.1); the teacher substitutes the real experiment with computer virtual learning environment using an Excel spreadsheets to model the effect of concentration changes on chemical rate of reaction. This lesson involves students modelling the effects of concentration change on the rate of reaction. Students make predictions, hypothesizing or asking 'what if?' questions, and discuss and share their ideas in groups. The teacher provides support and assists them to see what happens to the rate when concentration changes. The teacher relays students' results to the whole class. The teacher provides opportunities for students to try out their ideas, develop theory and test their theory themselves, make those ideas their own and gradually take responsibility for their independent working.

In the next section we will look at the detailed aspects of the teaching plan.

4.15 Detailed teaching sessions based on communicative approach 'cycle'

This section of the chapter presents further illustrations of the detailed aspects of the planned teaching sequence in terms of specific learning and teaching functions attributed to the chosen teaching / learning activities, as well as indications of the pattern of changes in communicative approach 'cycle' during classroom lessons.

4.16 Lesson 1: Chemical rate of reaction - effect of temperature on rate of reaction (Computer simulations)

Teaching & learning activities	Teacher role	Learner role (interaction with computer & real experiment)	Learning gains
Episode 1.0 (administering of base-line test)			
Episodes 1.1-1.3 (double period, 80 minutes)			
1. Whole class /social plane discussion (interactive / dialogic)	Performs a precipitation reaction to prompt discussion about factors which affects chemical rate of reaction Elicit & explore students ideas	Respond with suggestions/ answers	
2. Small group discussion (Non-interactive / dialogic)	Prompts further activity within groups, draws & presents from the different point of view on the blackboard list of factors which affects chemical rate of reaction Circulates groups probes, scaffold and note content of discussion	Consult in groups about factors that affects chemical rate of reaction Discussion proceed with group leaders taking the notes Group comes to agreement & report their ideas	
Episode 1.2			
3. Whole class presentation (Non-interactive / authoritative)	Present the definition of chemical rate of reaction	Make sense of and internalize the concept	Defining rate of reaction as amount of product formed per unit time or amount of reactants used up per unit time
4. Whole class discussion (interactive/authoritative)	Prompt discussion focuses attention to determination of rate of reaction from amount of product formed in a given time /reactant use up in a given time. Address misconceptions/ alternative views	Discuss the meaning of their various ideas	Determination of a rate of reaction from product formed in unit time Rate = product/time; units are in g/sec, dm ³ /sec or s ⁻¹ cm ³ /sec or s ⁻¹
Episode 1.3			
5. Small group discussion (Non-interactive/dialogic)	Manages learners in groups Provide worksheet for group work Prompt discussion on how temperature affects	Use worksheet to discuss and share ideas in group discussion, proceed with group leaders taking the notes Each group briefly reports	Behaviour of reacting particles when temperature is increased or decreased

	<p>chemical reactions Ask learners to make predictions and test their prediction using computer simulations Probes / explore on learners ideas Circulates groups probes and scaffold and note content of discussion</p>	<p>to class their observations from the computer simulations</p>	
6. Whole class/ social plane (interactive/authoritative)	<p>Prompt discussion focuses attention to orientation of reacting particles, collision of particles & activation energy, E_a Address misconceptions/ alternative views</p>	<p>Discuss the meaning of their various ideas about orientation of reacting particles, collision of particles & activation energy, E_a</p>	<p>That for reaction to occur, the molecules must collided, posses enough energy & have proper orientation of the reacting particles</p>
7. Whole class (Non-interactive/authoritative)	<p>Present the relationship between temperature, activation energy, E_a & chemical rate of reaction Explains effects of temperature on chemical rate of reaction sing collision theory</p>	<p>Make sense of and internalize the concepts</p>	<p>That when temperature increases, the reactant molecules are moving rapidly & coming into contact with each other more often (frequent), this increases the reaction rate</p> <p>That for reaction to occur, the molecules must possess enough energy & proper orientation of the reacting particles</p> <p>That there must be minimum amount of energy that reacting particles must have to form the activated complex & lead to reaction and this energy is called activation energy</p>

4.17 Lesson 2: Effect of temperature on rate of reaction (Laboratory experiment investigation)

Teaching & learning activities	Teacher role	Learner role (interaction with computer & real experiment)	Learning gains
Episodes 2.1-2.2 (double period, 80 minutes)			
1. Whole class (Non-interactive/authoritative)	<p>Present and conduct an experimental demonstration showing on effect of temperature on chemical rate of reaction, reading of thermometer, Explains how to use & record stop clock time</p>	<p>Make sense of and internalize the concept</p>	<p>Procedural, measuring & recording skills</p>
2. Whole class/ social plane (interactive/authoritative)	<p>Ask learners what results indicate by way of the marked cross on a piece of paper disappearing when a solution mixture of sodium thiosulphate & HCl is placed over the paper Ask learners to write down the equation for the reaction. Proves, scaffolds & notes</p>	<p>Discuss the meaning of their various ideas why the marked cross disappear Write down equation for the reaction and share with the whole class</p>	<p>Observational skills Development of explanation ability Symbolic representation of a chemical reaction</p>

	content of discussion		
Episodes 2.2			
3. Small group discussion (Non-interactive/dialogic)	Manages learners in groups Provide worksheet for group work Provide real laboratory experimental activity, reaction between solutions of sodium thiosulphate & HCl & manages learners in groups Provide worksheet for group work Prompt discussion on how temperature affects chemical reactions Probes / explore on learners ideas Ask learners to plot & explain using collision theory the shapes of temperature against time or temperature against 1/time Circulates groups probes, scaffold and note content of discussion	Investigation of effect of temperature on rate of reaction using solutions of sodium thiosulphate & HCl Use worksheet to discuss and share ideas in group Discussion proceed with group leaders taking the notes Each group briefly reports to class their observations from the real laboratory investigation of effect of temperature	Analysis and interpretation of temperature-time graph or temperature-rate graph Explain shapes of graph
4. Whole class (Non-interactive/authoritative)	Present relationship between temperature and time, temperature and rate (1/time) Explain how affect chemical rate of reaction using collision theory	Make sense of and internalize the concept	That rate of reaction is directly proportional to change in temperature That when temperature increases the molecules are moving more rapidly and coming into contact with each other more often (frequent), which increase the reaction rate (this collision theory)

4.18 Lesson 3: Effect of temperature on rate of reaction (Modelling with computer spreadsheets)

Teaching & learning activities	Teacher role	Learner role (interaction with computer & real experiment)	Learning gains
Episodes 3.1 (double period, 80 minutes)			
1. Whole class /social plane discussion (interactive / authoritative)	Provide modelling tool-spreadsheets to prompt discussion on relationship between temperature and time; temperature and rate. Engages learners by asking what the graph would look like. Scaffolds & notes content of discussion	States and explains the shape of graph	
2. Small group discussion (Non-interactive/dialogic)	Manages learners in groups and prompts to make prediction, instruct them to carry out modelling temperature and note down the effect on rate and time for the reaction to	Make predictions, hypothesis and share ideas in group Discussion proceed with group leaders taking the notes Each group briefly reports	Analysing results and hypothesizing

	finish Circulates groups probes, scaffold and note content of discussion	to class their observations from the computer modelling	
3. Whole class/ social plane (interactive/authoritative)	Ask learners what happens to change time , rate and the shape of the graph as the vary temperature from 70 ^{0c} ,60 ^{0c} ,50 ^{0c} ,40 ^{0c} ,30 ^{0c} ,25 ^{0c} and from 25 ^{0c} ,30 ^{0c} ,40 ^{0c} ,50 ^{0c} ,60 ^{0c} ,70 ^{0c} Address misconceptions/ alternative views	Discuss the meaning of their observations	Focus on analysing and hypothesizing Relationship between temperature & rate; temperature & time
4. Whole class (Non interactive/authoritative)	Present shape of graph that remain the same whether experiment is carried out beginning with the higher temperature and reducing to low temperature or beginning with the low temperature to higher temperature	Make sense of and internalize the concept	Rate of reaction decreases with increase in temperature Time taken for the reaction to finish reduces with increase in temperature.

4.19 Lesson 4: Effect of concentration on rate of reaction (Computer simulations)

Teaching & learning activities	Teacher role	Learner role (interaction with computer & real experiment)	Learning gains
Episodes 4.1-4.2 (double period, 80 minutes)			
1. Whole class /social plane discussion (interactive / dialogic)	Prompts discussions other ways apart from temperature which increases chemical rate of reaction	Respond with suggestions/ answers	
2. Whole class (Non-interactive/authoritative)	Present explanation of effect of concentration on rate of chemical reaction	Make sense of and internalize the concept	That increasing the concentration of a substance in solution means that there will be more particles per dm ³ of that substance
3. Whole class /social plane (Interactive / dialogic)	Prompts discussion on how concentration affect the rate of reaction	Respond with suggestions/ answers	
Episodes 4.2			
4. Small group discussion (Non-interactive/dialogic)	Manages learners in groups Provide worksheet for group work Prompt discussion on how concentration affects chemical reactions Ask learners to make predictions and test their prediction using computer simulations Probes / explore on learners ideas Circulates groups probes, scaffold and note content of discussion	Use worksheet to discuss and share ideas in group Discussion proceed with group leaders taking the notes Each group briefly reports to class their observations from the computer simulations	Behaviour of reacting particles when concentration is increased or decreased
5. Whole class/ social plane	Prompts discussion further Asking learners about	Each group briefly reports to class their observations from the	Actively reflect on conflict mismatch between learner's prior ideas and

(interactive/authoritative)	their predictions, addresses learners alternative view	computer simulations	scientific point presented by the teacher
6. Whole class (Non-interactive/authoritative)	Present relationship between concentration and time, concentration and rate (1/time) Explain how affect chemical rate of reaction using collision theory	Make sense of and internalize the concept	That rate of reaction is directly proportional to change in concentration That when concentration increases the molecules are coming into contact more often / frequent which increases the reaction rate (this collision theory)

4.20 Lesson 5: Effect of concentration on rate of reaction (Laboratory experiment investigation)

Teaching & learning activities	Teacher role	Learner role (interaction with computer & real experiment)	Learning gains
Episodes 5.1-5.2 (double period, 80 minutes)			
1. Whole class (Non-interactive/authoritative)	Present and conduct an experimental demonstration showing on effect of concentration on chemical rate of reaction, reading of thermometer, Explains how to use & record stop clock time	Make sense of and internalize the concept	Procedural, measuring & recording skills
2. Whole class/ social plane (interactive/authoritative)	Ask learners what results indicate by way of the marked cross on a piece of paper disappearing when a solution mixture of sodium thiosulphate & HCl is placed over the paper Ask learners to write down the equation for the reaction. Addresses misconceptions/ alternative views	Discuss the meaning of their various ideas why the marked cross disappear Write down equation for the reaction and share with the whole class	Observational skills Development of explanation ability Symbolic representation of a chemical reaction
Episodes 5.2			
3. Small group discussion (Non-interactive/dialogic)	Manages learners in groups Provide worksheet for group work Provide real laboratory experimental activity, reaction between solutions of sodium thiosulphate & HCl & manages learners in groups	Investigation of effect of concentration on rate of reaction using solutions of sodium thiosulphate & HCl Use worksheet to discuss and share ideas in group Discussion proceed with group leaders taking the notes	Analysis and interpretation of concentration -time graph or concentration - rate graph Explain shapes of graph

	Provide worksheet for group work	Each group briefly reports to class their observations from the real laboratory investigation of effect of concentration	
	Prompt discussion on how concentration affects chemical reactions		
	Probes / explore on learners ideas		
	Ask learners to plot & explain using collision theory the shapes of concentration against time or concentration against 1/time		
	Circulates groups probes, scaffold and note content of discussion		
4. Whole class (Non-interactive/authoritative)	Present relationship between concentration and time, concentration and rate (1/time)	Make sense of and internalize the concept	That rate of reaction is directly proportional to change in concentration
	Explain how affect chemical rate of reaction using collision theory		That when concentration increases the molecules are coming into contact more often / frequent which increases the reaction rate (this collision theory)

4.21 Lesson 6: Effect of concentration on rate of reaction (Modelling with computer spreadsheets)

Teaching & learning activities	Teacher role	Learner role (interaction with computer & real experiment)	Learning gains
Episodes 6.1 (double period, 80 minutes)			
1. Whole class /social plane discussion (interactive / authoritative)	Provide modelling tool-spreadsheets to prompt discussion on relationship between concentration and time; concentration and rate. Engages learners by asking what the graph would look like. Addresses misconceptions/ alternative views	States and explains the shape of graph	
2. Small group discussion (Non-interactive/dialogic)	Manages learners in groups and prompts to make prediction, instruct them to carry out modelling concentration and note down the effect on rate and time for the reaction to finish Circulates groups and scaffold and note content of discussion	Make predictions, hypothesis and share ideas in group Discussion proceed with group leaders taking the notes Each group briefly reports to class their observations from the computer modelling	Analysing results and hypothesizing

3. Whole class/ social plane (interactive/authoritative)	Ask learners what happens to change time , rate and the shape of the graph as the vary concentration from,50 cm ³ , 40 cm ³ ,30 cm ³ ,20cm ³ 10 cm ³ and from 10 cm ³ ,20 cm ³ ,30 cm ³ ,40 cm ³ ,50 cm ³ Addresses misconceptions/ alternative views	Discuss the meaning of their observations	Focus on analysing and hypothesizing Relationship between concentration & rate; concentration & time
4. Whole class (Non interactive/authoritative)	Present shape of graph that remain the same whether experiment is carried out beginning with the higher concentration and reducing to low concentration or beginning with the low concentration to higher concentration	Make sense of and internalize the concept	Rate of reaction decreases with increase in concentration Time taken for the reaction to finish reduces with increase in concentration.

This is the intended sequence and how it was implemented in practice will be investigated in **Chapter Seven**.

Appendix 7 offers a detailed extension of the above account of the whole teaching sequence, with more specificity both of lesson content worked examples and of particular various forms of classroom interaction activities.

The next chapter presents the coding schemes, their meanings and examples.

CHAPTER FIVE

5 THE CODING SCHEMES

5.1 Introduction

The purpose of this chapter is to justify the coding schemes developed for the analysis of students' responses in the post-test, classroom interactions and the interview data. This is to aid future replication of the study.

5.2 The data coding schemes and Inter-rater reliability conformity / agreement

In this section, I present the coding schemes and inter-rater reliability for the post-test, interviews and classroom talk.

5.3 For post-test scripts

This section presents the coding schemes developed for the analysis of students' responses in the post-test. The coding was carried out to standardise the coding categories for the individual items of each learning area in order to ensure that all responses were similarly coded and scored. The coding schemes data followed similar criteria suggested by Abraham et al. (1994) for scoring and coding student responses. Students' responses to test items were classified as: 'Correct response (coded 3)' for responses that included all components of the validated answers; 'partially correct response (coded 2)' for responses that included at least one of the components of a validated response, but not all the components; 'incorrect response (coded 1)' for responses that included illogical or incorrect information, unclear information and no response.

As explained in Chapter Three, the post-test serves a major purpose to compare the performances of the students who followed the computer and talk approach (C&TA) teaching sequence with those who followed the normal teaching approach (NTA).

As previously mentioned (**section 3.7.4**), the post-test questions were used to make an evaluation of the teaching in order to investigate whether the students who followed the C&TA had a better understanding of the difficult areas (learning demands) as identified in **section 4.7**.

In order to carry out the analysis, the coding categories in each learning area were developed to ensure that the responses to the two groups, experimental class and

comparison class, were similarly coded. Thus, from analyses, students' understanding and performance in each learning area can be evaluated, and the evidence collected used to make judgement about the effectiveness of the C&TA teaching sequences when the comparison is made between the experimental and comparison classes.

5.4 Inter-rater reliability conformity / agreement

Inter-rater reliability decision to assign codes to the students' responses was agreed by four experienced chemistry teachers based upon the appropriate scientific explanations or answers for the questions. I coded draft data responses separately and negotiated the classification. There was a high agreement with 90 % for the post-test items. All disagreements were resolved by negotiation.

5.5 The coding schemes and categories

As explained in **section 3.7.4**, the item questions were designed to allow the students to explain their ideas about the concepts of chemical rate of reaction in as much detail as possible after the intervention.

The accepted answers to the key concepts of chemical rate of reaction were developed mainly from the analysis of chemistry text books (see **section 4.4**), some were taken from the content of the C&TA teaching worked example (**Appendix 7**). Students' responses have been presented in this chapter in order to show examples of the responses analysed from the students' papers. In this section, the coding schemes for: definition/determination rate of chemical reaction; proper orientation of the reacting particles; activation energy, E_a of reacting particles; using collision theory to explain the effect of temperature on reacting particles, and using collision theory to explain the effect of concentration on reacting particles are presented.

The following are discussions on the coding schemes for learning demands which relate to their individual item in the post test.

5.6 Definition/determination rate of chemical reaction

Question 2b presents students with data about the amount of gas collected over a period of time. Students were asked, 'If 40 cm^3 of gas is collected in 10 seconds with 1M HCl acid. What is the rate of reaction?'

The following are descriptions of how the responses are coded as 'correct response', 'partially correct response' and 'incorrect response' for the item above.

Question 2b

The answer can be found in the textbook as, rate of chemical reaction is that rate of reaction is the amount of product formed per unit of time or the amount of reactants used up per unit time. That is, Rate of reaction = amount/time. In solution, this amount is in moles per litre (or grams per litre). If the time is in seconds, then the units of rate are mol l⁻¹/s or mol l⁻¹s⁻¹. Mol l⁻¹s⁻¹ is read as "moles per litre per second".

Correct response (coded 3)

Following the above account taken from the textbook, we consider all components as validated responses / answers as:

$$\begin{aligned} \text{Rate} &= \text{amount of product/ time,} \\ \text{Rate} &= 40/10 \\ \text{Rate} &= 4 \text{ cm}^3 / \text{s or cm}^3 \text{ s}^{-1} \end{aligned}$$

Examples of responses from the students which were coded as 'correct response'.

$$\begin{aligned} \text{'Rate of reaction} &= \text{Amount of gas collected/ time taken} \\ &= 40 \text{ cm}^3 / 10 \text{ seconds} \\ &= 4 \text{ cm}^3 / \text{second.}' \\ \text{'Rate of reaction} &= \text{volume/ time taken} \\ &= 40 \text{ cm}^3 / 10 \text{ seconds} \\ &= 4 \text{ cm}^3 / \text{s.}' \end{aligned}$$

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components as shown in the following examples:

b) If 40 cm³ of gas is collected in 10 seconds with 1M HCl acid. What is the rate of reaction?



$$\frac{40}{10}$$

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response.

Example of responses from the students which were coded as 'incorrect response' is shown below:

b) If 40 cm^3 of gas is collected in 10 seconds with 1M HCl acid. What is the rate of reaction?

$$\begin{aligned} \text{Rate of reaction is} &= \frac{40 \times 10}{44} \\ &= \frac{400}{44} \\ &= 9.09 \text{ KJ} \end{aligned}$$

5.7 Proper orientation of the reacting particles

Questions 3di, ii, and iii present students with data about reacting particles under different scenarios (A, B & C) where sometimes they miss or collide. In question 3di, students were presented with pictures and were asked to draw reacting particles in; *a state of missing each other and a head on collision*. In question 3d ii students were then asked to state the two cases they have drawn, which collision results into a reaction. Question 3d iii required students then to explain their answer in 3d ii in terms of proper orientation of the reacting particles.

Questions 3di, ii & iii

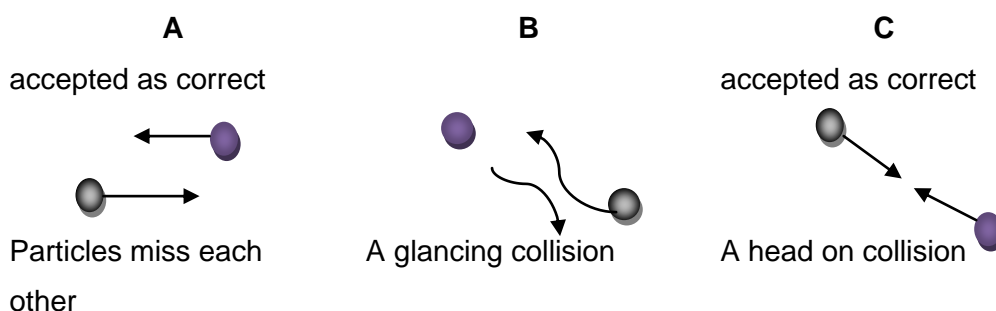
The answers can be found in the textbook as, chemical reactions occur only when the reacting molecules collide with the correct orientation. That is unless the alignment is favourable; the reaction will not be successful. Of course, as the overall number of collisions increases, it becomes more likely that a collision with a favourable orientation will occur hence the rate of the reaction would increase. Thus, *proper orientation* means atoms must be aligned in such a manner that they bond together.

Question 3di

Correct response (coded 3)

Students are asked to draw the missing pictures (in A & C) to show what might be happening to the particles in each case.

Following the above account taken from the textbook, diagrams in A and C below were considered correct

**Question 3dii**

We consider all components as validated responses / answers as:

'C' or 'collision C results into a reaction' or 'a head on collision'

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response.

Examples of responses from the students which were coded as 'incorrect response' are shown below:

'Collision A' or 'collision A results into a reaction'

'B'

Question 3dii

We consider all components as validated responses / answers as:

Reacting particles or atoms or molecules or ions must be aligned in such a way or manner that they bond together, react and form product.

Examples of responses from the students which were coded as 'correct response' are shown below:

'The collision C will result into a reaction because according to proper orientation, it is aligned in a way that the particles bond together which will result into formation of products'.

'In C particles are well aligned which also make them to bond together thereby reaction taking place and products forming'.

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components as shown in the following examples:

'A head on collision (C) resulted into a reaction because the particles were facing or near each other hence forming products faster'.

'A head on collision leads to higher chance of collision thus reaction will take place since reactions require the particles to meet for they cannot react when there is no meeting / collision'.

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response.

Examples of responses from the students which were coded as 'incorrect response' are shown below:

'Collision A results into a reaction because the particles have an attractive force between them which transfers reaction energy between the particles hence making them to react'.

'When particles are properly oriented, they require kinetic energy and increase the rate of movement thus easy collision; products are formed in a short time possible'.

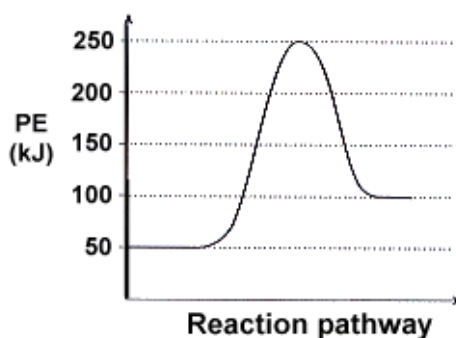
5.8 Activation Energy, E_a of reacting particles

Questions 3b, 3ci and 3cii present students with data about activation energy, E_a for chemical reaction to occur.

The answers can be found in the textbook as activation energy, E_a involves recognition that the molecules must collide with enough energy to overcome the activation energy-barrier. There must be a minimum amount of energy that reacting particles must have to form the activated complex and lead to chemical reaction / form products.

Question 3b

In 3b, students were asked to determine activation energy, E_a from a graphical representation below.



Correct response (coded 3)

Following the above account taken from the textbook, we consider all components as validated responses / answers as:

$$\begin{aligned} & 'E_a = 250-50 \\ & E_a = + 200 \text{ KJ}' \end{aligned}$$

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components as shown in the example below

'Activation complex are formed and the PE (KJ) is 200'.

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response.

Examples of responses from the students which were coded as 'incorrect response' are shown below:

'Activation energy for this reaction is 50KJ'

'Activation energy is at 50'

'Activation energy is 250 KJ'

'250-100 = 150KJ'

'E_a = 250/50 = 5KJ'

Question 3ci

In item 3ci, students were asked to explain as best as they can what is meant by activation energy, E_a.

Correct response (coded 3)

We will consider all components coded as validated responses / answers as:

'Activation energy, E_a is minimum amount of energy, required by reacting particles, to form the activated complex and in order for the chemical reaction to occur or take place / lead to chemical reaction / form products'.

Examples of responses from the students which were coded as 'correct response' are shown below:

'Activation energy is the minimum energy needed for the reacting particles to collide and reach the activated complex in order for the reaction to take place'.

'Activation energy is the minimum energy possessed by reactants to reach the activation complex and form products'.

'Activation energy is the minimum amount of energy that reacting particles must have to form an activation complex'.

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components as shown in the following examples:

'Activation energy is the minimum amount of energy the reacting particles must have to form a product'.

'It is the minimum amount of energy taken for the particles to collide and form a product'.

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Examples of responses from the students which were coded as 'incorrect response' are shown below:

'It is the highest point of a reaction pathway'.

'This is the minimum energy possessed by products which brings about effective collision'.

Question 3cii

In question 3cii, students were asked to explain the relationship between activation energy and chemical rate of reaction.

Correct response (coded 3)

We will consider all components coded as validated responses / answers as:

'High activation energy leads faster chemical reaction'.

Examples of responses from the students which were coded as 'correct response' are shown below:

'For reaction to take place the particles require a given force in order for product to be formed, therefore if the activation energy is high, the rate of a chemical reaction will increase'.

'The higher the activation energy, the faster the chemical rate of reaction. The lower the activation energy, the slower the chemical rate of reaction'.

'When the activation energy is high, the chemical rate of reaction will be high and if the activation energy is low, the chemical rate of reaction will be low'.

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components as shown in the following examples:

'The activation energy determines the chemical reaction as products are formed'.

'Reactants in any chemical reaction must have a minimum energy (E_a) in order to simulate their reaction'.

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Examples of responses from the students which were coded as 'incorrect response' are shown below:

'The higher the activation energy, the slower the rate of reaction and vice versa'.

'In activation energy and chemical rate of reaction, collision of reactant particles occurs which results into reaction hence products is formed'.

'Chemical rate of reaction is the amount of rate of molecules formed per unit time while activation energy is the increase of the reaction pathway according to the energy'.

5.9 Using collision theory to explain effect of temperature on reacting particles

Questions 1b, 1bi, 1bii and 1biii present students with data about effect of temperature on chemical rate of reaction.

The answers for these questions can be found in the chemistry textbook as chemical rate of reaction is directly proportional to change in temperature. That is, when the temperature increases, the reaction takes less time or a shorter time to come to stop.

From collision theory: When temperature increases the reactant molecules are moving more rapidly and coming into contact with each other more often, which increases the reaction rate. Thus, increasing the temperature gives the reactant molecules more kinetic energy, thus more high energy collisions can occur.

Question 1b

In question 1b students were asked to identify which class carried out the experiment at the highest temperature from the table below

Class	Time for tree to disappear in seconds
A	120
B	200
C	150

The answer to this question was categorised as 'correct response' or incorrect response' because it had only two options.

Correct response (coded 3)

'Class A carried out the experiment at highest temperature'.

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components:

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Examples of responses from the students which were coded as 'incorrect response' are shown below:

'Class B carried out the experiment at the highest temperature'.

'The highest temperature is in B 200'.

'Class C with 200'.

'Class C'.

Question 1bi

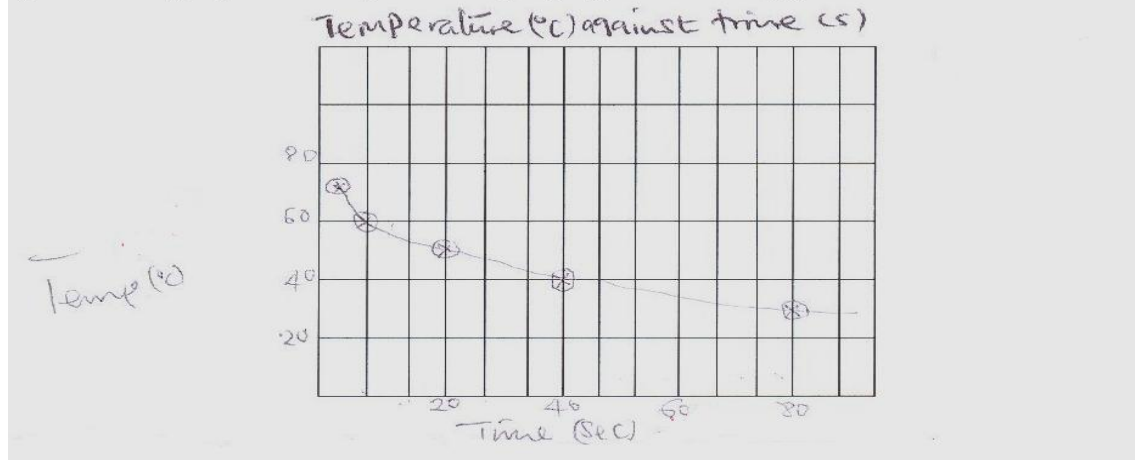
In question 1bi, students were asked to plot a graph of temperature ($^{\circ}\text{C}$) against time (s) using the data below.

Temperature ($^{\circ}\text{C}$)	30	40	50	60	70
Time taken (s)	80	40	20	10	5

Correct response (coded 3)

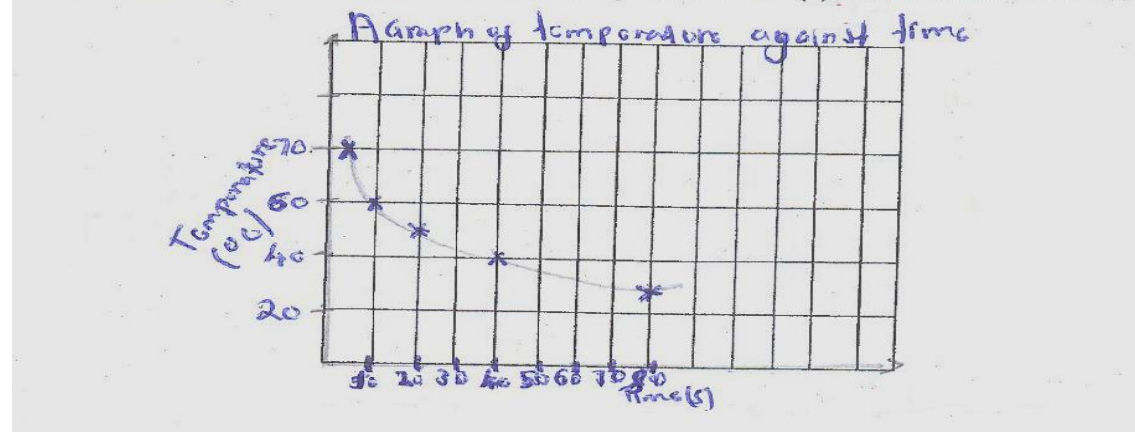
We will consider all components coded as validated responses / answers as:

i) Plot a graph of temperature ($^{\circ}\text{C}$) against time (s) in the table below.



Example of responses from the students which were coded as 'correct response' is shown below:

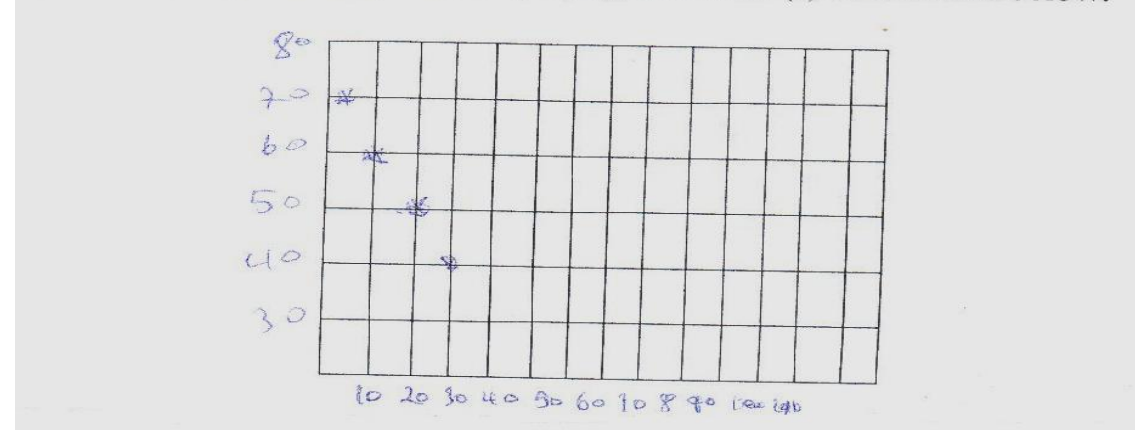
i) Plot a graph of temperature ($^{\circ}\text{C}$) against time (s) in the table below.



Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components, as shown in the following example:

i) Plot a graph of temperature ($^{\circ}\text{C}$) against time (s) in the table below.

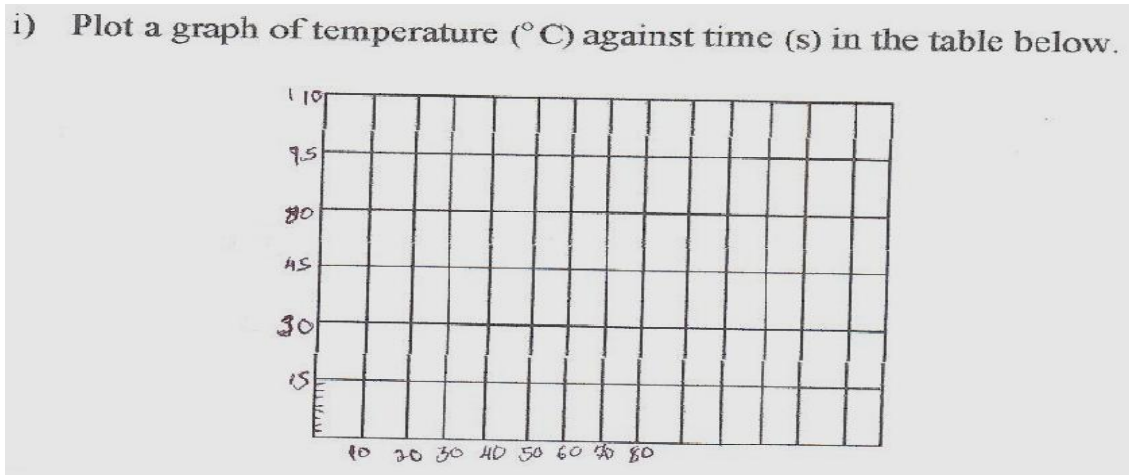


Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response.

Example of responses from the students which were coded as 'incorrect response' is shown below:

i) Plot a graph of temperature ($^{\circ}\text{C}$) against time (s) in the table below.

**Question 1bii**

In question 1bii students were asked to use the graph to describe in as much detail as they can the effect of temperature on the time taken for the reaction to finish.

Correct response (coded 3)

'When temperature increases the time taken for the reaction to finish reduces'.

Examples of responses from the students which were coded as 'correct response'.

'The graph shows that the lower the temperature, the longer it takes for the reaction to finish while at higher temperatures the reaction takes a much shorter time'.

'When the temperature is increased, the time taken for the reaction to finish is low and when the temperature is decreased, the time taken for the reaction to finish is high'.

'When the temperature is increased, the time reduces'.

'When temperature is high, the time is low and when temperature is low, the time is high'.

'When temperature is increased, the time taken is decreased'.

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components (Not applicable in this question)

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Examples of responses from the students which were coded as 'incorrect response' are shown below:

'As the temperature is increased, the time taken for the reaction to finish is higher compared to the time taken for the reaction to start...'

'The increase in temperature speeds up the time taken for the reaction to finish hence increase in temperature increases the rate of reaction'.

'Due to the temperature there was a slow reaction thus taking a long period of time to finish since the higher the temperature the slower the reaction and the lower the temperature, the higher the rate of reaction'.

Question 1biii

In question 1biii students were asked to use the collision theory to explain the effect of temperature on rate of reaction as best as they can in terms of particles.

Correct response (coded 3)

We consider all components as validated responses / answers as:

'When the temperature increases, particles gain kinetic energy, move faster, collide more frequently with each other and hence form products faster'.

Examples of responses from the students which were coded as 'correct response'.

'When the temperature is high, the rate of reaction increases, and the particles gain kinetic energy, they move at a faster rate colliding faster and hence products are formed at a higher rate and less time'.

'When the temperature increases, the particles gain the kinetic energy, the frequency of collisions increases, therefore products are formed faster and this increases the rate of reaction and thus a short time taken'.

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components as shown in the following examples:

'The higher the temperature, the higher the rate of collisions whereas the lower the temperature the lower the rate of collision among the particles'.

'The increase in temperature increases the kinetic energy of the particles that enables the reaction to occur faster'.

'The high temperature increases the movement of atoms/molecules hence in the rate of reaction'.

'The higher the temperature, the higher the rate of collision whereas the lower the temperature the lower the rate of collision among the particles'.

'When increasing the temperature, the kinetic energy increases'.

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Example of responses from the students which were coded as 'incorrect response' is shown below:

'When the temperatures are high, the reacting particles are affected to slow the reaction which is not the case when the temperatures are low'.

5.10 Using collision theory to explain effect of concentration on reacting particles

Questions 2c, 2di, 2dii and 2diii present students with data about effect of concentration on chemical rate of reaction.

The answers for these questions can be found in the chemistry textbook as concentration refers to how close together the solute particles are in a given solution. Increasing the concentration of a substance in solution means that there will be more particles per dm^3 of that substance. From collision theory - increasing concentration of a reactant simply means there are more molecules coming into contact with each other more often, particles collide more frequently with each other and the rate of the reaction increases.

Question 2c

In question 2c students were asked to compare rate if 0.5 M HCl acids are used instead of 1M HCl when reacted with a Calcium carbonate

Correct response (coded 3)

We will consider all components coded as validated response / answer as:

'The rate would decrease or reduce / slow due to decrease in moles of HCl'.

Examples of responses from the students which were coded as 'correct response'.

'The rate will decrease because of decrease in the moles of hydrochloric acid'.

'The rate of the reaction will reduce because the concentration of hydrochloric acid as been reduced'.

'The high the concentration, the higher the reaction, hence rate of reaction will decrease since it decreases from 1MHCl to 0.5MHCl'.

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components as shown in the following examples:

'The rate would be slower'.

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Examples of responses from the students which were coded as 'incorrect response' are shown below:

'If we used 0.5M HCl acid the rate would still remain constant because concentration does not collide with time'.

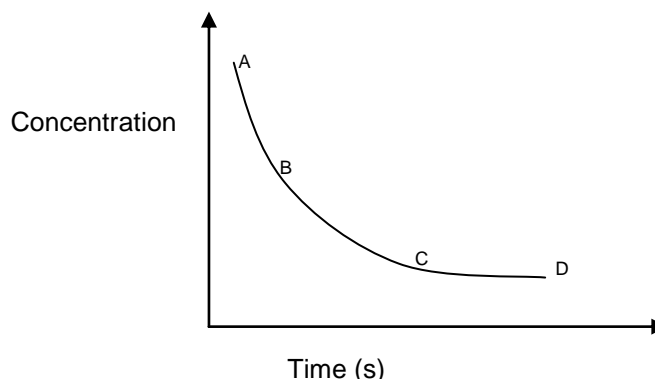
'The rate of reaction remains the same even when a smaller Molarity is used, that is, Molarity doesn't affect rate of reaction'.

'Rate of reaction = volume x concentration/time = 40 x 0.5/10 = 20 /10 = 2 cm³ per second'.

Questions 2di and 2dii

Questions 2di and 2dii present students with the graph obtained for reaction: $\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

The answers to these questions were categorised as 'correct response' or 'incorrect response' because they had only two options.

**Question 2di**

In question 2di students were asked to name the position calcium carbonate reacts fastest on the graph.

Correct response (coded 3)

We will consider all components coded as validated responses / answers as:

'Position calcium carbonate reacts fastest is A'.

Examples of responses from the students which were coded as 'correct response'.

'Position A'.

'A'

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components.

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Examples of responses from the students which were coded as 'incorrect response' are shown below:

'Calcium carbonate reacts fastest at C'.

'C'

'At position B'.

'The calcium carbonate reacts faster in position D'.

'Position D'.

Question 2dii

In question 2dii students were asked to name the position the concentration of hydrochloric acid is highest

Correct response (coded 3)

We will consider all components coded as validated responses / answers as:

'Position the concentration of hydrochloric acid is highest as A'.

Examples of responses from the students which were coded as 'correct response'.

'The concentration of hydrochloric acid is highest at A'.

'Position A'

'A'

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components (Not applicable in this question)

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Examples of responses from the students which were coded as 'incorrect response' are shown below:

'D'

'C'

'Position C'

Question 2diii

In question 2diii students were asked to use the collision theory to explain as best as they can in terms of particles generally why the reaction time is short if the concentration is higher?

Correct response (coded 3)

Following the above account taken from the textbook, we consider all components as validated responses / answers as:

'Increasing concentration increases the number of reacting particles per unit volume, particles become closer to each other, the chances of particles colliding more frequently is high and products form faster'.

Examples of responses from the students which were coded as 'correct response'.

'When the concentration is higher, the number of particles in a given solution are increased meaning that the particles will be closely packed together and as they try to move they will end up colliding with each other resulting to the formation of products hence the high rate of reaction thus a short time is taken'.

'When the concentration is high, the numbers of reacting particles increase in the given volume. The particles come into contact with each other. The collision frequency increases. The chances of the particles to react with each other increases hence products are formed faster in a shorter time'.

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components as shown in the following examples:

'Highly concentrated substances have many particles of the material in it and when other solution or substance reacts with it, the reaction is faster'.

'The higher the concentration of the reacting particle, the higher the rate of the reaction'.

'In a higher concentration, the particles are the close to each other, which increases the rate of reaction'.

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Examples of responses from the students which were coded as 'incorrect response' are shown below:

'When the concentration is high, it increases the surface area of the reacting particles hence takes less time for particles to collide with each other so they take shorter time for the reactions to occur'.

'The more the concentration the less time taken because concentrated acid tends to burn up the particles reducing their numbers hence the rate of reaction becomes faster'.

'Since the concentration of the acid is high, this will create a very large surface area for the particles to react thus it will be very fast'.

'A high concentration of the acid increases the surface area of over which the reactions take place and hence increasing the rate of reaction'.

Question 2e

In question 2e students were asked to explain why a reaction carried out with 1M HCl solution with Magnesium under room temperature (25⁰C) and reaction carried out with 0.5M HCl solution heated to a temperature of 35⁰C with same amount of Magnesium can have similar rate of production of the gas (10cm³ per second).

The answers for these questions can be found in the chemistry textbook as the effects of concentration and temperature can be compensated by the each other in a chemical reaction.

Correct response (coded 3)

We will consider all components coded as validated responses / answers as:

'The reduction, in concentration, was compensated for, by the increase in temperature and hence similar rate. Or the concentration reduced, particles were therefore fewer but the increase in temperature 25-35 ⁰C, increased the kinetic energy of the particles and the rate increased to 10cm³ per second'.

Examples of responses from the students which were coded as 'correct response'.

'In the first experiment the concentration was high therefore the number of particles was increased and the frequency of collisions was also increased therefore leading to a high rate of reaction. In the second experiment, the temperature was high and the particles gained kinetic energy leading to more collision hence products formed faster therefore the rate of reaction increased. Inclusion, the increase in temperature compensated for the decrease in concentration and the increased in concentration compensated for the decrease in temperature'.

'The increase in temperature in the second experiment helped to compensate the amount of hydrochloric acid which was reduced therefore increased temperature increased the kinetic potential of the particles and the rate of collision'.

Partially correct response (coded 2)

For responses that included at least one of the components of a validated response, but not all the components as shown in the following examples:

'The higher the temperature, the faster the reaction and the higher the concentration the faster the reaction thus same rate of reaction'.

'When the concentration was decreased and the temperature was increased, the kinetic energy increased hence there was a faster collision and products were formed faster'.

Incorrect response (coded 1)

For responses that included illogical or incorrect information, unclear information and no response. Examples of responses from the students which were coded as 'incorrect response' are shown below:

'The reaction is the same because when 1M of HCl solution needed its temperature 25^oC and hence when the concentration of HCl was lowered to 0.5M, the temperature of the solution was increased to 35^oC hence they have similar rate of reaction'.

'The two experiments have similar rate of reaction because as the temperature is increased, the time taken for the rate of reaction to occur will increase thus forming their products faster'.

5.11 Coding schemes for classroom talk

This section presents the coding schemes used to analyse the classroom talk or patterns of interactions between the teacher and students in a science classroom. The coding schemes were derived from two main sources, namely from the review of the existing literature (refer to Chapter Two) and from the classroom talk excerpts. The coding schemes are developed based on a sociocultural framework to gather information on the teaching purposes, content, approach, forms of teacher intervention and patterns of interaction from the classroom interactions (for details, refer to Chapter Three).

According to literature, (see, in particular, Mortimer and Scott, 2003, pg. 69; Edwards and Mercer, 1987; Lemke, 1990; Scott, 1998; Alexander et al. 2004, p.26-7) the patterns of interactions in a science classroom featured words such as, questions, initiation to (introduce ideas, explore ideas, review ideas, summarise ideas), response to (answer questions), motivation, selecting, marking students key ideas, shaping students ideas and evaluation of students' ideas by the subject teacher.

In addition, as mentioned under **section 3.9.1**, a “grounded analysis” of the teacher-students’ classroom talk was carried out, paying attention to evidence of engagements, tailored to making meaningful understanding of chemical rate of reaction in the classroom. The use of grounded analysis allowed for the establishing of more codes from the classroom excerpts. These codes were initiation to factual questions [I(fqs)] and initiation to check / confirm understanding [I(cu)], response to factual questions [R(fq)] and response to confirm understanding [R(cu)], classroom management moves (Cmm) and echoing students’ idea(s) to reinforce the correct answer or acknowledgement of an answer as acceptable.

Drawing from the sociocultural framework for analysing classroom talk presented in Chapter Three for this coding purpose, I first distinguished whether an initiation by the teacher was a question aimed at factual ideas or to explore ideas, or to introduce ideas, or to review or summarise ideas. Secondly, I focused on the nature of teacher follow-up moves and the functions that they performed. Attention was given to the teacher intervention such as shaping ideas, selecting ideas, marking key ideas, sharing ideas, evaluation of ideas, checking student understanding and reviewing. Attention was also given to classroom management moves such as prompts (‘hurry up’), directives (‘write down’ or ‘draw the diagram’). I also coded the student moves in response to the teacher initiations which includes response to factual questions, response to explorative questions, response to confirm understanding as well as initiation to seek clarity from the teacher.

Table 5-1: The Coding Schemes

Categories of talk Code	Meaning	Example
I(i)	Initiation to introduce ideas (by teacher)	‘we are going to look at the rate at which chemical reactions occur’ ‘well, in studying factors that affects rate of chemical reaction, their effects centres on the kinetic theory of matter’, ‘We will look at concentration’ ‘ Let’s look at the graphical interpretation’
I(r)	Initiation to review ideas (by teacher)	‘ok, in the previous lesson we saw that when you increase the temperature the molecules of reactants gain kinetic energy, move fast, collide more frequently and the rate at which products are formed also increases’, ‘what else?’ ‘We said that the rate is proportion or increases with increase in temperature’, ‘What other factors did we mention...Having finished temperature...what are other factors which affect chemical rate of

		reaction?
I(e)	Initiation to explore ideas (by teacher)	'So how would we define rate of reaction?', 'another definition?', 'what do you think would happen?', 'anything else?', 'what else?', 'So how does this affect rate of reaction?' 'So why does the cross disappear?'
I(fq)	Initiation of factual questions (by teacher)	'What are these bubbles called?', 'In what form are CaCO ₃ ?'
I(s)	Initiation to summarize ideas/ share ideas (by teacher)	Therefore, rate of reaction is defined as the amount of product (s) formed in a given time or the rate at which reactants are used up in a reaction. This is also expressed as Rate = Product/time, units dm ³ /sec " ' Therefore, if atoms of reactants in a reaction are well oriented, the two will combine and we shall say the reaction has taken place.
I(cu)	Initiation to check / confirm understanding (by teacher)	'It is clear?' or 'are we together?', 'I hope we are together?'
R (aeq)	Response to answer explorative question (by student)	'uhm...change of reaction', 'it is a straight line',
R(fq)	Response to factual questions (by student)	'Powder', 'Carbon dioxide'
R(cu)	Response to confirm understanding (by student)	'Yes' or 'yes Sir' or 'yes in chorus' or 'yeah'
Echoes / Feedback	Echoes –to emphasize the point/ reinforce the correct answer/ acknowledge of an answer as acceptable	'yeah... speed of reaction' 'yes, comparing the two'
N(F)	Neutral feedback - by offering listening, considering different views and ideas left floating on the social plane of the classroom	'yeah' or 'ok' or 'no comment....long pause',
S(pi)	Selecting parts of ideas / Focus attention on a particular student response; overlook a student response	'collisions, faster movement, products may be form not the product is formed very fast '
M(i)	Marking key ideas / Repeat an idea / enact a confirmatory exchange with a student	'When these collisions are ok', 'thank you',
S(i)	Shaping ideas, modifying and correcting the ideas / paraphrase a student's response differentiate between ideas/ rephrasing students ideas	'Yes, atoms move slowly...'
M	Motivation	'thank you', 'give yourself a clap!', 'I am happy with your responses'
E(i)	Evaluation of ideas (by teacher)	'Yes...that is true' or 'good' or 'very good or that is very good', 'I think that would be quite best.', 'Exactly', 'yeah less collision', 'that is good', 'yes...that is the relationship'
Cmm	Classroom management moves	'Please, write this down', ' ok, let's write', ' hurry up with the drawing', 'please, hurry up and we continue...You are a bit slow!', 'I want you to be attentive'

In practice, a successfully dialogic interactive lesson which involves the above classroom talks or moves can be characterized along communicative approaches presented in **Chapter Three (section 3.9.3)**.

5.12 Coding procedure and Inter-rater reliability conformity / agreement

The coding was done manually by labeling turn (statement) according to their meanings. Inter-rater reliability was carried out by both supervisors to ensure that the codes were robust enough to produce consistent results. Both supervisors concluded that the codes were sufficient and robust enough to produce the desirable results.

In **Chapter Seven**, the codes are used to show the patterns of talk and forms of teacher intervention that were influential in promoting students' understanding of the chemical rate of reaction concept.

5.13 Coding schemes and analysis of the interview data

The aim of this sub-section is to give an overview of how I coded the transcribed interview data.

Bearing in mind that there are many approaches to analysing qualitative data, a few methodological approaches were reviewed. For example, the grounded theory (Strauss and Glaser, 1967) in which the researcher approaches data with a blank mind and lets the data speak for itself, this approach was considered as unfeasible for this part of the study as the interview questions were semi-structured to collect specific data about the intervention. Another example is the thematic approach to qualitative data analysis described by Braun and Clarke (2006).

Thematic analysis 'is a method for identifying, analysing, and reporting patterns (themes) within the data. It organises and describes your data set in (rich) detail' (Braun and Clarke, 2006. p.79). According Braun and Clarke (2006, p.87), this process involves six phases:

1. Familiarisation by reading the data, noting down initial ideas
2. Generating initial codes by coding interesting features of the data
3. Searching for themes by pulling together codes into potential themes
4. Reviewing themes by checking if themes work in relation to coded extract and the entire data set, generating a thematic 'map' of the analysis
5. Defining and naming themes through on-going analysis to refine the specifics of each theme
6. Producing a report for the final analysis

Although the analysis process of the interview data was quite straightforward, adaption of some steps of the Braun and Clarke's approach in structuring especially the sub-themes was inevitable (to be explained later) in section 5.13.3.

After each lesson, data were collect from the target group of students and the teacher. The purpose of these interviews was to gain immediate feedback on the students' understanding from both the students and the teacher.

At the end of the teaching intervention, data were collected from the teacher and students about their views on the benefits, challenges, as well as their perceptions about C&TA as compared with the NTA to teach and learn chemical rate of reaction concepts.

5.13.1 Coding and analysing after each lesson target group interviews

Semi-structured interview questions (**see appendices 10 and 11**) were used, focusing on the students' understanding of the taught content, the teacher's and students' perceptions of teaching. Here the themes were predefined so neither the grounded theory nor Braun and Clarkes' approach could be applied.

5.13.2 Coding and analysing end of the intervention interviews

Semi-structured interview questions used were linked to the two main research questions. **RQ3** which focused on discovering the major benefits and challenges of the implementation of the computer and talk approach, and **RQ4** which focused on the teacher and students' perceptions of the computer and talk approach.

In **RQ3** and **RQ4**, it can be seen that the main / major themes were predefined by the main research questions. The semi-structured interview questions were designed to collect these specific data from the teacher and students.

However, in the process of putting the data into themes and after reading, data became familiar to me; I noted that sub-themes could be identified.

5.13.3 Identification of sub-themes

In order to identify and structure the sub-themes, I adapted Braun and Clarke's (2006) steps 5 and 6. I did not carry out any initial coding, searching for themes and reviewing themes as described in Braun and Clarke's phase 2, 3 and 4, since main themes were predefined. I evaluated, defined by **bolding**, [bracketing] and tried to refine the sub-themes instead since the main themes were predefined. From the responses link to the

main themes, I directly identified phrases to derive my sub-themes. This was also guided by the semi-structured interview questions.

According to Braun and Clarke (2006), their fifth stage involved 'define and further refine the themes you will present for your analysis and analyse the data within them' (p.92). I made sure that the names given to the sub-themes were 'concise, punchy, and immediately give the reader a sense of what the theme is about' (p.93).

In the table below, I present the themes, an example on how sub-themes were derived, define sub-themes and refined/identified sub-themes.

Table 5-2: Coding schemes for RQ3

Main themes	Example on how sub-themes were derived	Define sub-themes	Refined/identified sub-themes
Benefits	<p>'With computers in front of students they were [all eager to see what it was they were learning]. You see when you enter the computer lab and the students [all fight for computers to ensure that they are going to do the things themselves]'</p> <p>"It has given me a lot of understanding of how we can [make such abstract information to be made simpler] especially to these juniors"</p> <p>Using computer simulations [brings clarity to abstract concepts and therefore better students' understanding].</p>	<p>All eager to see what it was they were learning & All fight for computers to ensure that they are going to do the things themselves</p> <p>Make such abstract information to be made simpler & brings clarity to abstract concepts and therefore better students' understanding</p>	<ul style="list-style-type: none"> • Increase attentiveness and engagement • Makes abstract concepts clear and understandable/ Bring clarity to abstract concepts
Challenges	<p>Using computers [required one to have skills and was a challenge], unless one had somebody to help them operate the machine.</p> <p>Simulations had a challenge in that when investigating the effect of temperature on rate, there is possibility of using single collision and many collisions. However, using many collisions were more suitable for investigating effect of concentration. This because when using many collisions it was confusing as it would appear as if the atoms are moving fast, a phenomenon only affect by change in temperature. So [it was upon the teacher to make this distinction clear that when investigating temperature, use single collision and use many collisions for investigating effect of concentration.]</p>	<p>Required one to have skills and was a challenge</p> <p>Make this distinction clear that when investigating temperature, use single collision and use many collisions for investigating effect of concentration</p>	<ul style="list-style-type: none"> • Lack of computer skills and competence • Lack of evaluation knowledge of the learning software

Table 5-3: Coding schemes for RQ4

Main themes	Example on how sub-themes were derived	Define sub-themes	Define/ identified sub-themes
Perceptions	<p>[C&TA allows clear flow of information].</p> <p>In terms of students' understanding, "using C&TA has done much indeed" appraised the teacher. He said [students had been able to see the behaviour of reacting particles and had understood the concept] of chemical rate of reaction.</p> <p>'Some students were not free with teachers; they had the attitude that the teacher was unfriendly, but during C&TA lesson, [they interacted with their friends, the normal people they chatted with her everyday and would go through these friends to get their queries to the teacher']</p>	<p>C&TA allows clear flow of information</p> <p>Students had been able to see the behaviour of reacting particles and had understood the concept</p> <p>They interacted with their friend, the normal people they chatted with her everyday and would go through these friend to get their queries to the teacher'</p>	<ul style="list-style-type: none"> • C&TA allows clear flow of information • C&TA enhances students' understanding • C&TA bridges the gap between teacher and students

As part of Chapter Eight, the main themes and sub-themes are presented following an analysis of interviews with the teacher and students.

CHAPTER SIX

6 ANALYSIS, PRESENTATION AND INTERPRETATION OF BASE-LINE TEST AND POST TEST RESULTS

6.1 Introduction

In this chapter, I present the analyses of the base-line test and post-test from a case study conducted on the use of a computer and talk approach (C&TA), as an alternative approach to normal teaching approach (NTA) in science classrooms in a Ugandan context.

This chapter presents evidence to support research question 1, that students who follow C&TA achieve better learning outcomes compared to the students who follow the 'normal' teaching (NTA). The evidence gathered on the learning outcomes will also be used to show whether the teaching goals were effective in supporting students learning. This will provide some answers to research question 2 on parts of the C&TA teaching sequence that were effective in supporting learning, and which were not.

The results of the post-test are presented in line with the learning aims. The students' achievement levels as the outcome of the use of the computer plus talk approach (C&TA) compared to the normal teaching approach (NTA) have been presented. The results are presented in the form of tables, error bars, histogram bars and figures.

This chapter will be mainly limited to the presentation of the findings and brief explanation of the findings, while a comprehensive discussion of their interpretation and possible implications will be offered in Chapter Nine.

6.2 Base-line test and post-test analysis

In order to address research question 1, analysis has been completed by comparing the experimental class and comparison class scores in the base-line test, post- test and by analysing further the students' responses to the test items.

6.2.1 Analysis of students' level of achievement

Research question 1 investigates whether students who received the computer and talk approach (C&TA) better understand the concept of chemical rate of reaction in

comparison to the students who followed the normal teaching approach (NTA). This sub-section, therefore, presents the results obtained from the independent t-test carried out on the base-line test and post-test to justify whether there was a statistical and practical significant difference between the mean scores of the students in the experimental class (C&TA class), and the comparison class (NTA class) in terms of their level of understanding the concept of chemical rate of reaction.

Results from a correlation test (Pearson r) conducted within groups and overall will be presented to ascertain if the students' initial understandings had a statistical and practical significant influence on the students' final post-test scores after the intervention.

Also, the results from General Linear Model (GLM) will be presented to provide a detailed analysis of any effect of the base-line test, group and gender on the post-test outcomes.

We will begin with by looking at the results obtained from the base-line test.

6.2.2 Mean score and the independent t-test for the base-line test scores

The base-line test analysis shows that the mean score of the comparison class was higher (10.36) than that of the experimental class (9.42), with a mean score difference of -.945.

Table 6-1: Base-line test mean scores of the comparison class and experimental class

	Group	N	mean	Std. Deviation	Std. Error mean
Base-line	Comparison	107	10.36	3.710	.359
Test Scores	Experimental	105	9.42	2.882	.281

When these mean scores were subjected to an independent t-test for equality of means, the t-test result showed that there was a statistical difference in the base-line test mean scores between the comparison class and the experimental class ($t = -2.070$, $df = 210$, $p = .040$, equal variance assumed, effect size $r = .195$; $-.141$, as measured by point-biserial correlation). This shows that the comparison class mean

score was significantly higher than that of the experimental class, although its practical significance is less and is much smaller (< 1 mark).

The finding above is further confirmed as in the error graph **figure 6-1**, both groups' scores have shown approximately normal distribution as in **figure 6-2**.

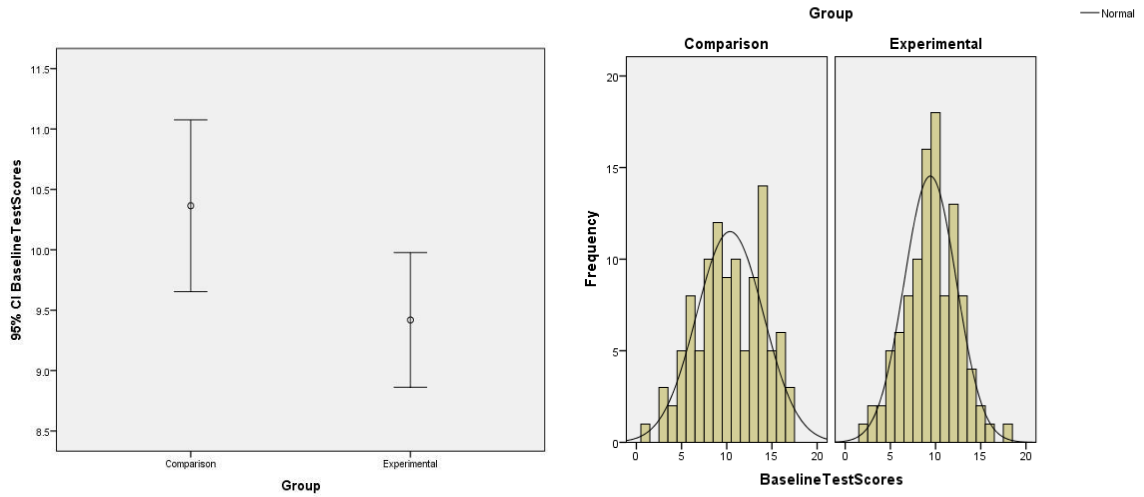


Figure 6-1: Error bar graph of base –line test scores

Figure 6-2: Histogram bar showing base-line test scores distribution

This result indicated that before the intervention the comparison class had a better understanding of state of matter and the kinetic theory of matter compared to the experimental class.

6.2.3 Mean score and independent t-test for the post-test scores

An independent t-test analysis was done to compare the achievement levels of students who received the C&TA teaching instruction with students who received NTA instruction. The results obtained are presented in the table below.

Table 6-2: Post-test mean scores of the comparison class and experimental class

	Group	N	Mean	Std. Deviation	Std. Error
					Mean
Post Test Scores	Comparison	131	14.447	6.8935	.6023
	Experimental	104	26.957	6.4812	.6355

The finding above shows that the post-test mean score of the experimental class was higher (26.96) compared to the comparison class (14.45) with a mean score difference of 12.51.

The t-test results show that there was statistical difference in the post-test mean scores between the experimental class and the comparison class ($t=14.19$, $df=233$, $p < 0.001$, equal variance assumed, effect size $r = .681$ as measured by point-biserial correlation).

The finding above is further confirmed as in the error graph **figure 6-3**, suggesting that the mean scores from post-test for the comparison class were much lower than that for the experimental class. The scores of each group were approximately normally distributed as shown by histogram bars (**figure 6-4**).

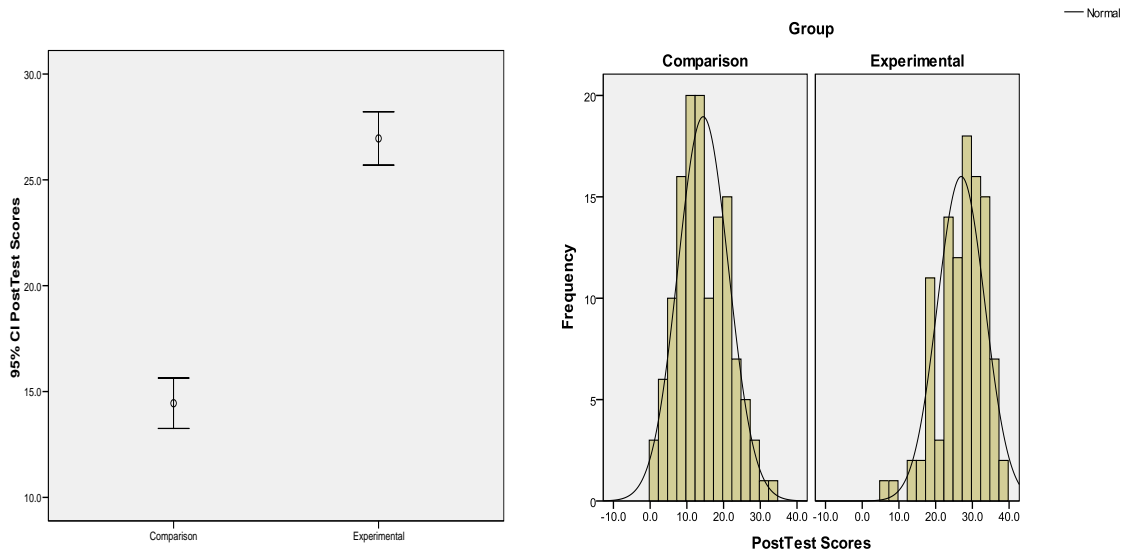


Figure 6-3: Error bar graph of post- test scores

Figure 6-4: Histogram bar showing post- test scores distribution

6.2.4 Relationship between base-line test and post-test scores

The scatter plot below shows scores for base-line test on the X-axis (horizontal axis) and post-test on the Y-axis (vertical axis). The pattern of association shows that increasing values of post-test generally correspond to increasing values for base-line test and the different groups.

The fact that the separate lines of best fit (green and blue) are more or less parallel indicates that the intervention had an effect of the same magnitude across the ability range.

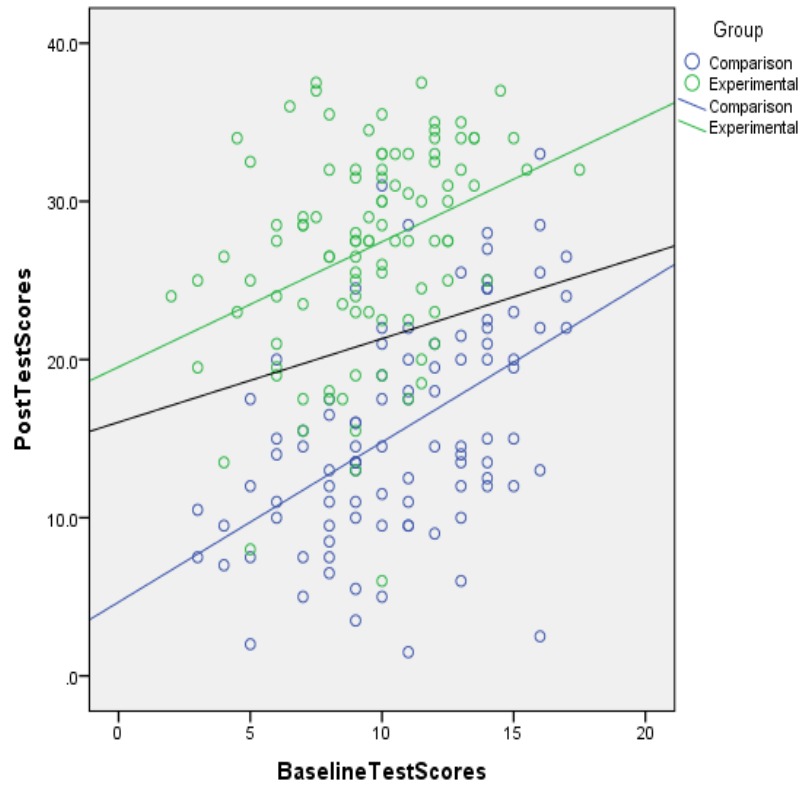


Figure 6-5: Relationship between base-line test and post-test scores

To quantify the relationship between post-test scores and base-line test scores, the Pearson's correlation coefficient (r) tests were performed within group and as an overall for the base-line test scores and post-test scores as shown in the table below.

Table 6-3: Relationship between post-test and base-line test scores

Correlation coefficient (r) test	R	n	p	r^2	=shared variance= effect size
Within experimental class	.353	102	<0.01	.125 (12.5%)	
Within comparison class	.509	99	<0.01	.259 (25.9%)	
Overall correlation	.195	201	<0.01	.038 (3.8%)	

The correlation between the base-line test and post-test of the comparison class was stronger than that of the experimental class. However, the correlation test shows that in both classes, students' initial understandings had some influence on their final post-test scores.

For the comparison class, effect size is ($r^2=.259$). That is, 25.9% of the variation in one score is shared with the other score.

For the experimental class, the relationship shows a smaller effect size ($r^2=.125$) compared to the comparison class. That is, 12.5% of the variation in one score is shared with the other score.

The overall correlation shows that there was a statistically significant relationship between the base-line test scores and the post-test scores (relationship, r ($n=201$) = 0.195, $p < 0.01$). However, this is actually quite a small effect size ($r^2=.038$).

The correlation overall is low but the correlation for the comparison class is relatively high. This means that in general it does not matter where the student in the comparison class started from in the base-line test, they scored higher in the post-test and therefore this weakens the correlation overall.

6.2.5 Further analysis of post-test in terms of base-line test, group and gender effects

Further analysis was conducted using the General Linear Model (GLM) procedure to compare the post-test scores based on base-line test, group and gender to determine if their effects predicted the final students' achievement levels, the post-test outcomes.

That is, post-test (outcomes) = base-line test + group + gender + Gender * Group interaction.

6.2.6 The main effect and interaction effect (Group with Gender effect)

Table 6-4: General Linear Model results

Source	Df	F	Sig.	Partial Eta Squared
Base-line test	1,196	48.037	.000	.197
Group	1,196	212.778	.000	.521
Gender	1,196	.001	.981	.000
Gender * Group	1,196	4.203	.042	.021

a. R Squared = .543 (Adjusted R Squared = .534)

The adjusted $R^2 = .534$ indicates that 53.4% of variation in post-test is accounted for using these predictor variables (gender and group).

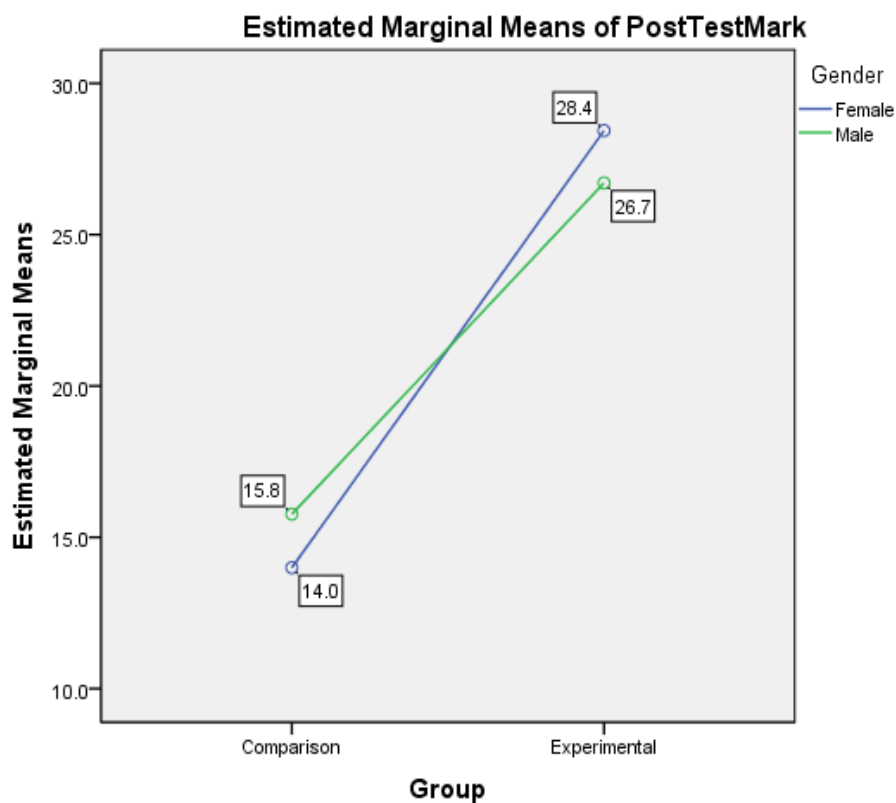
The results also show that the base-line test had a statistical significant main effect, $F(1, 196) = 48.037$, $p < .001$, partial eta squared = 0.197, thus the base-line test was a significant main predictor for post-test scores.

The results show that there was a substantial main effect for the group, $F(1, 196) = 212.778$, $p < .001$, partial eta squared = .521, a confirmation that the intervention had a substantial positive effect on the post-test scores.

The results also show that gender had no statistical significant main effect, $F(1, 196) = .001$, $p = .981$, partial eta squared = 0.000, thus gender was not a significant main predictor for post-test scores.

However, the results indicated that the interaction between gender with group was statistically significant, $F(1, 196) = 4.203$, $p = .042$, partial eta squared = .021. This implies that gender and group combinations predicted, albeit weakly, the outcome of the post-test scores.

There is some suggestion in the profile plots in **figure 6-6** below that females generally benefited (a little) more from the intervention than did males. On average, controlling for any difference on the base-line test, the girls do not do as well by 1.8 marks in the comparison group, but do better by 1.7 marks in the experimental group. In other words, girls seem not to perform as well under the normal teaching, but appear to perform better under the C&TA. However, the size of the apparent effect is very small and needs further research.



Covariates appearing in the model are evaluated at the following values: EquivalenceTestMark = 10.11

Figure 6-6: Interactive effect between groups with gender

6.2.7 Learning aims - analysis of Items responses

The results in this sub-section show the performance of the experimental class and comparison class in the post-test items matched to the learning outcomes. It presents the findings on Ugandan students' understanding after they had been taught aspects of chemical rate of reaction in order to answer research question 1.

The responses were coded using similar coding schemes, as stated in **Chapter Five**.

In each table and figure presented, the two classes are categorised as experimental class and comparison class, and the coding schemes for each category are labelled as follows:

- Correct response
- Partially correct response
- Incorrect response

We will now turn our attention to the descriptive statistics of the students' performances in meeting the learning demands presented in **section 4.7**.

6.2.8 Students' performance in the post-test items

In this part, a descriptive analysis of each item is presented using percentages and histogram bars.

The teaching intervention was designed with the intention of promoting the students' understandings of chemical rate of reaction in line with the Ugandan national curriculum aims. In order to ascertain the achievement of these learning aims, students' responses on the post-test were evaluated with regards to a number of aspects of a grasp of the concept of chemical rate of reaction. Although the test used included three questions with sub-sections totalling 20 items on the question sheet, detailed analyses were considered only for questions which were more linked to the evidence obtained from the research literature (see **Chapter Two**) as students having difficulties (learning demands) in understanding certain aspects of chemical rate of reaction. It was decided that analyses should focus on the post-test questions **Q1b ii, iii; Q2b; Q2d i, Q2d ii, iii; Q3c i, ii; Q3d i, ii & iii (Appendix 9)**. The section in each learning area presents the analyses of results and brief discussions based on the percentages of achievement under each criterion.

6.2.9 Determination of rate of chemical reaction

For this item, students were asked in question 2b, 'If 40 cm³ of gas is collected in 10 seconds with 1M HCl acid. What is the rate of reaction?'

The results for question 2b are presented in **table 6-5** and **figure 6-7**. It can be seen that 74.3% of students in the experimental class compared to 29.0% in the comparison class were able to correctly determine the rate of chemical reaction.

Table 6-5: Percentages of students indicating ability to determine chemical rate of reaction by class

Questions	Students' achievement level					
	Experimental class			Comparison class		
	Incorrect response	Partially correct response	Correct response	Incorrect response	Partially correct response	Correct response
Q2b Determination of rate of chemical reaction	10.5%	15.2%	74.3%	52.7%	18.3%	29.0%

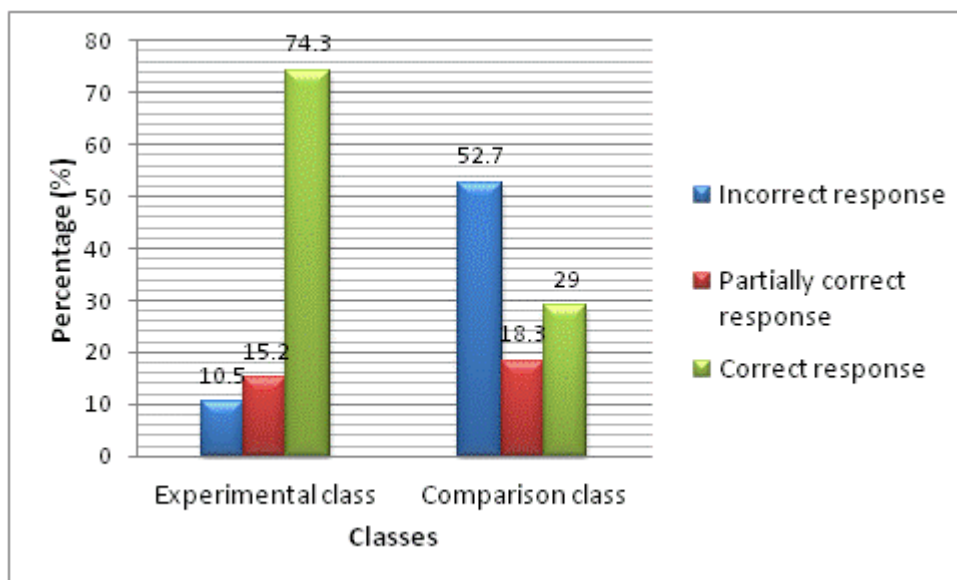


Figure 6-7: Percentages of students indicating ability to determine chemical rate of reaction by class (Q2b)

This shows that the experimental class had a better ability to determine chemical rate of reaction compared to the comparison class.

6.2.10 Proper orientation of the reacting particles

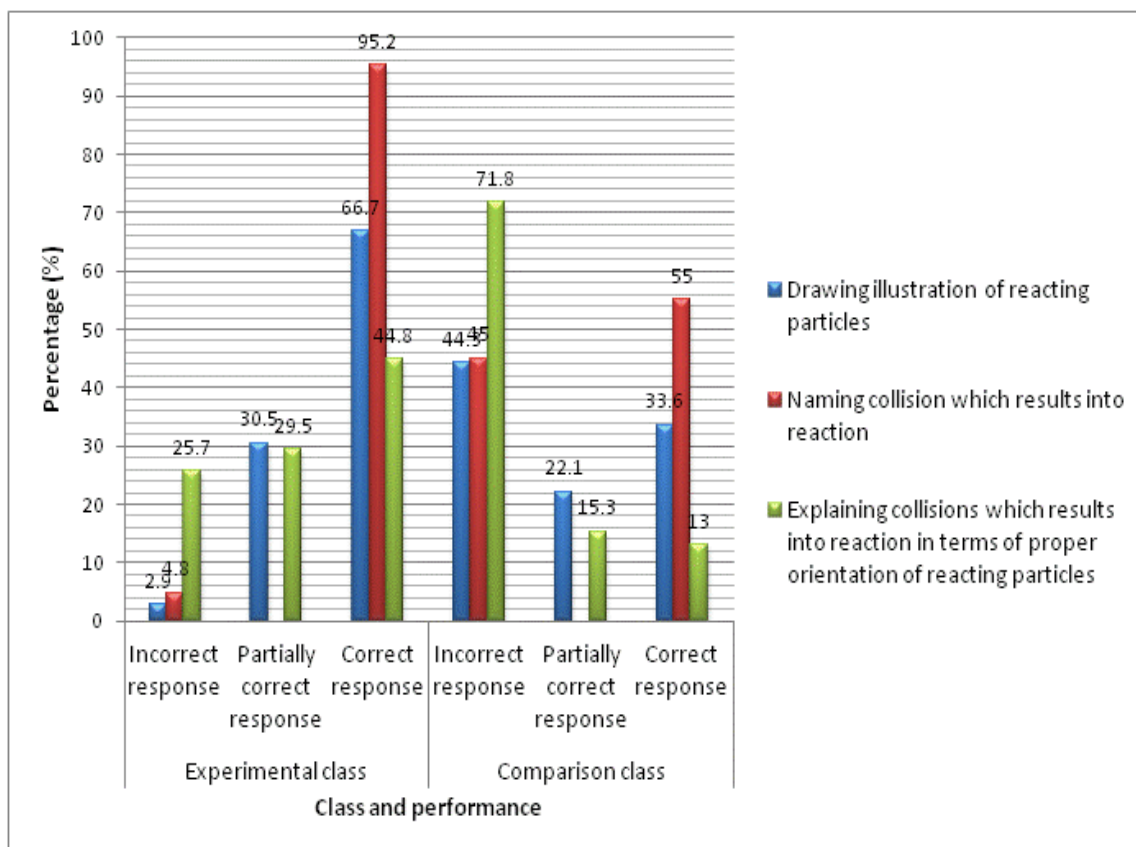
For this item, students were presented with pictures and were asked in question 3di to draw reacting particles in - *a state of missing each other and a head on collision*, in question 3d ii students were asked to state the two cases they had drawn, which collision results into a reaction, and question 3d iii students were asked to explain their answer in 3d ii in terms of proper orientation of the reacting particles.

The results for questions 3di, 3dii and 3diii are presented in **table 6-6** and **figure 6-8**. It can be seen that 66.7% of students in the experimental class compared to only 33.6% in the comparison class were able to correctly draw an illustration of reacting particles; a state of missing each other and a head on collision.

Also from the **table 6-6**, 95.2% of students in the experimental class compared to only 55.0% in the comparison class were able to correctly name collision which results into reaction. Furthermore, the results indicated that 44.8% of students in the experimental class, compared to only 13.0% in the comparison class, were able to correctly explain collisions which resulted in chemical reaction in terms of proper orientation of reacting particles.

Table 6-6: Percentages of students indicating understanding of collision which results into a chemical reaction

Questions	Students' achievement level					
	Experimental class			Comparison class		
	Incorrect response	Partially correct response	Correct response	Incorrect response	Partially correct response	Correct response
Q3di Drawing illustration of reacting particles	2.9%	30.5%	66.7%	44.3%	22.1%	33.6%
Q3dii Naming collision which results into reaction	4.8%	0.00%	95.2%	45.0%	0.00%	55.0%
Q3diii Explaining collisions which results into reaction in terms of proper orientation of reacting particles	25.7%	29.5%	44.8%	71.8%	15.3%	13.0%

**Figure 6-8: Percentages of students indicating understanding of collision which result in a chemical reaction (3di, 3dii and 3diii)**

It is clear that the experimental class had a better level of understanding of chemical reaction in terms of proper orientation of reacting particles.

6.2.11 Activation Energy, E_a of reacting particles

For this item, students were asked in question 3b to determine activation energy, E_a from a graphical representation, in question 3ci to explain activation energy, E_a and question 3cii to explain the relationship between activation energy and chemical rate of reaction.

The results for questions 3b, 3ci and 3cii are presented in **table 6-7** and **figure 6-9**. It can be seen that 60% of the students in the experimental class compared to only 3.1% in the comparison class were able to correctly determine activation energy; E_a .

Also from the **table 6-7**, 27.6% of students in the experimental class compared to only 5.3% in the comparison class were able to correctly explain activation energy, E_a of the reacting particles. Furthermore, the results show that 46.7% of students in the experimental class compared to only 11.5% in the comparison class were able to correctly explain the relationship between activation energy, E_a and chemical rate of reaction. These results are presented in the table below.

Table 6-7: Percentages of students indicating understanding of activation energy, E_a
Students' achievement level

Questions	Experimental class			Comparison class		
	Incorrect response	Partially correct response	Correct response	Incorrect response	Partially correct response	Correct response
Q3b Determination of activation energy, E_a	34.3%	5.7%	60%	94.7%	2.3%	3.1%
Q3ci Explaining activation energy of reacting particles	21.9%	50.5%	27.6%	68.7%	26.0%	5.3%
Q3cii Explaining relationship between activation energy & chemical rate of reaction	51.4%	1.9%	46.7%	86.3%	2.3%	11.5%

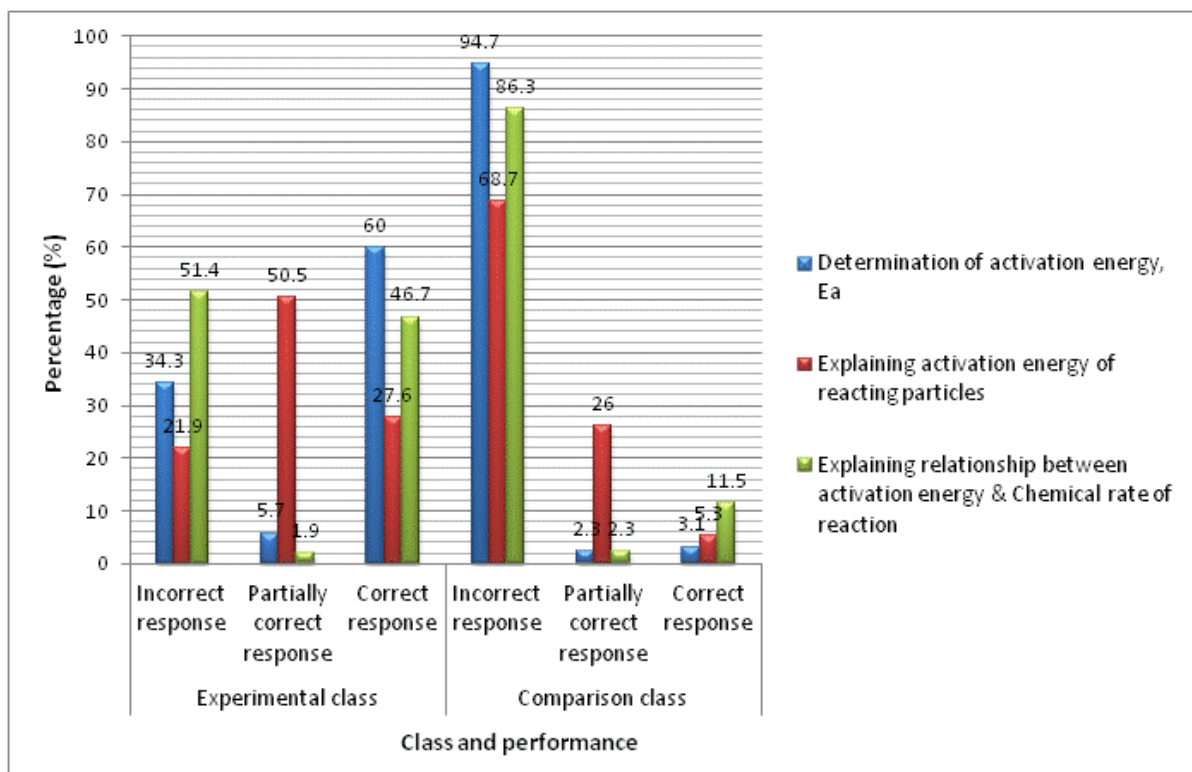


Figure 6-9: Percentages of students indicating understanding of activation energy, Ea (Qns 3b, 3ci and 3cii)

It is clear that the experimental class had a better level of understanding of activation energy, Ea and relationship between activation energy, Ea and chemical rate of reaction compared to the comparison class.

6.2.12 Graphical interpretation of the effect of temperature on chemical rate of reaction

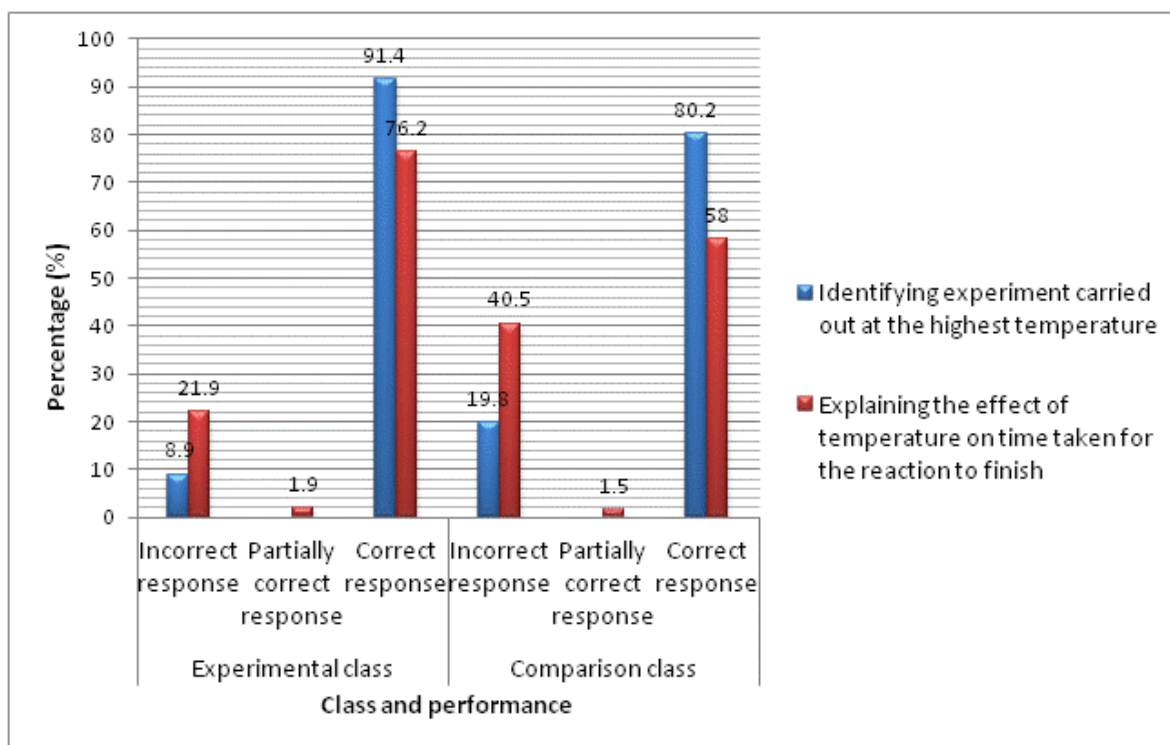
For this item, students were asked in question 1b to identify which class carried out the experiment at the highest temperature, and question 1bii to use the graph to describe in as much detail as they can the effect of temperature on the time taken for the reaction to finish.

The results for questions 1b and 1bii are presented in **table 6-8** and **figure 6-10**. It can be seen that 91.4% of the students in the experimental class compared to 80.2% in the comparison class were able to correctly identify an experiment carried out at the highest temperature, given different times for the reaction to stop.

Also from **table 6-8**, 76.2% of students in the experimental class compared to 58% in the comparison class were able to correctly explain the effect of temperature on time taken for the reaction to stop / finish. These results are presented in the table below.

Table 6-8: Percentages of students indicating ability to interpret graphically the effect of temperature on chemical rate of reaction

Questions		Students' achievement level					
		Experimental class			Comparison class		
		Incorrect response	Partially correct response	Correct response	Incorrect response	Partially correct response	Correct response
Q1b	Identifying experiment carried out at the highest temperature	8.9%	0.0%	91.4%	19.8%	0.0%	80.2%
Q1bii	Explaining the effect of temperature on time taken for the reaction to finish	21.9%	1.9%	76.2%	40.5%	1.5%	58.0%

**Figure 6-10: Percentages of students indicating ability to interpret graphically the effect of temperature on chemical rate of reaction (Qns 1b and 1bii)**

It is clear that the experimental class had a better ability of interpreting graphically the effect of temperature on chemical rate of reaction compared to the comparison class.

6.2.13 Using collision theory to explain effect of temperature on reacting particles

For this item, students were asked in question 1biii to use the collision theory to explain the effect of temperature on rate of reaction as best as they can in terms of particles.

Table 6-9 and **figure 6-11** present the results for item Q1biii where students were asked to use collision theory to explain the effect of temperature on reacting particles. The results show that 61% of students in the experimental class compared to only 5.3% in the comparison class were able to correctly explain. These results are presented in the table and figure below.

Table 6-9: Percentages of students indicating ability to use collision theory to explain the effect of temperature on reacting particles

Questions	Students' achievement level					
	Experimental class			Comparison class		
	Incorrect response	Partially correct response	Correct response	Incorrect response	Partially correct response	Correct response
Q1biii Using collision theory to explain the effect of temperature on reacting particles	18.1%	21.0%	61.0%	48.9%	45.8%	5.3%

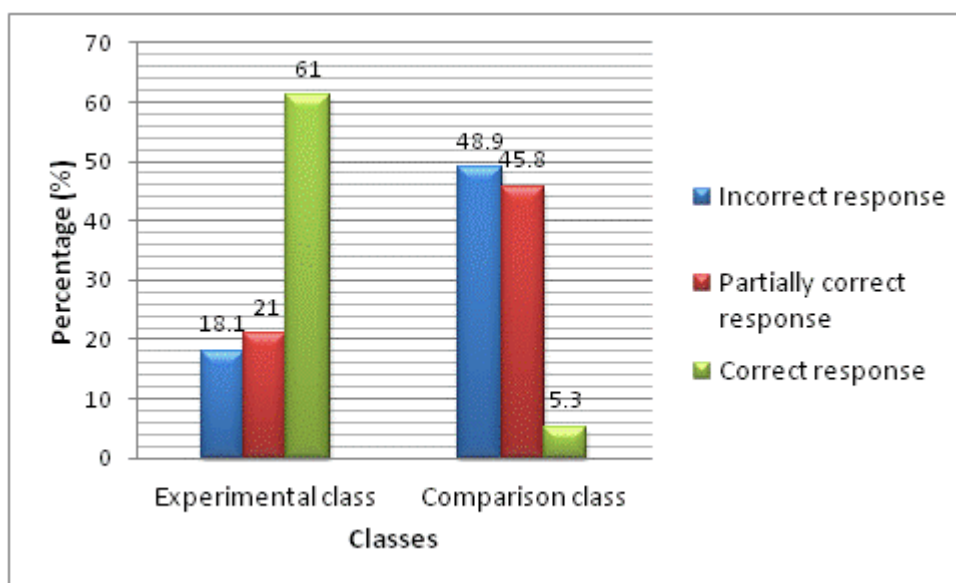


Figure 6-11: Percentages of students indicating ability to use collision theory to explain the effect of temperature on reacting particles (Qn1biii)

This shows that the experimental class had a better ability of using collision theory to explain the effect of temperature on reacting particles compared to the comparison class.

6.2.14 Graphical interpretation of the effect of concentration on chemical rate of reaction

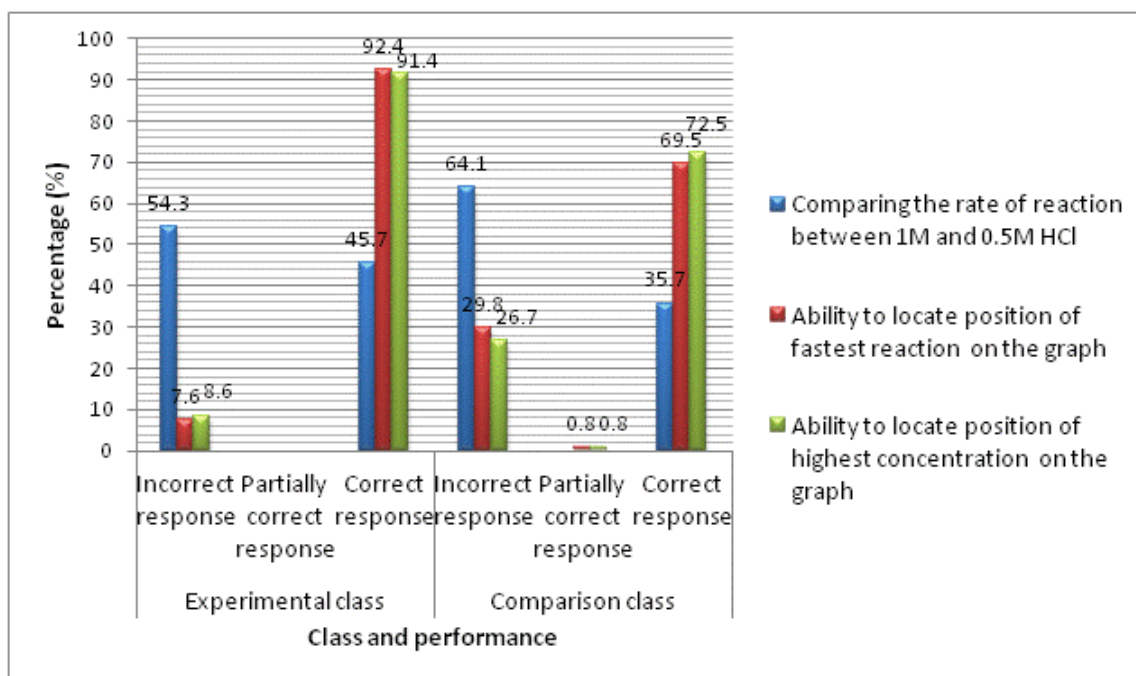
For this item, in question 2c students were asked to compare rate if 0.5 M HCl acid is used instead of 1M HCl when reacted with a calcium carbonate, in question 2di to name the position calcium carbonate reacts fastest on the graph and in question 2dii students were asked to name the position that the concentration of hydrochloric acid is highest.

The results for questions 2c, 2di and 2dii are presented in **table 6-10** and **figure 6-12**. It can be seen that 45.7% of students in the experimental class compared to 35.7% in the comparison class were able to correctly compare rate of reaction between 1M and 0.5M hydrochloric acid solution (item Q2c).

Also from the **table 6-10**, 92.4% of students in the experimental class compared to 69.5% in the comparison class were able to correctly locate on the graph the position when calcium carbonate reacts fastest (Q2di). Furthermore, the results indicate that 91.4% of the students in the experimental class compared to 72.5% in the comparison class were able to correctly locate on the graph the position the concentration of hydrochloric acid is highest (Q2dii). These results are presented in the table below.

Table 6-10: Percentages of students indicating ability to graphically interpret the effect of concentration on rates of reaction

Questions		Students' achievement level					
		Experimental class			Comparison class		
		Incorrect response	Partially correct response	Incorrect response	Incorrect response	Partially correct response	Correct response
Q2c	Comparing the rate of reaction between 1M and 0.5M HCl	54.3%	0.0%	45.7%	64.1%	0.0%	35.7%
Q2di	Ability to locate position of fastest reaction on the graph	7.6%	0.0%	92.4%	29.8%	0.8%	69.5%
Q2dii	Ability to locate position of highest concentration on the graph	8.6%	0.0%	91.4%	26.7%	0.8%	72.5%

**Figure 6-12: Percentages of students indicating ability to graphically interpret the effect of concentration on rates of reaction (Qns 2c, 2di and 2dii)**

These results show that the experimental class had a better to ability to compare rate of reaction between different concentrations of the same reactant, graphically interpret on the graph positions for - fastest rate of a reaction and highest concentration compared to the comparison class.

6.2.15 Using collision theory to explain effect of concentration on reacting particles

For this item, students were asked in question 2diii to use the collision theory to explain as best as they can in terms of particles generally why the reaction time is short if the concentration is higher.

Table 6-11 and **figure 6-13** presents the results for item Q2diii where students were asked to use collision theory to explain the effect of concentration on reacting particles. The results show that 27.6% of the students in the experimental class compared to only 1.5% in the comparison class were able to correctly explain. These results are presented in the table and figure below.

Table 6-11: Percentages of students indicating ability to use collision theory to explain the effect of concentration on reacting particles

Questions	Students' achievement level					
	Experimental class			Comparison class		
	Incorrect response	Partially correct response	Correct response	Incorrect response	Partially correct response	Correct response
Q2diii Using collision theory to explain the effect of concentration on reacting particles	18.1%	54.3%	27.6%	67.2%	31.3%	1.5%

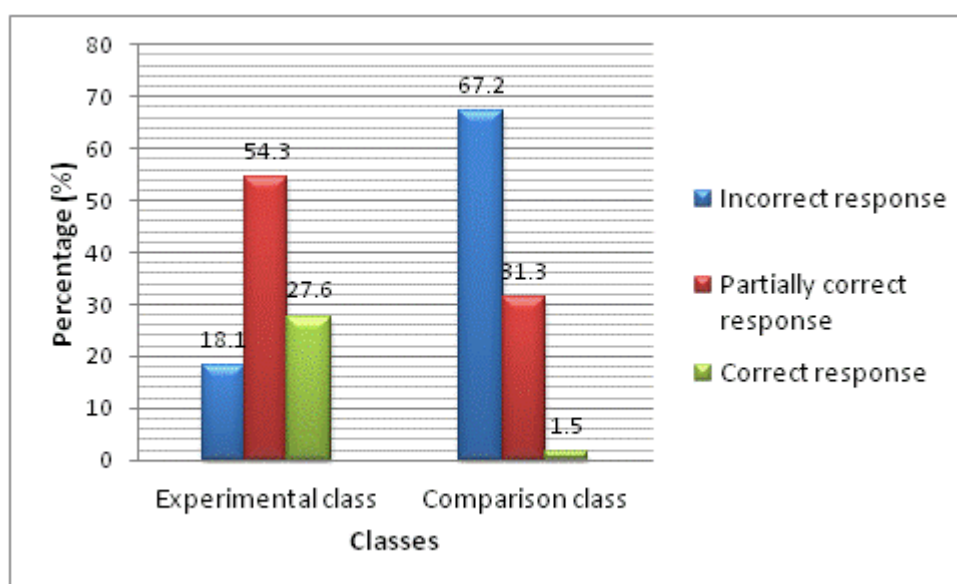


Figure 6-13: Percentages of students indicating ability to use collision theory to explain the effect of concentration on reacting particles (Qn2diii)

This analysis shows that the experimental class had a better ability to use collision theory to explain the effect of concentration on reacting particles compared to the comparison class.

6.2.16 Explanation on why two experiments under different conditions can have similar rate of reaction

For this item, students were asked in question 2e to explain why a reaction carried out with 1M HCl solution with magnesium under room temperature (25°C) and reaction carried out with 0.5M HCl solution heated to a temperature of 35°C with same amount of magnesium can have a similar rate of production of the gas (10cm³ per second).

Table 6-12 and **figure 6-14** of results show that 52.4% of students in the experimental class compared to only 3.8% in the comparison class were able to correctly explain item 2ei. These results are presented in the table and figure below.

Table 6-12: Percentages of students indicating ability to explain why two experiments with different conditions can have similar rate of reaction

Questions		Students' achievement level					
		Experimental class			Comparison class		
		Incorrect response	Partially correct response	Correct response	Incorrect response	Partially correct response	Correct response
Q2e(i)	Explain why two experiments with different conditions can have similar rate of reaction	38.1%	9.5%	52.4%	85.5%	10.7%	3.8%

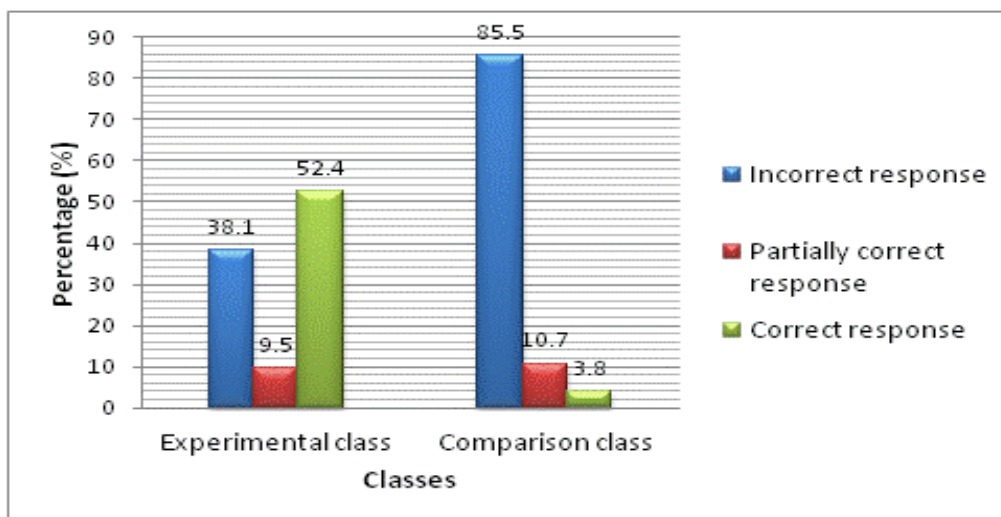


Figure 6-14: Percentages of students indicating ability to explain why two experiments with different conditions can have similar rate of reaction (Qn2e i)

This analysis of the students responses show that the experimental class had a better ability to explain that the effects of concentration and temperature can be compensated by the each other in a chemical reaction compared to the comparison class.

6.3 Summary evidence to answer research question 1 (RQ1)

1. The statistical analyses showed that there was good evidence that C&TA had a strong effect compared to NTA in enhancing students' understandings of chemical rate of reaction.
2. The findings indicate that the C&TA supports female students' understanding of chemical rate of reaction a little more compared to the male students.
3. The findings also indicate that the C&TA teaching sequence had an effect of the same magnitude across the ability range.
4. The sequences of the activities were able to promote students' understanding of chemical rate of reaction. It was evident that C&TA teaching favoured more students' understanding of: definition of rate of reaction (74.3% of C&TA students compared to 29.0% of NTA students) followed by understanding effect of temperature on chemical rate of reaction (61% of C&TA students compared to 5.3% of NTA students), then understanding activation energy, E_a (60% of C&TA students compared to 3.1% of NTA students), understanding proper orientation of reacting particles (44.8% of C&TA students compared to 13.0% of NTA students) and an understanding of the effect of concentration on chemical rate of reaction was

least supported (27.6% of C&TA students compared to 1.5% of NTA students). This confirms the difficulty of this concept.

5. The statistical analyses show that :
- The designed activities were able to support students' essential needs in learning the chemical rate of reaction.
 - The teaching goals and learning outcomes in the lessons were achieved in addressing students understanding of rate of reaction, proper orientation of reacting particles, activation energy, E_a , the effects of temperature and concentration on chemical rate of reaction.
 - The students in C&TA class were more able to conceptualise behaviour of molecules at a molecular level (microscopic) and relate to the macroscopic and symbolic levels.
 - The students in C&TA class were more able to generate detailed scientific explanations of the concepts of chemical rate of reaction.

These learning gains were attributed to the features of C&TA teaching sequence which will be presented in Chapter Seven, Chapter Eight and discussed in Chapter Nine.

CHAPTER SEVEN

7 ANALYSIS, PRESENTATION AND INTERPRETATION OF CLASSROOM TALK

7.1 Introduction

This chapter presents evidence relating to **RQ2**. The results were obtained through transcriptions and analyses of recorded audio-video episodes of classroom talk.

So far, in Chapter Six I presented evidence indicating that students in the experimental class achieved significantly higher learning gains in relation to being able to apply scientific explanations to aspects of chemical rate of reaction, collision (kinetic) theory / orientation of reacting particles or atoms, temperature, activation energy, E_a and concentration. The evidence from the post-test supports the following claim: students from the experimental class achieved significantly higher learning gains / understanding in the relevant concepts of chemical rate of reaction than students from the comparison class who followed the NTA. This is an effect of the use of the designed teaching intervention, C&TA. This claim, however, is rather limited in that it says nothing about which characteristic(s) of the use of C&TA might have made a difference. This is because the student learning outcome does not provide direct evidence about the effectiveness of C&TA in supporting learning.

Research question 2 seeks to identify which parts (features) of the teaching sequence are effective in supporting learning and which are less effective.

Therefore, an analysis of classroom interactions based on the sociocultural framework was carried out to provide details of the teaching activities and their staging by the teacher that was influential in promoting students' understanding specifically those intended to address the learning demands (Leach & Scott, 2002). It focuses on forms of various communicative approaches, patterns of interaction and forms of teacher intervention to maximize students' learning.

7.2 A review of the classroom talk coding schemes

To collect evidence on teaching activities (approaches, forms of teacher intervention and patterns of interaction) coding schemes which draw on the sociocultural framework were used as a tool for analyzing the C&TA and NTA teaching sequences.

Thus the coding schemes to be applied in this section of analysis are:

Initiation to introduce ideas [**I(i)**]; Initiation to review ideas [**I(r)**];
Initiation to explore ideas [**I(e)**]; Initiation of factual questions [**If(q)**];
Initiation to summarize ideas/sharing ideas [**I(s)**]; Initiation to
check/confirm understanding/ checking understanding [**I (cu)**];
Response to answer explorative question [**R(aeq)**]; Response to
factual questions [**R (fq)**]; Response to confirm understanding [**R**
(**cu**)]; **Echoes**; Neutral feedback (**N/F**); Selecting parts of ideas [**S**
(**pi**)]; Shaping ideas [**S(i)**]; Marking key ideas [**M(i)**]; Motivation (**M**);
Evaluation of ideas [**E(i)**] and Classroom management moves (**Cmm**)

For details on these codes see **Chapter Five, table 5-1**.

7.3 Generated chain patterns of interaction

Generated chain patterns of interaction inform of [**I(i)**] or [**I(r)**] or [**I(s)**] or [**I(i)-R(aeq)-E(i)**] or [**I(i)-R(aeq)- N (F)**], derived from the coded turns of talk between the teacher and students for each lesson episode, will be used to illustrate how the chain of interaction was developed during classroom interactions. It will provide a detailed account of the purpose of the talk, the content of the talk, the different types of communicative approaches used during each lesson as illustrated in the review in the next section and evidence of teacher support to students learning.

7.4 A review of the characterisation of the classroom talk

Drawing from the socio-cultural framework outlined earlier in Chapter Three, the expected key differences will be drawn from the use of communicative approaches (CA) with their purposes in supporting students' understanding.

- Interactive/dialogic-**I/D (I-R-F** pattern): The teacher seeks to elicit and explore students' ideas about a particular issue with a series of 'genuine' questions (open questions where the teacher is amenable to various different responses from students).
- Non-interactive/dialogic-**NI/D (N** pattern): The teacher is in presentational mode (non-interactive) working with small groups but explicitly considers and draws attention to different points of view (dialogic), possibly in providing a summary of an earlier discussion.
- Interactive/authoritative-**I/A (I-R-E** pattern): The teacher typically leads the students through a sequence of instructional questions and answers with the aim of reaching one specific point of view.
- Non-interactive/authoritative-**NI/A (I**-pattern): The teacher presents a specific point of view.

For details on characterization of classroom talk see **section 3.9**.

To derive the key differences, patterns of interaction (e.g. **I-R-E**) have been obtained from the chain patterns of interaction developed during the classroom talk between

the teacher and students. The patterns of interaction are then linked to their respective CA as described under the characterisation of the talk above.

The frequency counts (tallies) of the occurrence of CA were conducted to determine the proportion of CA use during each lesson.

The frequency counts were converted to percentage frequency in order to show the proportion of the particular CA used in each lesson. Percentage frequencies were determined by computing the relative frequency of each CA: by dividing the frequency (f) by the number of observations (n= total number of CA): that is, (f ÷ n). Thus:

Relative frequency = frequency ÷ number of observations in the lesson

The percentage frequency is found by multiplying each relative frequency value by 100. Thus:

Percentage frequency = relative frequency X 100 = f ÷ n X 100

For example in C&TA class, Lesson 1 Episode 1.2.1, the generated chain patterns of interaction is:

[I] (i)-[I (e)-R (aeq)-F]-[I (e)-R (aeq)-Ei] - [I (e)-R(aeq)-E (i)-Echoes]-[I(e)-R (aeq)-E (i)]-[I (s)] [I (r)]- (I)e-R(aeq)-E (i)-M (i)]-[I(e)-R (aeq)-N(F)- [I (e)-R (aeq)-E(i)]-[I (e)-R(aeq)-I(i) & I(e)-R (aeq)-I (e)-R (aeq)-(E (i)- Echoes]- [I (e)-R (aeq)-E(i)]-[I(e)-R(aeq)-E (i)]- [I(s)]

The bracket acronym(s) in full:

Acronym	Phrase (s) or word (s)
(i)	Ideas
(e)	Explore
(r)	Review
(s)	Summarise
(aeq)	answer explorative question
(pi)	Part of ideas
(fq)	factual question

And the corresponding patterns of interaction are:

[I]-[I-R-F]-[I-R-E]-[I-R-E]-[I-R-E]-[I-R-E]-[I]-[I]-[I-R-E]-[I-R-F]-[I-R-E]-[I-R-E]-[I-R-E]-[I-R-E]-[I]

Frequency of [I]- N/A is 4; [I-R-E]-I/A is 9; [I-R-F]-I/D is 2 and the respective percentage proportions are 4/(4+9+2)x100 = (26.7%); 9/(4+9+2)x100 = (60%) and 2/9+9+2)x100 = (13.3%).

7.5 Presentation of the analysis of classroom talk

The presentation of the analysis follows Mortimer and Scott (2003) three key phases (see **section 2.6.2** for a detailed discussion): staging scientific view point; supporting student internalisation and handing-over responsibility to the students.

In the first part of the classroom analysis, commentary will be used to highlight the communicative approach modes of interactions to summarise activities and the forms of teacher's intervention for each episode or lesson.

In the second part, in explaining the key differences between the experimental class (C&TA) and comparison class (NTA), commentaries are made based on the percentage proportion of the CA, its intended purpose along with the forms of teacher intervention used to support students understanding.

Finally, a comparison of the planned C&TA (see **section 4.15**) and the actual teaching will be evaluated and presented to determine the extent to which the teacher had indeed followed the C&TA pattern designed in the teaching sequence.

7.6 Selections and analyses of lesson episodes

The C&TA teaching sequence had six lessons, each lasting 40 minutes (that is, 240 minutes altogether).

The selections of the lesson episodes for analyses were conducted based on five areas that students find difficult to understand. The main aim is to show how the teachings of the five areas were conducted in the C&TA class and NTA class in order to draw significant differences in the two approaches.

In the subsequent sections, I will present C&TA teaching activities used to address the areas students find difficult to understand (learning demands), along with analysis of classroom talk. I will also present analysis of the corresponding NTA teaching activities for the same 'context' in order to give the reader the perspective on why C&TA proved more useful and helpful in supporting students' learning of chemical rate of reaction.

7.7 L1 Episode 1.2.1: Chemical rate of reaction

It is important to point out that analysis of episode 1.1 is not presented because it was a starter activity that the teacher used to explore students ideas on various factors which affect chemical reaction. Therefore, analysis of episode 1.2 was carried out and presented as it was about the concepts that students find difficult to understand (learning demand).

7.7.1 L1 Episode 1.2.1 Learning gains: Definition / determination

One area of chemical rate of reaction where the experimental class (C&TA class) performed significantly better in relation to the comparison class (NTA class) was the knowledge of application of the definition of rate of reaction to determine rate of chemical reaction from the amount of product form in a given time (definition). Students in the experimental class (C&TA class) obtained 74.3% compared to only 29% in the comparison class, on the fact that rate = amount of product / time, unit cm^3/s or $\text{cm}^3/\text{s}^{-1}$ (in this case rate = $40/4 = 4 \text{ cm}^3/\text{s}$ or $\text{cm}^3 \text{ s}^{-1}$).

7.7.2 Episode 1.2.1 Teaching determination of rate of reaction in C&TA class: Patterns of interaction

7.7.3 Staging the scientific story

Teaching about this aspect of chemical rate of reaction was conducted by way of reviewing the work on collision theory drawing from the ideas of behavior of atoms in the three states of matter. The teacher got students to recall arrangements of particles and how particles behave if temperature increases through a mixture of communicative approaches, exploring students' ideas as follows:

7.7.4 Supporting students' internalisation

Table 7-1: Episode 1.2.1. Whole classroom interaction

	Turn	Codes	Remarks
1T:	Well, in studying factors that affects rate of chemical reaction, their effects centre on the kinetic theory of matter.	I (i)	
	When you recall, how are particles in states of matter arranged	I (r)	
	Are they arranged in the same way?	I (e)	
2SS :	No! (Chorus)	R (aeq)	
3T:	OK.	N (F)	Acknowledgement feedback
	So where are they more spaced - is it in gases,	I (e)	

	liquids or solids?		
4SS :	in gases, they are more (chorus)	R (aeq)	
5T:	Yes	E(i),	'yes' to mean correct idea(s)
	In gases...so we have what is called the collision theory.	Echoes	to emphasize the point/ reinforce the correct answer/ acknowledge of an answer as acceptable
	Can anyone tell us what happens to particles if the temperature to 40 ⁰ C?	I (e)	
6S:	The atoms move faster	R (aeq)	
7T:	Yes,	E(i)	'yes' to mean correct idea(s)
	Actually the atoms will move faster...	Echoes	'Echoes' to emphasize the point
	And what if it is increased to 60 ⁰ C, then to 80 ⁰ C?	I (e)	
8S:	At 60 ⁰ C, atoms will be moving rapidly and at 80 ⁰ C, atoms will be moving more rapidly.	R (aeq)	
9T:	yes...that is true	E(i)	
	yes, in chemical reaction, the atoms will move rapidly, collide and react to form products	I (s)	

Generated chain patterns of interaction: I (i)-[I (e)-R (aeq)-F]-[I (e)-R (aeq)-Ei] - [I (e)-Raeq-E (i)-Echoes]-[I(e)-R (aeq)-E (i)]-[I(s)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through I-pattern linked to **non-interactive/authoritative** when the teacher was introducing the concepts on factors which affect chemical rate of reaction; **I-R-F-pattern (interactive/dialogic)** where the teacher explores different points of view by engaging the students in sequences of turn-taking; **I-R-E-pattern (interactive/authoritative)** where the teacher moved towards the effect of temperature on rate of reaction and concludes the lesson using I-pattern (**non-interactive/authoritative**) to summarise the key ideas. The forms of teacher intervention denoted in brackets are present in table 7-2.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-2: Episode 1.2.1. Key features of the teaching process

Teaching purpose	Factors affecting chemical rate of reaction
Content	States of matter and collision theory
Communicative Approach	Non-interactive/authoritative; Interactive/Dialogic; interactive/Authoritative and non-interactive/authoritative
Patterns of interaction	[I]-[I-R-F]-[I-R-E]-.--[I]
Forms of teacher intervention	Introducing ideas, exploring, evaluating and echoing, sharing ideas and summarising ideas

Commentary: It is observed from above excerpt that the teacher used non-interactive/authoritative (NI/A), interactive/dialogic (I/D), interactive/authoritative (I/A) and non-interactive/authoritative (NI/A).

The teacher began the lesson in a non-interactive/authoritative way, introducing and developing ideas of chemical rate of reaction with a focus on the states of matter and the kinetic theory of matter. He interacted dialogically to explore students' ideas about states of matter. He also interacted authoritatively by asking questions and waiting for students to answer; used strategies such as evaluating, sharing ideas and echoing to emphasize the point/reinforce the correct answer/acknowledge an answer as acceptable to the whole class. He then summarised the key ideas that 'in chemical reaction, the atoms will move rapidly, collide and react to form products' before moving onto relate these ideas of movement of particles to chemical rate of reaction as follows:

Table 7-3: Episode 1.2.2. Whole classroom interaction

10T:	Ok.. in chemical reaction, the atoms will move rapidly, collide and react to form products So how would you then define rate of reaction?	I (r) I (e)
11S:	I think ...is the speed at which reaction is taking place	R (aeq)
12T:	yeah, speed of reaction , another definition?	E (i) M (i) I (e)
13S:	uhm...change of reaction	R (aeq)
14T:	ok! another definition?	N I (e)
15S:	the degree of reaction	R (aeq)
16T:	...Is it degree of hotness or coldness?	E(i)/I (e)
17S:	the degree of change in a given time	R (aeq)
18T:	Listen, I want us to consider, if two people are competing in eating 100g of food. How will you tell that A is eating faster than B? (Here, the teacher uses analogy to arrive at the definition of rate of reaction)	I (i) & I (e)
19S:	I will see the quantity of food A is taking at the given time	R (aeq)
20T:	how will you measure what I am eating how will you know the quantity of food I am eating?	I (e)
21S:	I will compare of the two...which (whose) food is reducing more... faster	R (aeq)
22T:	Yes comparing the two... what else?	E(i), Echoes I (e)
23S:	measure the time taken for 100g to get finished	R (aeq)
24T:	I think this would be quite best ... so how would we then define the rate of reaction?	E(i) I (e)
25S:	the amount used in a given time	R (aeq)
26T:	very good if you have A reacting with B, the product would be AB $A + B \longrightarrow AB$, we measure the time AB is formed or the rate at which A and B are disappearing, that would be the rate of the reaction. Therefore, rate of reaction is defined as the amount of product (s) formed in a given time or the rate at which reactants are used up in a reaction. This is also expressed as Rate = Product/time, units dm^3/sec Now we are going to use computers for today, make predictions, test our predictions using computer and explain our observations on the effect of temperature on rate of reaction.	E(i) I(s)

Generated chain patterns of interaction: [I(r)]-[I(e)-R(aeq)-E(i)-M(i)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-E(i)]-[I(e)-R(aeq)-I(i)]&I(e)-R(aeq)-I(e)-R(aeq)-(E(i)-Echoes)]-[I(e)-R(aeq)-E(i)]-[I(e)-R(aeq)-E(i)]-[I(s)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through I-pattern linked to **non-interactive/authoritative** when the teacher was reviewing the concepts on collision which results in chemical reaction leading to formation of a chemical product; **I-R-E-pattern (interactive/authoritative)** where the teacher move was towards the definition of rate of reaction; **I-R-F-pattern (interactive/dialogic)** where the teacher explores different points of views by engaging the students in sequences of turn-taking; and concludes the lesson using I-pattern (**non-interactive/authoritative**) to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-4.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-4: Episode 1.2.2. Key features of the teaching process

Teaching purpose	Define the term 'rate of reaction'
Content	Determination/ Definition of rate of reaction
Communicative Approach	Non-interactive/ authoritative; Interactive/authoritative; Interactive/dialogic; and Non-interactive/authoritative
Patterns of interaction	[I]-[I-R-E]-[I-R-F]-[I-R-E]-[I-R-E]-.-[I]
Forms of teacher intervention	Introducing ideas, exploring ideas, evaluating students ideas, echoing ideas, sharing ideas and summarising ideas

Commentary: In this part of the lesson, it is observed from the above excerpt that the teacher used non-interactive/authoritative (NI/A), interactive/authoritative (I/A), interactive / dialogic (I/D), and non-interactive/authoritative (NI/A).

The teacher began the lesson in a non-interactive/authoritative way, reviewing: "O.K., in chemical reaction, the atoms will move rapidly, collide and react to form products". The teacher then interacted dialogically to develop ideas about rate of reaction through exploring and working on students' ideas by asking a question: "how would you then define rate of reaction?". This lead to responses in which the students were required to 'think' or 'guess' what the acceptable answer was that the teacher was looking for. For example, when 'the degree of reaction' was suggested, the teacher seizes the phrase and initiates a confirmatory exchange with students (turns 16 to 17). The exchange serves the two functions of evaluating and disapproving the student's response. In this episode, the teacher has a purpose, so he uses an analogy to help students think about the definition of rate. He draws

students to consider two people (A and B) competing in eating 100g of food (turn 18) to derive the definition of rate of reaction.

He then further interacted authoritatively asking questions such as "how will you tell that A is eating faster than B?", and then waiting for students to answer, he used strategies such as exploring "what else?", evaluating, sharing ideas and echoing, for example, "comparing the two" (turn 22) to emphasize the point and reinforce the correct answer, as well as acknowledging an answer as acceptable to the whole class. He then summarises the key ideas, such as therefore, rate of reaction is defined as the amount of product(s) formed in a given time, or the rate at which reactants are used up in a reaction. This is also expressed as Rate = Product/time, units dm^3/sec ' (turn 26).

7.7.5 For Episode 1.2.1 Teaching determination of rate of reaction in NTA class: Patterns of interaction

7.7.6 Staging the scientific story

In this lesson the teacher used a graph of the volume of hydrogen evolved with time when magnesium is reacted with hydrochloric acid through a mixture of communicative approaches, exploring students' ideas as follows in the next section.

7.7.7 Supporting students' internalisation

Table 7-5: For Episode 1.2. Whole classroom interaction

	Turn	Codes	Remarks
1T:	First and foremost when you look at 0.5M, 1M and 2M which one has got the highest concentration? uhm...yes	I (e)	
2S:	2M	R (aeg)	
3T:	2M ...do we... all agree on that...uhm	E(i)-Echoes & I (cu)	
4S:	yes...it is 2M in chorus	R (cu)	
5T:	2M we all agree on that ...do we all agree? Because, that means concentration...that means the higher the number of moles in a particular liquid or substance then that will be greater the concentration...it is clear? Are you through? Monitors and checks students' notes ...so are you ok with that? Points to note By the way as we are carrying out this experiment remember we are investigating on the effect of concentration, but put in mind that we have already looked at temperature. So in order not to affect our investigation or experiment, we assumed we are carrying out this experiment at a constant temperature because you might ask what if the temperature is changed. ... Do not bring in temperature here...we assume temperature is	Echoes & I (cu) I (s) I (cu) Cmm	

	<p>constant.</p> <p>The volume of hydrogen increases along AB because Mg reacts with HCl to give Hydrogen gas ...you can write that simple equation. (Transcribes equation on board)</p> $\text{Mg (s)} + 2\text{HCl (aq)} \longrightarrow \text{MgCl}_2 \text{ (aq)} + \text{H}_2 \text{ (g)}$ <p>Teacher cautions the students make sure you balance the equation....write that simple equation...</p> <p>Teacher carries on with the interpretation of the graph , at point BC, the graph remains constant because all the Mg is used up and the reaction is complete</p> <p>By the way sometimes you can be given figures and you can be asked to plot a graph.</p> <p>But is Everything clear?</p> <p>Are you sure! Are we together?</p> <p>So now...uhm...what normally we call the rate of production... what normally we call the rate of production...the rate of production is normally given ...how do we calculate rate?</p> <p>Rate always involve time....so in order to get the rate you get whatever you have gotten in that period of time, then you divide by that time. It is that clear?</p>	<p>I (cu)</p> <p>I (cu)</p> <p>I (e)</p> <p>I (s)</p> <p>I (cu)</p>	
6SS:	yes in chorus		
7T:	<p>when they say the rate of production that will mean we shall divide the amount of hydrogen produced within a given time and we shall know the rate which hydrogen has evolved.</p> <p>So we get the hydrogen produced divide by the time then we shall get rate...is that clear?</p>	<p>I (i)</p> <p>I (s)</p> <p>I (cu)</p>	
8S:	Yes	R (cu)	
9T:	for this we shall have 200 cm ³ divide by 4 minutes and what shall we get?	I (e)	
10S:	50 cm ³ / minutes	R (aeq)	
11T:	<p>good, the units...depends on the time given</p> <p>If you are sure of your mathematics you can use min⁻¹ ...are sure?</p>	<p>E(i) & I (s)</p> <p>I (cu)</p>	
12SS:	somehow...	R (cu)	
13T:	If not then use per minute or second if in seconds...can you calculate the next?	I (s) & I (e)	
14SS:	...		
15T:	<p>so in conclusion we shall find that the rate is higher when the concentration is high</p> <p>Therefore, the reaction is faster with 2M HCl...is that clear?</p>	<p>I (s)</p> <p>I (cu)</p>	
16SS:	yes...in chorus	R (cu)	
17T:	<p>use this table to plot...it is something simple</p> <p>But have you all understood those two factors...</p> <p>Can you be able to answer any questions on those two factors?</p>	I (cu)	
18SS:	yes... in chorus	R (cu)	
19T:	<p>So we are ok...with that...are we ok!</p> <p>Nicolas!...are you ok with concentration and temperature</p>	I (cu)	
20S:	not really	R (cu)	
21T:	not really why? Where is the problem?	I (e)	
22S:	graph	R (aeq)	

23T:	the graph, once you are drawing the graph just plot time...put it under measurement or scale...just exactly like the graph we have just drawn. Put in scale ...for example 2, 3 & 4 In our next lesson we shall carry out an experiment to determine the effect of concentration on rate of reaction. We will still use the same solution of sodium thiosulphate and hydrochloric acid, but we shall be varying the concentration.	I(r) I (i)	
24T:	Nicholas, are you now comfortable?	M	
25S:	Yeah!		

Generated chain patterns of interaction: [I (e)-R (aeq)-E (i)- Echoes]-[I (cu)-R (cu)-Echoes- I (cu)-I (s)-I (cu)-Cmm-I (cu)-I(cu)-I(e)-I (s)-I (cu)-I (i)-I (s)-I (cu)-R (cu)]-[I (e)-R(aeq)-E(i)]-[I (s)-I (cu)-R (cu)-I(s)-I(e)-N-I (s)-I (cu)-R (cu)-I (cu)-R (cu)-I (cu)-R (cu)-I(e)-R (aeq)-I(r)-I(i)-M]

In this episode the generated chain patterns of interaction show that the classroom talk was developed through the **I-R-E**-pattern (**interactive/authoritative**) where the teacher moves towards the definition rate of reaction. The patterns of reaction show wide spread use of **I**-pattern linked to **non-interactive/authoritative**, and also show less engagement of the students in the lesson. The forms of teacher intervention indicated in brackets are presented in table 7-6.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-6: For Episode 1.2. Key features of the teaching process

Teaching purpose	Define the term 'rate of reaction'
Content	Determination/ Definition of rate of reaction
Communicative Approach	Interactive/authoritative; Non-interactive/authoritative; Interactive/authoritative; Non-interactive/authoritative
Patterns of interaction	[I-R-E]-[I]-[I-R-E]-[I]
Forms of teacher intervention	Exploring, checking students' understanding, echoing, classroom management moves, evaluating, reviewing and motivating students

Commentary: From the above excerpt, it is clear that the teacher used interactive/authoritative (I/A), non-interactive/authoritative (NI/A), interactive/authoritative (I/A) and non-interactive/authoritative (NI/A).

He interacted authoritatively to develop ideas about rate of reaction through exploring and working on students' ideas by asking a question ... "when you look at 0.5M, 1M and 2M which one has got the highest concentration?". Waiting for the students to answer, he used strategies such as evaluating, sharing ideas, echoing to emphasize the point, reinforce the correct answer and acknowledge an answer as acceptable to the whole class and checking understanding.

He then moved on to present notes through dictation in a non-interactive-authoritative way, characterised more by classroom management moves. He presented a summary of how chemical rate of reaction can be obtained when products and time for the reaction is given in non-interactive/authoritative way (turn 5). He further interacted authoritatively exploring and working on students' ideas by asking questions and waiting for students to answer (turn 9-14). He used strategies such as evaluating and checking understanding. In turns (17-25), he gave out an assignment as a follow up exercise for students.

7.7.8 L1 Episode 1.3.1 Learning gains: Proper orientation of reacting particles

Another area where the experimental (or C&TA) class performed significantly better than the comparison (or NTA) class was the understanding of collision which results into a chemical reaction. Students in the experimental class obtained 95.2% compared to 55% in the comparison class, on that fact that particles must collide in correct orientation for effective collision to occur leading to reaction, bonding and product formation.

7.7.9 Episode 1.3.1 - Teaching proper orientation of reacting particles in C&TA class: Patterns of interaction

7.7.10 Staging the scientific story

In the episode 1.3.1 (continuation), the teacher put students in groups to explore the microscopic behavior of molecules during a chemical rate of reaction. Students worked in groups exploring, making predictions and trying their predictions using a computer simulated model of rate of reaction. The teacher used worksheet activities to engage students in group discussions through non-interactive/dialogic (NI/D). As the groups worked through the worksheet, the teacher provided support through probing, scaffolding and helping them to make sense of, and internalize those ideas, as they navigated computer simulations of rate of reaction. Group discussions and explanations were relayed to the whole class in which a student responded as part of a group to teacher prompts through communicative approaches as follows:

7.7.11 Supporting students' internalisation

Table 7-7: Episode 1.3.1. Whole classroom interaction

	Turn	Codes	Remarks
1T:	When the temperature increases, particles get energy and collide... What do you think would happen?	I (i) I (e)	
2S:	I think molecules A and BC combine quickly to form AB and C	R (aeq)	
3T:	Yes Products may form Anything else?	E(i) S(i) I (e)	
4S:	The reactants reduces very fast and the product is formed very fast	R (aeq)	
5T:	OK...assuming for example if we are subject to heat in this room, people might start knocking or hitting each other...that hitting each other in terms of chemistry Is what we shall refer to as?	N (F) I (e)	Elaborative follow-up
6S:	There will be a lot of collisions and faster movements of particles	R (aeq)	
7T:	Thank you Collision	E(i) Mi Echoes	
	When these collisions are ok, for example Oboso if you are colliding with her (Victoria) and she is facing you, what do you think will happen?	I (e)	
8S:	Laughter changes direction	R (aeq)	
9S:	Bounced back [laughter]	R (aeq)	
10T:	May bounce back , yeah!	Echoes & N (F)	Neutral feedback
	Look here...assuming we have Oboso as particle A and Victoria as particle B... and she is facing him because they were facing each other it means the two particles are in what we called proper orientation. But if Victoria changes posture, Oboso may not find it comfortable hugging her, then ...?	I (e)	Use analogy / metaphor
11S:	he reaction will not take place	R (aeq)	
12 T:	Take for example Oboso and Victoria is facing each other, when they knock on each other and they fall down together... because, they were facing each other, we call it proper orientation. Therefore, if atoms of reactants in a reaction are well oriented, the two will combine and we shall say the reaction has taken place. When atoms collide they must be properly oriented that is why in the simulations there were many collisions but very few products being form because they were not properly oriented. Therefore, in any chemical reaction, the collision may occur, but if the orientations are not very clear (properly aligned), the product will not occur (formed) <i>Proper orientation</i> means atoms must be aligned in such a manner that they bond together. For example, consider the chemical reaction between NaOH and HCl to produce NaCl and H ₂ O NaOH (aq) + HCl (aq) → NaCl (aq) + H ₂ O (l) [written on the blackboard] In this reaction, atom of Cl is transferred from HCl to Na atom and OH to H atom. The collision orientation most favourable for these occur are that, Cl atom from HCl must be near a Na atom from NaOH at the moment of collision.	I(r) I (s)	

Generated chain patterns of interaction: [I(i)]-[I(e)-R(aeq)-E(i)-S(i)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-E(i)-M(i)-Echoes]-[I(e)-R(aeq)-R(aeq)-Echoes & N (F)]-[I(e)-R(aeq)-I(r)-I(s)]

This episode showed that the generated chain patterns of interaction of the classroom talk were developed through I-pattern, linked to **non-interactive/authoritative** when the teacher introduced the lesson; **I-R-F-pattern (interactive/dialogic)** where the teacher explores different points of views by engaging the students in sequences of turn-taking; **I-R-E-pattern (interactive/authoritative)** where the teacher moves towards the concept of proper orientation, and concludes the lesson using I-pattern (**non-interactive/authoritative**) to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-8.

The key features of this episode of the lesson are summarized in the table below.

Table 7-8: Episode 1.3.1. Key features of the teaching process

Teaching purpose	To explain that particles must collide in the correct orientation for an effective collision to occur
Content	Proper orientation of reacting particles
Communicative Approach	Non-interactive/authoritative; Interactive/authoritative; Interactive/dialogic; Interactive/authoritative and non-interactive/authoritative
Patterns of interaction	[I]-[I-R-E]-[I-R-F]-[I-R-E]-[I-R-F]-[I]
Forms of teacher intervention	Introducing ideas, exploring ideas, shaping students' ideas, marking ideas, evaluating ideas, echoing ideas, reviewing and summarising ideas

Commentary: It is observed from the above excerpt that the teacher used non-interactive/authoritative (NI/A), interactive/dialogic (I/D), interactive/authoritative (I/A) and non-interactive/authoritative (NI/A).

In this part of the lesson, the teacher prompted discussion on collision orientation of reacting particles when temperature is increased through a non-interactive/authoritative way reviewing, "when the temperature increases, particles get energy and collide...." He also interacted authoritatively by asking questions such as, "what do you think would happen?", and waiting for students to answer, using strategies such as evaluating and shaping ideas (turns 2 to 3). The teacher then interacted dialogically to develop ideas about collision orientation of reacting particles through exploring and working on students' ideas by asking a question and using illustrations (turns 3 to 5). He further interacted authoritatively by asking questions and waiting for students to answer, and used strategies such as evaluating, marking key ideas, sharing ideas and echoing to emphasize the

point/reinforce the correct answer/acknowledge an answer as acceptable, and make available to the whole class (turns 5-10).

He then presented a review and summary of the proper orientation in a non-interactive/authoritative way (turn 12).

7.7.12 For Episode 1.3.1 - Teaching proper orientation of reacting particles in NTA class: Patterns of interaction

Point to note, the excerpt presented is the only section and refers to the content we are discussing.

7.7.13 Staging the scientific story

In this part of the lesson, the teacher presented ideas of collision in a non-interactive- authoritative way, as follows:

7.7.14 Supporting students' internalisation

Table 7-9: For Episode 1.3.1. Whole classroom interaction

	Turn	Codes	Remarks
1T:	Ok, we are going to look at the rate at which chemical reactions occur. The rate of reaction depends on the frequency of collision between the reacting molecules. The greater the frequency of collision, the faster the reaction and the higher the rate. What this means is that for a reaction to place there must be collisions between the reacting molecules... more collisions more reactions...are we together?	I (i) I (s) I (cu)	
2SS:	yes (in chorus)	R(cu)	

Generated chain pattern of interactions: [I(i)-I(s)-I(cu)-R(cu)]

The generated chain patterns of interaction in this episode show the teacher used I-pattern linked to **non-interactive/authoritative**, and it shows no engagement of the students in the lesson. The forms of teacher intervention indicated in brackets are presented in table 7-10.

The key features of this episode of the lesson are summarized in the table below.

Table 7-10: For Episode 1.3.1. Key features of the teaching process

Teaching purpose	To explain that particles must collide in the correct orientation for an effective collision to occur
Content	Proper orientation of reacting particles
Communicative Approach	Non-interactive/authoritative
Patterns of interaction	No interaction
Forms of teacher intervention	Introducing ideas, summarising ideas and checking understanding

Commentary: It is observed from above excerpt that the teacher used non-interactive/authoritative (NI/A) in introducing and summarizing ideas about the proper orientation of reacting particles. It is evident that the teacher used a didactic approach and there was passiveness on the side of the students during the lesson. Thus, there were no teacher and student interactions enabled by questions, other than a brief move by the teacher to check whether students were following his explanations 'are we together? (Turn 1).

7.7.15 L1 Episode 1.3.2: Learning gains: Activation energy, E_a and chemical rate of reaction

In this area, the experimental (or C&TA) class performed better than the comparison (or NTA) class. For example, students in the C&TA class obtained 46.7%, compared to 11.5% in the NTA class, on the fact there must be a minimum amount of energy that reacting particles must have to form the activated complex and lead to reaction, and this energy is called activation energy, and that high activation energy leads to faster chemical reaction.

7.7.16 Episode 1.3.2: Teaching activation energy, E_a and chemical rate of reaction in C&TA class: Patterns of interaction

7.7.17 Staging the scientific story

In this session the teacher presented the relationship between temperature, activation energy, E_a and chemical rate of reaction using computer simulations. The teacher provided support and assisted students to see what happens to the rate when activation energy, E_a changes.

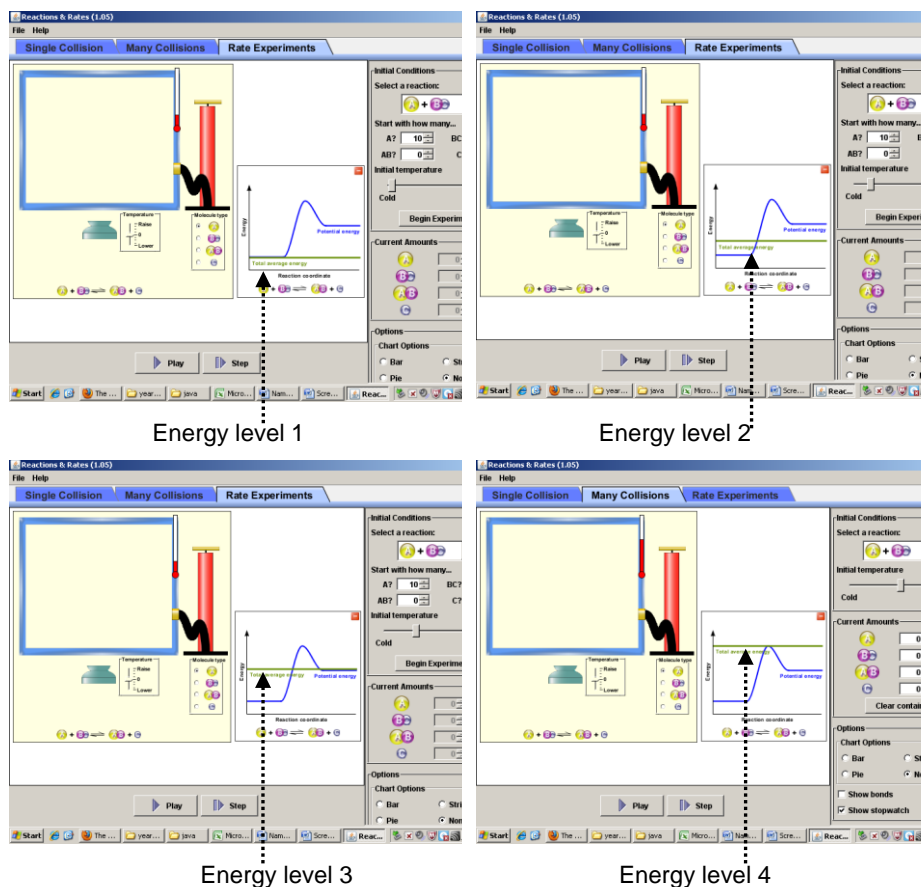


Figure 7-1: Simulations depicting different energy levels

The teacher used the energy level graph to explain the concept of activation energy, E_a . Explaining ‘there must be a minimum amount of energy that the reacting particles must have to form an activation complex and this minimum energy is called activation energy, E_a as follows:

7.7.18 Supporting students' internalisation

Table 7-11: Episode 1.3.2. Whole classroom interaction

Turn	Code s	Remarks
1T: ...ok now... let us look here, when we had the temperature is increased, the two are colliding at a high rate but when you had the temperature low, the collisions where there but less products were formed Note: when I am increasing the temperature, the energy also increases. If the energy does not go beyond activation energy, E_a , the reaction does not occur. When particles collide, they need enough energy for them to react and form a product. When atoms collide they must be properly oriented that is why in the simulations there were many collisions but very few products being form because they were not properly oriented. Therefore, in any chemical reaction, the collision may occur, but if the orientations are not very clear (properly aligned), the product will not occur (formed)	I(r) I(i) I(s)	

Generated chain pattern of interactions: [I(r)-I (i)-I(s)]

The generated chain patterns of interaction in this episode show that the teacher used I-pattern linked to **non-interactive/authoritative** and shows no engagement of the students in the lesson. The forms of teacher intervention indicated in brackets are presented in table 7-12.

The key features of this episode of the lesson are summarized in the table below.

Table 7-12: Episode 1.3.2. Key features of the teaching process

Teaching purpose	Explain the term activation energy and how this affects the number of effective collisions and formation of the products in a reaction.
Content	Activation energy, E_a
Communicative Approach	Non-interactive/authoritative
Patterns of interaction	No interaction
Forms of teacher intervention	Reviewing ideas, introducing ideas and summarising ideas

Commentary: The teacher began the lesson in a non-interactive/authoritative (NI/A) way, reviewing the effect of temperature and relating it to develop ideas about activation energy, E_a . He used strategies such as reviewing, introducing and summarising the key ideas to maintain understanding the activation energy, E_a concept.

The teacher used the computer simulated energy level graph to explain the concept of activation energy, E_a . The simulation clearly helped and brought out the idea of rising energy levels of the reactants visibly to students, and they would see that when the energy was high and reaction takes place within a short time.

7.7.19 For Episode 1.3.2: Teaching activation energy, E_a and chemical rate of reaction in NTA class: Patterns of interaction

The teacher used the activation energy diagram⁷ to explain the concept of activation energy, E_a and how it is related to chemical reaction as follows:

7.7.20 Supporting students' internalisation

Table 7-13: For Episode 1.3.2. Whole classroom interaction

	Turn	Codes	Remarks
1T:	Also for this collision to occur molecules must possess certain minimum energy called activation energy, E_a . This is the energy barrier which must be overcome for the reaction to take place. In reaction therefore, only those molecules moving at high speed have enough energy for collisions to result in a reaction. Is that clear?	I (i) I (s) I (cu)	
2SS:	yes (in chorus)	R (cu)	
3T:	The activation energy can be represented using an activation energy diagram. I am going to draw and please, I expect everyone to draw ...in your note books.	I(i) Cmm	

Generated chain pattern of interactions: [I (i)-I (cu)-R (cu)-I (i)-Cmm]

The generated chain patterns of interaction in this episode show that the teacher used I-pattern linked to **non-interactive/authoritative**, and shows no engagement of the students through explorative questions during the lesson. The forms of teacher intervention indicated in brackets are presented in table 7-14.

The key features of this episode of the lesson are summarized in the table below.

Table 7-14: For Episode 1.3.2. Key features of the teaching process

Teaching purpose	Developing ideas about activation energy; maintaining development of activation energy
Content	Activation energy, E_a
Communicative Approach	Non-interactive/authoritative
Patterns of interaction	No interaction
Forms of teacher intervention	Introducing ideas, summarising ideas, checking understanding and using classroom management moves

Commentary: In this session the teacher presented the relationship between activation energy, E_a and chemical rate of reaction in a more non-interactive/authoritative (NI/A) way introducing, developing and summarising ideas about activation energy, E_a . It is evident that the teacher used a didactic approach and there was passiveness on the side of students during the lesson. Thus, there

⁷ The activation energy diagram is presented in **Chapter Two (section 2.1.3, figure 2-2)**

was no teacher and students' interaction lead through questions, except a little move by the teacher to check whether students were following his explanations and the use of classroom management moves... "please, I expect everyone to draw in your note books" (Turn 3). This pattern of class interaction, non-interactive/authoritative (NI/A) in teaching and learning is aimed at making science points of view clear to the students.

7.7.21 L1 Episode 1.3.2: Learning gains: Effect of temperature on chemical rate of reaction

Another area where the C&TA (experimental) class performed statistically significantly better than the NTA (comparison) class was in the understanding of the effect of temperature on chemical rate of reaction. The students in the C&TA (experimental) class obtained 61 % compared to only 5.3 % in the NTA (comparison) class on- when temperature increases, the reactant molecules are moving rapidly and coming into contact with each other more often (frequent), this increases the reaction rate (this is collision theory).

7.7.22 Episode 1.3.2: Teaching effect of temperature on chemical rate of reaction in C&TA class: Patterns of interaction

7.7.22.1 Staging the scientific story

In the episode 1.3, the teacher put students in groups to explore the microscopic behavior of molecules when temperature is increased or decreased during a chemical rate of reaction. The teacher used worksheet activities to engage students in group discussions through non-interactive/dialogic (NI/D).

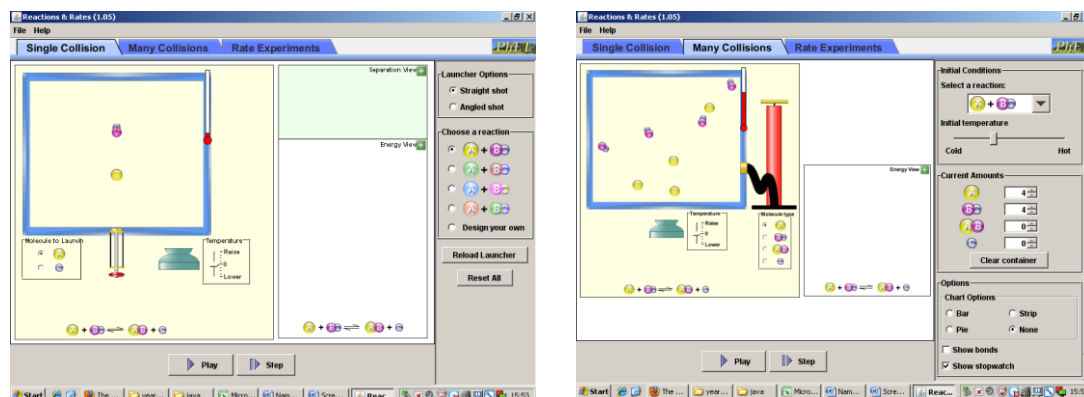


Figure 7-2: Simulations used to investigate effect of temperature on chemical rate of reaction (Source: PHET Sims)

The simulations were used to depict what happens to reacting particles when the temperature is increased or decreased.

Students worked in small groups, making predictions, testing, discussing and sharing before explaining their ideas to the whole class. The teacher circulated, providing support and assisting students to see what happens to the rate when temperature changes.

7.7.22.2 Supporting students' internalisation

During the whole interaction, the teacher gave opportunities to the different groups to share their ideas with the whole class. The teacher used this opportunity to address the students' alternative conceptions.

A student responded as part of a group to teacher prompts through a mixture of communicative approaches as follows:

Table 7-15: Episode 1.3.2. Whole class interaction

	Turn	Codes	Remarks
1T:	...so what happened when you increase temperature to the particles?	I (e)	
2S:	...the atoms move faster	R (aeq)	
3T:	...yes... ..	E(i)	
	Atoms are seen to be moving faster	Echoes	
	Can I hear from another group?	I (e)	
4S:	...there are a lot of collisions and faster movements of particles	R (aeq)	
5S:	I think molecules A and BC combined quickly to form AB and C	R (aeq)	
6S:	The reactants reduces very fast and the product is formed very fast	R (aeq)	
7T:	...yes	E(i)	
	Collisions, faster movement, products may be form ...	S(pi), S(i) & Echoes	
	So how does this affect rate of reaction?	I (e)	
8S:	...the reaction takes place in a shorter time...when temperature is increased, the atoms move faster...uhm thus combining faster	R (aeq)	
9T:	...ok	N (F)	Neutral feedback
	The atoms move faster...and combine faster...	M (i)	
	Someone from another group?	I (e)	
10S:	There is rapid movement and product C forms when A and B combine...that is rate of reaction and temperature increase respectively	R (aeq)	
11S:	...at high temperature molecules move faster...uhm molecules gain kinetic energy and collide	R (aeq)	
12T:	Yes,	E(i)	
	Molecules gain kinetic energy and collide.	M (i) & Echoes	
Session 2			
13T:	So What happen when you decrease temperature?	I (e)	
14S:	...the atoms move slower	R (aeq)	
15T:	...yes	E(i)	
	Atoms move slowly...	S(i)	
	Can I hear from other groups?	I (e)	
16S:	There are no collisions and ...uhm slow movements of particles	R (aeq)	
17S:	Molecules move slowly	R (aeq)	
18T:	OK...	N	Neutral

			feedback
	So how does this affect rate of reaction?	I (e)	
19S:	...the reaction takes place...in a long time...uhm meaning the atoms take long to combine	R (aeq)	
20T:	... yeah...	E(i),	
	Atoms take long to collide...	Mi	'Mi' Marking key idea(s)
	Can we hear from other members in other groups?	I (e)	
21S:	There is slow movement and also no collision present...uhm no product formed...rate of reaction is slow due to decrease in temperature.	R (aeq)	
22S:	Molecules move slowly ...coz the kinetic energy decreases.	R (aeq)	
23S:	The molecules start moving slowly because the molecules loose kinetic energy	R (aeq)	
24T:	... Yeah... ..	E(i)	
	There is less collision due to low kinetic energy	S(pi) & S(i)	
	Any group?	I (e)	
25S:	Particles move slowly causing the reaction to take place slowly	R (aeq)	
26S:	Molecules move slowly and collision decreases due to decrease in energy	R (aeq)	
27T:	... Yeah... ..	E(i)	
	There is less collision due to low kinetic energy	Spi & S(i)	
	Any group?	I (e)	
28S:	Particles move slowly causing the reaction to take place slowly	R (aeq)	
29S:	Molecules move slowly and collision decreases due to decrease in energy	R (aeq)	
30T:	...less collision. ...ok now let us look here, when we had the temperature is increased, the two are colliding at a high rate but when you had the temperature low, the collisions were there but less products were formed When the temperature is increased, the particles gain kinetic energy, they start to move, as they move, they happen to collide, as you continue to increase the temperature collision also increases...the number of collisions will also increase, when the number of collisions increases and the particles are properly oriented, then the rate at which the products are formed also does....what? increases Therefore, in explaining, we are saying...the particles gain more kinetic energy, collisions increases, particles collide with each other and as they collide with each other, they are able to form the product in a very short time.	E(i), I(r) I(s)	

Generated chain patterns of interaction: [[I (e)-R (aeq)-E (i)-Echoes]- [I (e)-R (aeq)-R (aeq)-R (aeq)-E (i)-Echoes]-[I (e)-R (aeq)-N(F)-M (i)]-[I (e)-R (aeq)-R (aeq)-R (aeq)-Ev-S (i)]-[I (e)-R (aeq)-R (aeq)-N(F)]-[I (e)-R (aeq)-Ev-M (i)]-[I (e)-R (aeq)-R (aeq)-R (aeq)-E(i)-S (pi) & S (i)]-[Ie-R (aeq)-R (aeq)-Ev-S (pi) & S (i)]-[I (e)-R (aeq)-R (aeq)-E(i)] -[I (r)-I (s)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through a communicative approach 'cycle': **I-R-E-pattern (interactive/authoritative)** where the teacher's move was towards the effect of temperature on chemical rate of reaction; **I-R-F-pattern (interactive/dialogic)**

where the teacher explores different points of views by engaging the students in sequences of turn-taking and concluded using I-pattern (**non-interactive/authoritative**) to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-16

The key features of this episode of the lesson are summarized in the table below.

Table 7-16: Episode 1.3.2. Key features of the teaching process

Teaching purpose	To explain how varying the temperature affects the rate of reaction using collision theory
Content	Effect of temperature on chemical rate of reaction
Communicative Approach	Interactive/authoritative; Interactive/dialogic; Interactive/authoritative; Interactive/dialogic; Interactive/authoritative and Non-interactive/authoritative
Patterns of interaction	[I-R-E]-[I-R-E]-[I-R-F]-[I-R-E]-[I-R-F]-[I-R-E]...-[I]
Forms of teacher intervention	Exploring ideas, echoing, marking key ideas, selecting ideas, shaping ideas, evaluating, reviewing and summarising ideas

Commentary: In this part of the lesson, the teacher prompted discussion on behavior of reacting particles when temperature is increased or decreased through interactive/authoritative (I/A), interactive/dialogic (I/D), interactive/authoritative (I/A), interactive/dialogic (I/D), and presented a summary of the effect of temperature on chemical rate of reaction in a non-interactive/authoritative (NI/A) way.

He also interacted authoritatively to explore and work on students' ideas by asking a question - '...so what happened when you increased temperature to the particles?' (turns 1-7) and waiting for students to answer; he used strategies such as evaluating, sharing ideas and echoing to reinforce the correct answer/acknowledge of an answer as acceptable to the whole class.

The teacher then interacted dialogically to develop ideas about the effect of temperature on rate of reaction exploring and working on students' ideas by asking a question - 'so how does this affect rate of reaction?' (turns 7-9). He used strategies such as marking key ideas and neutral feedback to encourage students to think deeply about their responses during the interaction.

The teacher further interacted authoritatively to explore and work on the student's misconception that 'there is rapid movement and product C forms when A and B combine...*that is rate of reaction and temperature increase respectively*' (turn 10). He used strategies such as evaluating, and shaping ideas (turns 11-13).

There was further use of interactive/dialogic and neutral feedback to encourage students to think deeply about their responses during the interaction (turns 14-16)

The teacher's focus was on reaching the scientific view as he continued to interact authoritatively (turns 16-26). He used strategies such as motivation, marking key ideas and selecting parts of students' ideas to emphasize key points, shaping ideas and evaluating students' ideas.

The teacher concluded this lesson by making a review and summarising ideas on how temperature affects rate of reaction in a non-interactive/authoritative way (turn 28).

7.7.23 For Episode 1.3.2: Teaching effect of temperature on chemical rate of reaction in NTA class: Patterns of interaction

7.7.24 Staging the scientific story

In this session of the lesson, the teacher prompted discussion on how temperature affects the rate of reaction in an interactive authoritative (I/A) and presented a summary on the effect of temperature on chemical rate of reaction in a non-interactive/authoritative way as follows:

7.7.25 Supporting students' internalisation

Table 7-17: For Episode 1.3.2. Whole classroom interaction

Turn	Codes	Remarks
1T: We want to begin with by looking at temperature. How does temperature affect the rate of reaction? Can I have someone to explain? Yes Shawa...	I (i) I (e)	
2S: The rate of a chemical reaction increase with temperature	R (aeq)	
3T: The rate of a chemical reaction increase with what...?	I (e)	
4SS: Temperature (chorus)	R (aeq)	
:		
5T: Not with the temperature but with increase in temperature	E(i) & S(i)	
So the rate of a chemical reaction increases with increase in temperature. We will begin with note in our next lesson, ok.	I (s) I (i)	

Generated chain patterns of interaction: [I (i)]-[I (e)]-R (aeq)-I (e)-R (aeq)-E (i)]-[I (s)]-I (i)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through I-pattern (**non-interactive/authoritative**) when the

teacher was introducing the lesson; **I-R-F-pattern (interactive/dialogic)** where the teacher explored different points of views by engaging the students in sequences of turn-taking; **I-R-E-pattern (interactive/authoritative)** where the teacher's move was towards the effect of temperature on chemical rate of reaction; and concluded the lesson using **I-pattern (non-interactive/authoritative)** to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-18.

The key features of this episode of the lesson are summarized in the table below.

Table 7-18: For Episode 1.3.2. Key features of the teaching process

Teaching purpose	To explain how varying the temperature affects the rate of reaction using collision theory
Content	Effect of temperature on chemical rate of reaction
Communicative Approach	Non-interactive/authoritative; Interactive/authoritative and Non-interactive/authoritative
Patterns of interaction	[I]-[I-R-E]-[I]
Forms of teacher intervention	Introducing, exploring, evaluating, shaping ideas, sharing ideas and summarising

Commentary: It is observed from above excerpt that the teacher used an interactive/authoritative (NI/A) approach to introduce and explore students' ideas by asking a question - '...so how does temperature affect rate of reaction?' (turn 1) and waiting for students to answer. He then used strategies such as evaluating, shaping ideas, sharing ideas and making it available to the whole class.

The teacher concluded this lesson by summarising ideas on how temperature affects rate of reaction in a non-interactive/authoritative way (turn 5).

7.8 L2 Episode 2.1 - 2.2: Learning gains: Graphical interpretation of how temperature affect chemical rate of reaction

In this area, the C&TA (experimental) class performed better than the comparison (or NTA) class. For example, students in the C&TA (experimental) class obtained 76.2 % compared to 58 % in the NTA (comparison) class, on the fact that when the temperature increases, the reaction takes less time or a shorter time to come to a stop.

7.8.1 Episode 2.1 - 2.2: Teaching graphical interpretation of relationship between temperature and time of chemical reaction in C&TA class: Patterns of interaction

7.8.2 Episode 2.1.1: Staging the scientific story

In this lesson, the teacher engaged students in groups to investigate the effect of temperature using a solution of sodium thiosulphate and HCl. He performed a demonstration to show students the experimental procedures, determination of plot scales, reading thermometers and recording a stop clock through a non-interactive/authoritative (NI/A) approach. Students in groups used worksheet activities to discuss through non-interactive/dialogic (NI/D) and present their results.

Students in small groups performed the experiment, discussed their results in groups and plotted graphs for temperature against time and temperature against rate. The teacher provided support through probing, scaffolding and helping them to make sense of, and internalize those ideas, as students worked in their groups.

7.8.3 Supporting students' internalisation

During whole interaction, the teacher gave opportunities to the different groups to share their ideas with the whole class. The teacher used this opportunity to address the students' alternative conceptions.

Students responded as part of a group to teacher prompts through a mixture of communicative approaches as follows:

Table 7-19: Episode 2.1-2.2. Whole class interaction

	Episode 2.1.2: Turn	Codes	Remarks
1T:	So why does the cross disappear?	I (e)	
2S:	Uhm the cross disappears because of the formation of the yellow precipitate of sulphur	R (aeq)	
3T:	Yeah...	E(i)	
	Formation of yellow precipitates of sulphur	Echoes	
	...anything else?	I (e)	
4S:	The reaction takes place; it forms yellow precipitate which abstracts the cross	R (aeq)	
5T:	Yeah... the reaction takes place, forms yellow precipitate which abstracts the cross	E(i) & Echoes	
	...anything else?	I (e)	
6S:	I think, it is due to the change in colour of the solution after reaction	R (aeq)	
7T:	OK well,	E(i)	
	A reaction occurs; yellow precipitate of sulphur formed abstracts the cross.	I (s)	
	Episode 2.2: Turn		
8T:	So what is the shape of your graph?	I (e)	

9S:	It is a straight line	R (aeq)	
10T:	Mmmm... ok	N (F)	
	Anyone with a curve? is the slope a negative or positive?	I (e)	
11SS:	Positive (chorus)	R (aeq)	
12T:	Positive	E(i) / Echoes	
	So how do we interpret the graph? yes Linda	I (e)	
13L:	Temperature increases with rate	R (aeq)	
14T:	Thank you Linda...is it the temperature affecting the rate or the rate affecting the temperature the language matter!	M (i), I (e)	
15L:	As temperature increases, the rate will also increase	R (aeq)	
16T:	.very good...	E(i)	
	As the temperature increases, the rate also increases.	I (s)	

Generated chain patterns of interaction: [I(e)-R(aeq)-E(i)-Echoes]-[I(e)-R(aeq)-E(i) & Echoes-I(e)-R(aeq)-E(i)]-[I(s)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-E(i)/Echoes]-[I(e)-R(aeq)- M(i)-I(e)-R(aeq)-E(i)]-[I(s)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through an **I-R-E**-pattern (**interactive/authoritative**) where the teacher's move was towards the concept of formation of sulphur when HCl and sodium thiosulphate are reacted; **I-R-F**-pattern (**interactive/dialogic**) where the teacher explores different points of views on graphical interpretation of the effect of temperature on chemical rate of reaction by engaging the students in sequences of turn-taking. The pattern is repeated through the episode and concludes the lesson using **I**-pattern (**non-interactive/authoritative**) to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-20

The key features of this episode of the lesson are summarized as in the table below.

Table 7-20: Episode 2.1-2.2. Key features of the teaching process

Teaching purpose	To interpret graphically how temperature affects rate of reaction
Content	Graphical interpretation of the relationship between temperature and time/rate of reaction
Communicative Approach	interactive authoritative; Non-interactive authoritative Interactive/dialogic; interactive authoritative; Interactive/dialogic; interactive authoritative; Interactive/dialogic; and Non-interactive authoritative
Patterns of interaction	[I-R-E]-[I]-[I-R-F]-[I-R-E]-[I-R-F]-[I-R-E]-[I]
Forms of intervention	Exploring, echoing, evaluating marking key ideas and summarising key ideas

Commentary: In this part of the lesson, the teacher used an interactive/authoritative approach to explore the students' ideas why a solution gets cloudy and the cross disappears (turn 1). He then engages the students through an interactive/dialogic way to explore and work on students' ideas by asking a question

- 'so what is the shape of your graph?' (turn 8), and waiting for students to answer. He then used strategies such as evaluating, echoing and neutral feedback to encourage students to think about their responses during the interaction. The teacher then interacted authoritatively (I/A) to explore and work on the students' ideas - 'anyone with a curve? Is the slope a negative or positive?' (turn 10). He used strategies such as evaluating, and shaping ideas echoing to reinforce the correct answer and acknowledge an answer as acceptable and making it available to the whole class (turn 12).

The teacher further interacted authoritatively to develop ideas about interpreting a graph of temperature against time of reaction exploring and working on students' ideas by asking a question - 'so how do we interpret the graph? Yes Linda' (turn 12). He used the 'marking key ideas' strategy, for example, Linda's response which was incorrect 'temperature increases with rate' (turn 14) was marked and initiated a confirmatory exchange (turn 14) which served the two functions of evaluating and disapproving the student's response which helped Linda to rethink her response correctly (in turn 15).

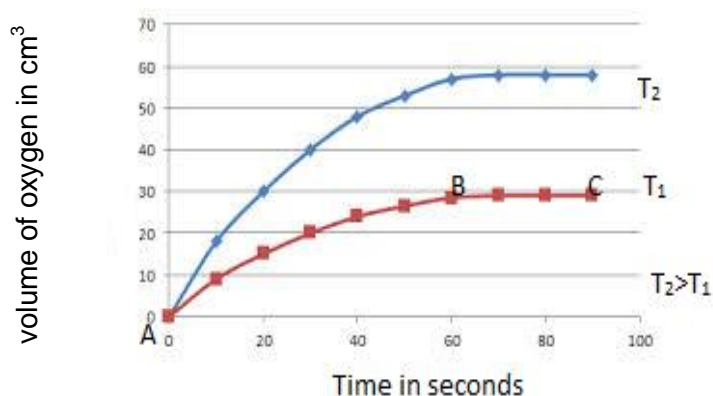
The teacher concluded this lesson by summarising ideas on how temperature affects rate of reaction in non-interactive/authoritative (NI/A) way (turn 16).

7.8.4 For Episode 2.1 - 2.2: Teaching graphical interpretation of relationship between temperature and time of chemical reaction in NTA class: Patterns of interaction

7.8.5 Staging the scientific story

In this lesson, the teacher used a graph of volume of oxygen produced with time to explain the relationship between temperature and rate of reaction.

A graph of volume of oxygen produced with time



7.8.6 Supporting student internalisation

The teacher conducted the teaching as follows:

Table 7-21: Episode 2.1-2.2. Whole classroom interaction

Turn	Codes	Remarks
1T: Draw the diagram, we shall use graph to show the volume of oxygen being produced at different time as time goes. This is the time in minutes Hurry up with the drawing [Supervises student work as the draw the graph from the blackboard] What is this space for...you need to be organized if you are to work with me in my class? I want you to be serious! Please, hurry up and we continue...you are a bit slow! So... has Everyone finishes the graph?	Cmm Cmm I (cu)	
2SS: Replies in chorus, 'yes'	R (cu)	
3T: So when you look at that graphsome of you have not drawn it very well and you may not get the explanation... I want you to be attentive These are two different experiments They are saying in the first experiment, when we carried out the first experiment, we are plotting volume of oxygen Evolved in seconds...ok? We will use the minutes because, seconds look very small When you look at the temperatures, t_1 and t_2 we find that at t_2 after 2 minutes we had already acquired 800 cm^3 of oxygen but as we carried out another experiment at t_1 we were using 4 minutes. So if I pose a question, which one was at high temperature?	Cmm I(i) I (e)	
4S: t_2 is higher	R (aeq)	
5T: Do we all agree...is it clear? So that is why we are saying $t_2 > t_1$. It that clear? So they will ask you to explain the shape of the curve... they will ask you why the curve goes flat? That means the whole of hydrogen peroxide has decomposed. Is that clear? He pauses to allow students digest what he has just explained. [Teacher carries on with interpretation] We have point A, B and C they will ask you to explain the shape of the curve. So the volume of oxygen produced or Evolved increases along AB as the reaction progresses. Along BC the volume of oxygen remains constant due to the completion of the reaction What do I mean? It means that the reaction has been completed...it that clear? That is why like we cannot produce more oxygen because the reaction has stopped, Hydrogen peroxide is finished. Assuming initial we are decomposing hydrogen peroxide to form oxygen when the experiment went... on as time goes, the oxygen increases... t_4 the volume of oxygen is only 800 cm^3 that is why the curve went flat....then they ask you why? It comes flat when all hydrogen has decomposed. I hope we are all together	E(i) / Icu I (cu) I (i) I (s) I (cu)	
6S: Replies in chorus, 'yes Sir'	R (cu)	
7T: Ok! Let write , dictates notes Points to note about the graph The volume of oxygen produced or Evolved increases along A, B & C...AB. Is that clear? I think you see this ...is it clear? As the reaction progresses along BC, we are looking at that a long BC...the volume of oxygen remains constant.....the volume of oxygen remains constant.....the volume of oxygen remains constant...due to completion of the reaction... due to completion of the reaction... due to completion of the reaction... What do I mean by that? What do I mean by that? It means reaction has been completed! Is that clear...and that is why we cannot produce more oxygen because the reaction has stopped...that means hydrogen peroxide is finished...that is what I told you assuming ...I took you back to the basic idea of chemistry...at the start you cannot see anything but as time goes you begin see the curve rising. The volume of oxygen remains constant due to the completion of the	Cmm I(i) & Icu I(i) I (s) & I	

	reaction At temperature t_1 the maximum volume of oxygen is 800 cm^3 is got after 4 minutes while at high temperature t_2 the volume of oxygen, 800 cm^3 only obtained after 2 minutes. So the decomposing of hydrogen peroxide is found to be faster at higher temperature... So are we ok with that?	(cu)	
8S:	Yes...in chorus	R (cu)	
9T:	That means you can be fully able to explain this factor		

Generated chain patterns of interaction:[Cmm-Cmm-I(cu)-R(cu)-Cmm-I(s)]-[I(e)-R(aeq)-E(i)/I(cu)]-I(cu)-I(i)-I(s)-I(cu)-R(cu)-Cmm-I(i)&I(cu)-I(i)-I(s)& I(cu)-R(cu)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through I-pattern (**non-interactive/authoritative**) when the teacher was introducing the lesson. There was limited use of I-R-E-pattern (**interactive/authoritative**) where the teacher's move was towards the graphical interpretation of effect of temperature on chemical rate of reaction; and concludes the lesson using I-pattern (**non-interactive/authoritative**) to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-22.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-22: Episode 2.1-2.2. Key features of the teaching process

Teaching purpose	To interpret graphically how temperature affects rate of reaction
Content	Graphical interpretation of the relationship between temperature and time/rate of reaction
Communicative Approach	Non-interactive/ authoritative; Interactive/authoritative and Non-interactive/ authoritative
Patterns of interaction	[I]-[I-R-E]-[I]
Forms of teacher intervention	Introducing , with little exploring of ideas, checking understanding, using classroom management moves and summarising ideas

Commentary: It is observed from the above excerpt that the teacher used a non-interactive/authoritative (NI/A) approach in introducing and developing ideas about the graphical interpretation of the relationship between temperature and time of chemical reaction to come to a stop or finish. It is evident that there was no teacher and student interaction lead through questions, except the use of classroom management moves, for example 'hurry up with drawing the graph', checking whether students had completed drawing the graph (turn 1).

The teacher also made a brief attempt of using interactive/authoritative (I/A) to explore students' ideas by posing a question 'which one was at high temperature' and waiting for students to answer (turns 3-4). He used an evaluative strategy as a

follow up feed, 'do we all agree' (turn 5) to make the ideas available to the whole class.

For the remaining part of this lesson the teacher used a didactic approach and there was passiveness on the side of students during the lesson. Thus, there was no teacher and student interaction lead through questions, except a little move by the teacher to check whether students were following his explanations (turns 5-9).

It is evident from the excerpt that the non-authoritative approach used shows there was poor engagement as chances for students to speak out their ideas, to think about what the teacher presented and to exercise more control over the talk and learning were limited. This was due to the strong transmission of ideas from the teacher and limitation in elaborative questions for the students to explain their views. It happened largely also because the teacher assigned the role of explanation and giving judgment to himself and restricted the role of students in the lesson.

7.9 L3 Episode 3.1: Handing over responsibility to students in C&TA class (computer modelling using spreadsheets)

In this episode, the laboratory investigation of the effect of temperature, the C&TA teacher substituted the real experimental data with virtual environmental data using computer spreadsheets as a modeling tool. The teacher interacted authoritatively (I/A) showing the students how rate of reaction changes temperature when it is altered using computer spreadsheets. He then engaged students in group discussions through a non-interactive/dialogic (NI/D) approach to make predictions, hypothesize, or ask 'what if?' and/or 'what about?' questions, and analyse results by changing temperature value while they observe its effect on reaction time or rate through graphical display.

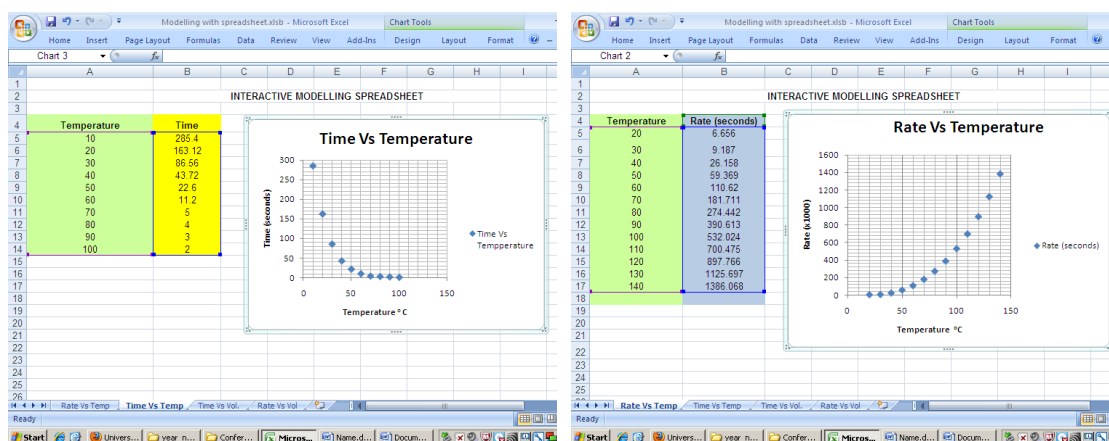


Figure 7-3: Graphical interactive spreadsheets for investigation of effect of temperature on chemical rate of reaction (Source: designed & developed by Moses Odongo, researcher)

Students responded as part of a group to teacher prompts through a mixture of communicative approaches as follows:

Table 7-23: Episode 3.1. Whole classroom interaction

Turn	Codes	Remarks
1T: So...how does time change when you increase the reaction temperature? Can someone explain?	I (e)	
2S: the time decreases	R (aeq)	
3T: Yes	E(i),	
Time decreases with increase in temperature	Echoes	
And how does the temperature graphically change with time can you explain this?	I (e)	
4S: As the temperature increases, the time for the reaction reduces...decreases	R (aeq)	
5T: Good	E(i)	
Also note that the shape of the graph remains the same whether you carry out your experiment beginning with higher temperatures and concluding with the lower temperature or you start with lower temperature and increasing temperatures. The plot of your graph show that the time against temperature graph is still a curve depicting increase in temperature leads to decrease in time for the reaction. And the plot of 1/time (rate) against temperature shows that rate increases with increase in the temperature of the reactants	I(r) Is	

Generated chain patterns of interaction:

[I(e)-R(aeq)-E(i)-Echoes]-[I(e)-R(aeq)-E(i)]-[I(r)-I(s)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through the **I-R-E**-pattern (**interactive/authoritative**) where the teacher's move was towards the graphical interpretation of effect of temperature on chemical rate of reaction; and concluded the lesson using **I**-pattern (**non-interactive/authoritative**) to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-24.

The key features of this episode of the lesson are summarized in the table below.

Table 7-24: Episode 3.1. Key features of the teaching process (Handing over responsibility to students)

Teaching purpose	To interpret graphically how temperature affects rate of reaction
Content	Graphical interpretation of the relationship between temperature and time/rate of reaction
Communicative Approach	Interactive/authoritative and Non-interactive / authoritative
Patterns of interaction	[I-R-E]...-[I]
Forms of teacher intervention	Teacher talking with individual groups, exploring ideas, echoing, reviewing and summarising key ideas

Commentary: In this part of the lesson, the teacher used non-interactive/authoritative; non-interactive/dialogic; interactive/authoritative and non-interactive/authoritative. During whole class session, he used an interactive authoritative approach in guiding students to apply and expand their ideas about the relationship between temperature and time/rate of reaction by asking a question - 'so...how does time change when you increase the reaction temperature? Can someone explain?' (turns 1-5) and waiting for students to answer. He used strategies such as evaluating, reviewing ideas, sharing ideas and echoing to reinforce the correct answer and making these ideas available to the whole class. He then presented a summary of the relationship between temperature and time or rate of chemical rate of reaction in a non-interactive/authoritative (NI/A) way (turn 5). Furthermore, the use of computer modelling using spreadsheets was found to be quite effective, and helped to engage in hypothesizing, or asking 'what if?' and/or 'what about?'. This helped in enhancing students' understanding of the relationship between temperature and time or rate of chemical reaction.

7.9.1 For L3 Episode 3.1: Handing over responsibility to students in NTA class

In this episode, the teacher carried out an experimental demonstration on how to investigate the effect of temperature using a solution of sodium thiosulphate and HCl. He performed a demonstration to show students the experimental procedures, determination of plot scales, reading thermometers, reading and recording a stop clock as follows:

Table 7-25: For Episode 3.1. Whole classroom interaction

Turn		Codes	Remarks
1T:	So last time we looked at effect of temperature on chemical rate of reaction and we said we can determine rate decomposing hydrogen peroxide and then measure the volume of oxygen gas produced / Evolved at time interval. Today we want to conduct an experiment to determine rate of reaction using by reaction two chemicals...we shall use a solution of sodium thiosulphate and Hydrochloric acid. Both sodium thiosulphate and hydrochloric acid are colourless liquids as you see, do we all see?	I(r) I(i) I (cu)	
2S:	Yes in chorus	R (cu)	
3T:	Now when the two are added or mixed, the resultant solution goes cloudy. This because when they react...when they react...they form sodium chloride, water, sulphur dioxide and sulphur. This is shown by this reaction: (transcribes equation on board) [Sodium sulphate + hydrochloric acid \longrightarrow Sodium chloride + water + sulphur dioxide + sulphur] [Teacher proceeds with explanation] The sulphur produced makes the solution appears cloudy. It takes some time to for the sulphur to appear and its appearance depends on the temperature at which the reaction is taking place. That means...that means we can be able to determine the rate at which it appears at different temperatures and compare temperature at which it takes a shorter time. Are we together?	I (i) I(cu)	
4SS:	Yes sir... (Chorus)	R (cu)	
5T:	Ok ...but before we do that...we shall need to have a thermometer to measure the temperatures. We will also need the stop clock to measure ...measure what? ... The time the sulphur will take to appear. We shall also need measuring cylinders and beakers...I hope we are together. So let's take down these procedures write down the procedures on the blackboard [teacher gives directive] Procedure: Mark a cross with blue or black ink on a piece of paper. Measure 50 cm ³ of 0.2M sodium thiosulphate solution into 250 cm ³ beaker. Add 10 cm ³ of 2M hydrochloric acid to the thiosulphate and at once start the stop clock. Shake gently for the solutions to mix well and place over the cross. Watch the cross through the solution from above the beaker. Stop the clock when the cross disappears. Record the time taken for the yellow precipitate of sulphur to appear in the table below. Repeat the experiment with different temperatures as indicated in the table. So you are required to follow these procedures to carry out this experiment and answer the questions that follow. I expect you to hand in your work for making..... Questions [Write an ionic equation for the reaction above Plot a graph of rate against temperature (the rate of a reaction may be found by dividing 1 by the time taken (1/t) From the graph, work out the rate of reaction or calculate the gradient (slope) of the graph and state its units.]	I (i) I (s) Cmm	5T:

Generated chain patterns of interaction: [I(r)-I(i)-I(cu)-R(cu)-I(i)-I(cu)-R(cu)-I(i)-I(s)-Cmm]

The generated chain patterns of interaction in this episode show that the teacher used I-pattern linked to **non-interactive/authoritative** and it shows no engagement of the students through explorative questions during the lesson. The forms of teacher intervention indicated in brackets are presented in table 7-26.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-26: For Episode 3.1 Key features of the teaching process (handing over responsibility to students)

Teaching purpose	To interpret graphically how temperature affects rate of reaction
Content	Graphical interpretation of the relationship between temperature and time/rate of reaction
Communicative Approach	Non-interactive/ authoritative
Patterns of interaction	No interaction
Forms of intervention	Reviewing, introducing , checking understanding, using classroom management moves and summarising ideas

Commentary: It is observed from the above excerpt that the teacher used non-interactive/authoritative (NI/A) guiding students to apply and expand their ideas about the relationship between temperature and time/rate of reaction. It is evident that the teacher used a didactic approach and there was passiveness on the side of students during the lesson. Thus, there was no teacher and student interaction lead through questions, except a little move by the teacher to check whether students were following his explanations and the use of classroom management move for example, ‘take down these procedures’, and ‘I expect you to hand in your work for marking’ (turn 5).

7.10 L4 Episode 4.1 Learning gains: Effect of concentration on chemical rate of reaction

Another area where the C&TA (experimental) class performed statistically significant better than the comparison class, was the understanding of effect of concentration on chemical rate of reaction. Students in the C&TA class obtained 27.6% compared to only 1.5% in the NTA (comparison) class on the idea that increasing concentration of a reactant or substance in solution means that there will be more particles per dm³ of that substance. That is, increasing concentration of reactant simply means there are more molecules coming into contact with each other more often, which increases the reaction rate (this is collision theory).

7.10.1 Episode 4.1. Teaching effect of concentration on chemical rate of reaction in C&TA class: Patterns of interaction

7.10.2 Staging the scientific story

In this lesson, the teacher began by recapping the previous lesson. He pointed out to the class that ‘we have dealt fully with temperature we will look at all these factors (pressure, surface area, catalysis and concentration) but for today, we will look at concentration’.

The teacher then introduced the concentration concept authoritatively by stating that 'increasing the concentration of the substance in solution means that there will be more particles per dm^3 of that substance'.

The teacher then observed that when investigating the effect of one factor, all other factors must be kept constant.

Simulations with fewer to many reacting particles

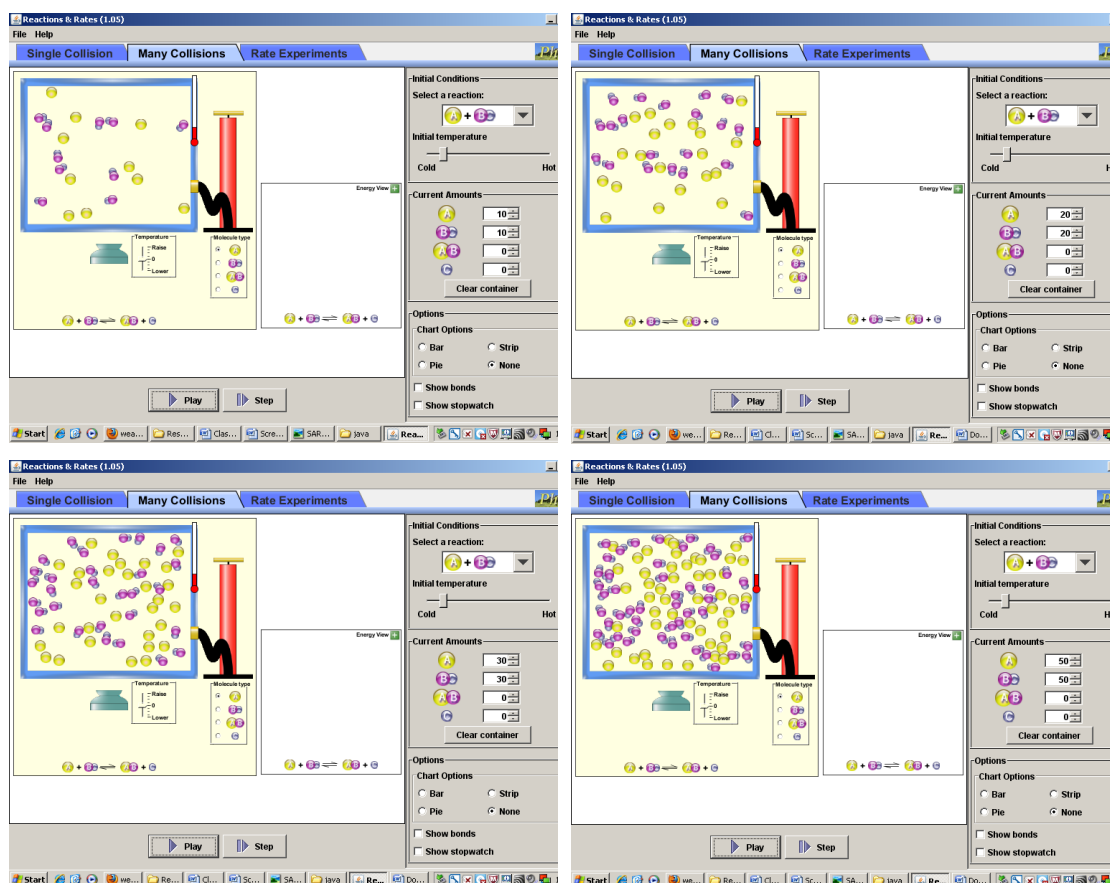


Figure 7-4: Simulation used to investigate effect of concentration on chemical rate of reaction (source: PHET)

The teacher put students in groups to explore the microscopic behavior of molecules using a computer simulated model when the concentration of the reactants are increased or decreased during a chemical rate of reaction.

Students worked in small groups, making predictions, testing, discussing and sharing their ideas before explaining them to the whole class. The teacher used worksheet activities to engage students in group discussions through non-interactive/dialogic (NI/D). The teacher provided support through probing,

scaffolding and helping them to make sense of, and internalize, those ideas as students worked in their groups.

7.10.3 Supporting students' internalisation

During whole interaction, the teacher gave opportunities to the different groups to share their ideas with the whole class. The teacher used this opportunity to address the students' alternative conceptions.

Students responded as part of a group to teacher prompts through a mixture of communicative approach cycles as follows:

Table 7-27: Episode 4.1. Whole class interaction

*Note: *Highlighted statements show students' misconception*

	Turn	Codes	Remarks
1T:	...so what happened when you increase concentration of the particles	I (e)	
2S:	the rate of reaction is high and collision is high	R (aeq)	
3T:	Yes...	N (F)	Neutral feedback
4S:	It increases the collision between the particles and formation of products	R (aeq)	
5S:	The rate of reaction of the molecules is high since they are more	R (aeq)	
6S:	The particles gain kinetic energy causing them to move rapidly and collisions increase hence, an increase in the rate of reaction	R (aeq)	
7S:	The particles are seen moving rapidly at a higher rate and colliding with each other very faster [quickly]	R (aeq)	
8S:	It caused increase in the collision of particles hence increasing the rate of reaction, even more products are formed	R (aeq)	
9S:	Increase in concentration increases the number of particles	R (aeq)	
10T:	...yeah...	N (F)	
	So how does this affect rate of reaction?	I (e)	
11S:	It increases the number of particles per unit volume...hence increase in collision and the rate of reaction is increased	R (aeq)	
12T:	Yeah....	N (F)	
13S:	Increase in concentration causes increase in the number of particles which reduces the distance between the particles which increase collision per unit time hence leading to increase in the rate of reaction	R (aeq)	
14T:	...ok.	N (F)	
	Let me hear from Abonyo's group	I (e)	
15S:	It leads to high rate of reaction, the molecules move at a faster rate colliding, hence the products are formed in a short period of time	R (aeq)	
16S:	The molecules are seen to be moving at a high speed due to high [increase] concentration	R (aeq)	
17T:	...thank you so much...	M	
	yes another group	I (e)	
18S:	When the concentration is high, the number of particles are high and more kinetic energy is gained causing the particles to move rapidly increasing collision, hence an increase in the rate of reaction	R (aeq)	
19T:	OK	N (F)	
	... another group	I (e)	
20S:	The more crowded the particles are, the more often they collide with each other, based on the kinetic theory, since they gain more kinetic energy hence increasing the rate of reaction	R(aeq)	
21T:	can we hear from another group...yes	I (e)	
22S:	Leads to particles gaining kinetic quickly and move faster since they are many, hence collision occurs and the rate of reaction increases	R(aeq)	
23T:	Your group please...	I (e)	
24S:	When concentration increases the numbers of particles increase	R (aeq)	

	and collide with each other faster and more collisions lead to faster rate of reaction		
25T:	So...What when you decrease concentration of the particles?	I (e)	
26S:	The rate of reaction is low	R (aeq)	
27T:	...nods...	N (F)	
	Yes...any else?	I (e)	
28S:	It decreases the collision between the particles and formation of products	R (aeq)	
29S:	The rate of reaction of the molecules is low since they are few	R (aeq)	
30S:	The molecules are seen to be moving at low speed since they are little due to decrease in concentration.	R (aeq)	
31S:	The particles lose kinetic energy causing them to move slowly and collision decreases hence a decrease in the rate of reaction	R (aeq)	
32S:	The particles collide at a low rate since they are few in number and have relatively bigger spaces in between them making them move randomly	R (aeq)	
33S:	It causes decrease in the collision of particles hence low rate of reaction, hence less products are formed	R (aeq)	
34S:	Decrease in concentration decreases the number of particles	R (aeq)	
35T:	OK...	N (F)	Neutral feedback
	So how does this affect rate of reaction?	I (e)	
36S:	...reduces the number of particles per unit volume hence decrease in collision and the rate of reaction	R (aeq)	
37T:	Yeah...	N (F)	
	Another group	I (e)	
38S:	Causes decrease in number of particles which the distance between the particles which reduces collision per unit time hence leading to a decrease in the rate of reaction.	R (aeq)	
39T:	...let's hear from another group	I (e)	
40S:	As the concentration decreases, the rate of reaction also decreases. The molecules move at a relatively slow velocity hence the collision rate is low leading to a slower rate of product formation	R (aeq)	
41T:	Another group...	I (e)	
42S:	The number of molecules in the reaction decreases. This decreases kinetic energy of the molecules thus decreasing the collisions and rate of the reaction per second.	R (aeq)	
43T:	Ok....	N (F)	
44S:	When the concentration is low, the number of particles is less and kinetic energy gained causing the particles to move slowly decreasing collision, hence a decrease in the rate of reaction.	R (aeq)	
45T:	...uhm!?	N (F)	
46S:	The less crowded the particles are, the less they are to collide with each other since they have low kinetic energy hence decreasing the rate of the reaction	R (aeq)	
47T:	...ok...	N (F)	
	Can we hear from another group	I (e)	
48S:	It leads to the particles taking long to gain kinetic energy since they are few hence particles move relatively slowly therefore collision takes long to occur hence reaction rate decreases.	R (aeq)	
49T:	Ok... any group...yes	N (F) & I (e)	
50S:	When concentration decreases the number of particles decrease. The collision is slower which leads to low rate of reaction	R (aeq)	
51T:	...ok now how did the test change your prediction? If you predicted increase in concentration increases the rate...give yourself a clap!	E(i) & M	
	Assuming we are in class, a person show up with a cane (stick), he finds in 3 people in the classroom. Another person show with a cane (stick), he finds in 40 people, who will find caning easier?	I(i) & I (e)	
52S:	The one with 40 people...	R (aeq)	
53T:	Exactly...has high number of people....has high concentration When you increase particles to 10 for example, you have not increase speed...so when you are increasing the concentration, you are increasing the number of particles in a given volume. When particles are many (high), collisions per second with each other is easier. So the speed at which the particles are colliding has not	E(i) & I (s) I(r) I(s)	

been increased. Speed is only associated with gain in kinetic energy and this, class! It only happens when temperature is increased not with concentration!		
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Generated chain patterns of interaction: [I(e)-R(aeq)-N(F)-R(aeq)-R(aeq)-R(aeq)-R(aeq)-R(aeq)-R(aeq)-N(F)]-[I(e)-R(aeq)-N-R(aeq)-N(F)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-I(e)-R(aeq)-I(e)-R(aeq)-I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-R(aeq)-R(aeq)-R(aeq)-R(aeq)-R(aeq)-R(aeq)-N(F)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-I(e)-R(aeq)-I(e)-R(aeq)-N-R(aeq)-N-R(aeq)-N(F)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-E(i) & M]-[I(i) & I(e)-R(aeq)-E(i)]- [I(s)-I(r)-I(s)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through an **I-R-F-pattern (interactive/dialogic)** where the teacher explores different points of views by engaging the students in sequences of turn-taking; **I-R-E-pattern (interactive/authoritative)** where the teacher's move was towards the effect of concentration on chemical rate of reaction; and concludes the lesson using an **I-pattern (non-interactive/authoritative)** to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-28.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-28: Episode 4.1. Key features of the teaching process

Teaching purpose	To explain how varying the concentration affects the rate of reaction using collision theory
Content	Effect of concentration on chemical rate of reaction
Communicative Approach	Interactive/dialogic; interactive/authoritative and Non-interactive/authoritative
Patterns of interaction	[I-R-F]-[I-R-F]-[I-R-F]-[I-R-F]-[I-R-F]...[I-R-E]-[I-R-E]-[I]
Forms of teacher intervention	Exploring, evaluating, motivating students, reviewing and summarising key ideas

Commentary: In this part of the lesson, the teacher prompted discussion on behavior of reacting particles when concentration is increased or decreased in an interactive/dialogic (I/D), interactive authoritatively (I/A), interactive /dialogic (I/D), interactive authoritatively (I/A), and non-interactive /authoritative (NI/A) way.

The teacher then interacted dialogically to develop ideas about the effect of concentration on rate of reaction exploring and working on students' ideas by asking questions - '...so what happened when you increase concentration of the particles?' and 'so how does this affect rate of reaction?' (turns 1-24). 'so, what happens when you decrease concentration of the particles?' and 'so how does this affect rate of reaction?' (turns 24-49). He used strategies such as motivation and neutral

feedback strategies to encourage students to think through their responses during the interaction.

He then interacted authoritatively to develop and maintain ideas by asking a question -‘how did the test change your prediction?’ (turns 51-53) and waiting for students to answer. He also used strategies such as evaluating, sharing ideas and echoing to reinforce the correct answer or acknowledge an answer as acceptable, and made it available to the whole class.

The teacher concluded this lesson by making a review and summarising ideas on how concentration affects rate of reaction in a non-interactive/authoritative way (turn 53).

7.10.4 For Episode 4.1: Teaching effect of concentration on chemical rate of reaction in NTA class: Patterns of interaction

7.10.5 Staging the scientific story

In this lesson, the teacher prompted discussion on how concentration affects the rate of reaction and presented a summary of the effect of concentration on chemical rate of reaction as follows:

7.10.6 Supporting students’ internalisation

Table 7-29: For Episode 4.1. Whole classroom interaction

	Turn	Codes	Remarks
1T:	So today let’s look at another effect... another effect. We shall deal with the effect of concentration Why do you write conc. you should write it in full! How does concentration affect the rate of reaction? Can I have someone to explain? Yes	I (i) Cmm I (e)	
2S:	the rate of reaction is proportional to ...murmurs	R (aeq)	
3T:	What is it proportional to?	I (e)	
4S:	concentration...murmurs	R (aeq)	
5T:	I beg your pardon...Osuna	I (e)	
6s:	the rate of proportional to...murmurs		
7T:	Let’s take chemistry simple So the rate of reaction is proportional to the concentration. What does that mean? The higher the concentration, the higher the rate of reaction Let’s write something ...	Cmm I(s)	

Generated chain patterns of interaction: [I(i)-Cmm-I(e)-R(aeq)-I(e)-R(aeq)-I(e)-Cmm-I(s)]

The generated chain patterns of interaction in this episode show that the teacher used I-pattern (**non-interactive/authoritative**), and it shows no engagement of the

students through explorative questions during the lesson. The forms of teacher intervention indicated in brackets are presented in table 7-30.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-30: For Episode 4.1. Key features of the teaching process

Teaching purpose	To explain how varying the concentration affects the rate of reaction using collision theory
Content	Effect of concentration on chemical rate of reaction
Communicative Approach	Non-interactive/authoritative
Patterns of interaction	No interaction (with limited interactive/dialogic)
Forms of teacher intervention	Introducing ideas, limited exploring, using classroom management moves and summarising key ideas

Commentary: In this lesson the teacher was more authoritative with a limited interactive/authoritative approach, which was not well developed and to introduce and explore students' ideas by asking a question - 'how does concentration affect the rate of reaction? Can I have someone to explain?' (turn 1), and waiting for students to answer. He used a marking key idea strategy, for example, student's response which was incomplete 'the rate of reaction is proportional to murmurs' (turn 2), was used to initiate an elaborative question, 'what is it proportional to?' (turns 3-5), to encourage the students to continue the thought. The teacher also used a classroom management move to encourage students to like the subject, for example 'let's make chemistry simple!' (turn 7), before concluding the lesson by summarising key ideas and sharing the ideas with the whole class in a non-interactive/authoritative way (**N/A**) (turn 7).

7.11 L5 Episode 5.1 Learning gains: Graphical interpretation of how concentration affect chemical rate of reaction

In this area, the C&TA (experimental) class performed better than the NTA (comparison) class. For example, students in the C&TA (experimental) class obtained 92.4 %, compared to 69.5 % in the NTA (comparison) class, on the fact when the concentration increases, the reaction takes less time or a shorter time to come to stop.

7.11.1 Episode 5.1. Teaching graphical interpretation of relationship between concentration and time of chemical reaction in C&TA class: Patterns of interaction

7.11.2 Staging scientific story

In this lesson, the teacher engaged students in groups to investigate the effect of concentration using a solution of sodium thiosulphate and HCl. He performed a demonstration to show students the experimental procedures, determination of plot scales and recording a stop clock through non-interactive/authoritative (NI/A). Students then used worksheet activities to discuss through non-interactive/dialogic (NI/D) and present their results.

Students in small groups performed the experiment, discussed their results in groups and plotted graphs for concentration against time and concentration against rate. The teacher provided support through probing, scaffolding and helping them to make sense of, and internalize those ideas as students worked in their groups.

7.11.3 Supporting students' internalisation

During whole class interaction, the teacher gave opportunities to different groups to share their ideas with the whole class. The teacher used this opportunity to address the students' alternative conceptions.

Students responded as part of a group to teacher prompts through a mixture of communicative approaches as follows:

Table 7-31: Episode 5.1 Whole class interaction

	Turn	Codes	Remarks
1T:	So...how does concentration affect the time for the cross disappear?	I (e)	
2S:	The higher the concentration of the thiosulphate the less time that will be taken for the cross to disappear	R (aeq)	
3T:	...ok...	N(F)	
	Can we hear from another group?	I (e)	
4S:	The higher the concentration of the thiosulphate the less time it takes for the cross to disappear and vice versa	R (aeq)	
5T:	...ok...	N(F)	
6S:	The concentration of thiosulphate kept on increasing with time because the concentration also kept reducing	R (aeq)	
7T:	...ok...	N (F)	
	can we hear from another group	I (e)	
8S:	The higher the concentration of thiosulphate, the less it will take for the cross to disappear and the lower the concentration of thiosulphate, the more time it takes for the cross to disappear	R (aeq)	
9T:	... Another group...yes.	I (e)	
10S:	When the concentration is high, collision is faster hence a short time is taken for the cross to disappear and when concentration is low collisions are slower hence a long time is taken for the cross to disappear.	R (aeq)	
11T:	...good	E(i)	
	What is the effect of concentration of thiosulphate on the rate of this cross to disappear?	I (e)	
12S:	The higher the concentration of the thiosulphate the higher the rate of reaction	R (aeq)	
13T:	Ok...	N (F)	

14S:	The higher the concentration of thiosulphate, the higher the rate for the cross to disappear while the lower the concentration of thiosulphate the lower the rate for the cross to disappear	R (aeq)	
15T:	OK Another group...yes	N (F) I (e)	
16S:	Increase in concentration of thiosulphate leads to the increase of the rate of the cross to disappear and decrease in concentration leads to the decrease of the rate of the cross to disappear	R (aeq)	
17T:	Yeah another group	N & I (e)	
18S:	The more the concentration of thiosulphate, the faster the rate of reaction and products are formed in less time / short period of time	R (aeq)	
19T:	OK Another group... yes	N I (e)	
20S:	When the concentrate is high the rate at which the cross disappears is higher while when the concentration is low the rate at which the cross disappears is lower	R (aeq)	
21T:	OK, we have all completed and plotted our graph, and can I now get each group's interpretation of the graph. What is the relationship between volume and rate?	I (e)	
22S:	As volume increases, the rate also increase	R (aeq)	
23T:	Yes...that is the relationship...	E(i)	
	Increase in the volume of the thiosulphate increases the rate, that is what the graph is saying	I (s)	
	...ok, using the collision theory, can you explain how concentration affect rate of reaction	I (e)	
24S:	When the molecules are increased, they gain kinetic energy which give them the motion to move causing collision and hence increase in rate of reaction	R (aeq)	
25T:	When do we get kinetic energy?	I (e)	
26SS:	When we are dealing with temperature... (Chorus)	R (aeq)	
27T:	When there is no temperature effect there is no gain or lost in kinetic energy. When dealing with concentration forget about the kinetic energy.	S(i)	
	Let's hear from another group	I (e)	
28S:	When the volume of thiosulphate is increased, the space between the molecules is reduced causing the high collision hence high rate of reaction	R (aeq)	
29T:	...ok Can we hear from another group	N (F) I (e)	
30S:	When the volume of thiosulphate increases its increase the concentration of the particles therefore there is more collision among the particles thus the time increases	R (aeq)	
31T:	...ok ... Yes, your group please	N (F) I (e)	
32S:	When volume of thiosulphate is increased the number of particles increases and they move faster and starts colliding faster per unit time hence increase in the rate of reaction.	R (aeq)	
32T:	...uhm yeah Another group...yes.	N (F) I (e)	
33S:	When the concentration is high, the molecules are closely packed resulting to frequent collisions hence a high reaction rate while when concentration is low, the molecules are fairly spaced, the collisions are reduced hence a low rate of reaction	R (aeq)	
34T:	Good, I happy with your responses When we increase concentration... we are increasing particles or atoms or ions or molecules. This means increase in concentration, means reduction in space, means more particles will collide, means the frequency of collision increases, more products form and the rate also increases In the next lesson we will be in the computer lab. We shall find values indicated on the table like these ones. You will be changing the values, and the graph will also be changing. It will be up to you to change the values (hypothesizing and theorizing)	E(i) & M I(r) Is I(i)	

Generated chain patterns of interaction: [I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-N-R(aeq)-N(F)]-[I(e)-R(aeq)-I(e)-R(aeq)-E(i)]-[I(e)-R(aeq)-N-R(aeq)-N(F)]-[I(e)-R(aeq)-N]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-I(e)-R(aeq)-E(i)-I(s)]-[I(e)-R(aeq)-I(e)-R(aeq)-S(i)-I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-E(i) & M]-[I(r)-I(s)-I(i)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through a communicative ‘cycle’, the **I-R-F**-pattern (**interactive/dialogic**) where the teacher explores different points of views by engaging the students in sequences of turn-taking, the **I-R-E**-pattern (**interactive/authoritative**) where the teacher’s move was towards the effect of concentration on chemical rate of reaction, and concluded the lesson using **I**-pattern (**non-interactive/authoritative**) to summarise the key ideas. The forms of teacher intervention used to support students’ understanding are indicated in brackets and presented in table 7-32.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-32: Episode 5.1. Key features of the teaching process

Teaching purpose	To interpret graphically how concentration affects rate of reaction
Content	Graphical interpretation of the relationship between concentration and time/rate of chemical reaction
Communicative Approach	Interactive/dialogic; interactive/authoritative; Interactive/dialogic; interactive/authoritative; Interactive/dialogic; interactive/authoritative; and Non-interactive/authoritative
Patterns of interaction	[I-R-F]-[I-R-F]-[I-R-E]-[I-R-F]-.-[I-R-E]-[I-R-F]-.-[I-R-E]-[I]
Forms of teacher intervention	Exploring, listening & considering various views, shaping and working students’ ideas

Commentary: In this lesson, the teacher interacted dialogically to develop ideas about the relationship between concentration of reactants and time/rate of reaction through exploring and working on students’ ideas by asking a question - ‘so, how does concentration affect the time for the cross disappear?’ (turn 1), and waiting for students to answer. He then used a neutral feedback strategy to encourage students to think deeply about their responses during the interaction (turns 3-7). The teacher then interacted authoritatively to exploring and working on the students’ ideas by inviting more responses ‘can we hear from another group?’ (turns 7-11). He used an evaluative strategy, for example, ‘good’, appraising students’ responses.

He then interacted dialogically to explore students’ ideas about the effect of concentration on rate of reaction by asking a question – ‘what is the effect of

concentration of thiosulphate on the rate of this cross to disappear?', and waiting for students to answer. He used a neutral feedback strategy to encourage students to think through their responses during the interaction (turns 11-19).

The teacher further interacted authoritatively to develop ideas about interpreting a graph of relationship between concentration of reactants and time/rate of reaction, exploring and working on students' ideas by asking a question - 'What is the relationship between volume and rate?' (turn 21). He used an evaluative strategy affirming students' responses and elaborating ideas to make it clearer to the students (turn 23).

The teacher dialogically continues to explore and work on students' ideas by asking students to apply and expand their ideas by drawing and explaining the effect of concentration on rate of reaction using the collision theory, such as 'OK, using the collision theory, can you explain how concentration affects rate of reaction?' (turn 23). This led to responses in which the students were required to 'think' or 'guess' the acceptable answer that the teacher was looking for. For example, a student's response (turn 24) had a misconception 'they gain kinetic energy', which prompted the teacher to seize the phrase and initiate a confirmatory exchange with the students, by asking 'when do we get kinetic energy?' (turn 25). The exchange serves the two functions of allowing students to rethink their responses and the teacher to address the misconception that '*when there is no temperature effect there is no gain or lost in kinetic energy. When dealing with concentration forget about the kinetic energy*' (turn 27).

There was a brief interactive/authoritative calling for more responses (turn 32) and the use of evaluative and motivation strategy to acknowledge students' answers as acceptable to the whole class.

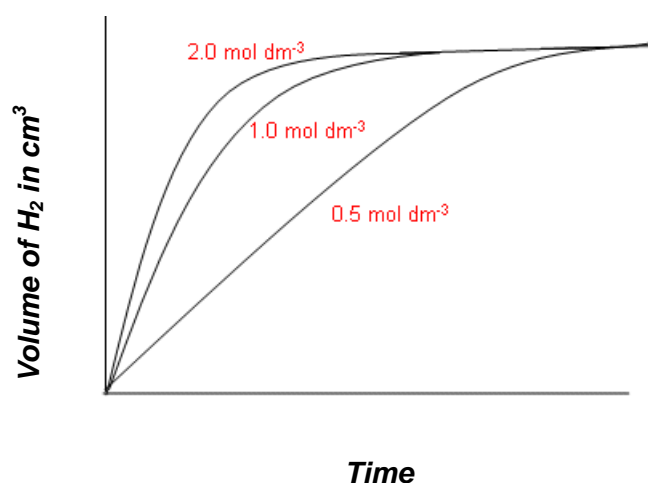
The teacher concluded this lesson by making a review and summarising ideas on how concentration of reactants affects rate of reaction in non-interactive/authoritative way (turn 34).

7.11.4 For Episode 5.1: Teaching graphical interpretation of relationship between concentration and time of chemical reaction in NTA class: Patterns of interaction

7.11.5 Staging the scientific story

In this lesson, the teacher used a graph of volume of hydrogen produced with time to explain the relationship between concentration and rate of reaction.

A graph of the volume of hydrogen evolved with time is then plotted for all the different concentrations of HCl, as below. Draws graph on board.



The teacher conducted the teaching as follows:

7.11.6 Supporting students' internalisation

Table 7-33: Episode 5.1. Whole classroom interaction

	Turn	Codes	Remarks
1T:	A graph of the volume of hydrogen Evolved with time is then plotted for all the different concentration of HCl as below First and foremost when you look at 0.5M, 1M and 2M which one has got the highest concentration? uhm...yes	I (e)	
2S:	2M	R (aeq)	
3T:	2M ... Do we... all agree on that...uhm?	Ev, Echoes & I (cu)	
4S:	yes...it is 2M in chorus	R (cu)	
5T:	2M we all agree on that ...do we all agree? Because, that means concentration...that means the higher the number of moles in a particular liquid or substance then that will be greater the concentration...it is clear? Are you through? Monitors and checks students' notes ...so are you ok with that? Points to note By the way as we are carrying out this experiment remember we are investigating on the effect of concentration, but put in mind that we have already looked at temperature. So in order not to affect our investigation or experiment, we assumed we are carrying out this experiment at a constant temperature because you might ask what if the temperature is changed. ... Do not bring in temperature here...we assume temperature is constant.	Echoes & I (cu) I (s) I (cu) Cmm	

	<p>The volume of hydrogen increases along AB because Mg reacts with HCl to give Hydrogen gas ...you can write that simple equation. (Transcribes equation on board)</p> $\text{Mg (s)} + 2\text{HCl (aq)} \longrightarrow \text{MgCl}_2 \text{ (aq)} + \text{H}_2 \text{ (g)}$ <p>Teacher cautions the students make sure you balance the equation....write that simple equation...</p> <p>Teacher carries on with the interpretation of the graph , at point BC, the graph remains constant because all the Mg is used up and the reaction is complete</p> <p>By the way sometimes you can be given figures and you can be asked to plot a graph.</p> <p>But is Everything clear?</p> <p>Are you sure! Are we together?</p>	I (cu)	
8S:	yes	R (cu)	

Generated chain patterns of interaction: [I(e)-R(aeq)-Ev/Echoes]-[I(cu)-R(cu)-Echoes & I(cu)-I(s)-I(cu)-Cmm-I(cu)-I(cu)-I(e)-I(s)-I(cu)-R(cu)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through **I-R-E-pattern (interactive/authoritative)**, where the teacher's move was towards the effect of concentration on chemical rate of reaction and concluded the lesson using **I-pattern (non-interactive/authoritative)** to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-34.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-34: Episode 5.1. Key features of the teaching process

Teaching purpose	To interpret graphically how concentration affects rate of reaction
Content	Graphical interpretation of the relationship between concentration and time/rate of chemical reaction
Communicative Approach	Interactive/authoritative and Non interactive/authoritative
Patterns of interaction	[I-R-E]-[I]
Forms of intervention	Limited exploring, echoing, checking students' understanding, using classroom management moves and summarising

Commentary: From the lesson excerpt above, the teacher used interactive/authoritative, introducing and developing ideas about the graphical interpretation of the relationship between concentration of reactants and time/rate of chemical reaction to come to a stop or finish.

It is evident at the beginning that there was teacher and student interaction, lead through the question, 'which one has got the highest concentration?' (turn1), and waiting for students' response (turn 2). However, there was a great deal of the use of strategies such as checking whether students were following his explanations and

the use of classroom management move for example, 'it is clear, is that clear, are we together?'. He used an evaluative strategy as a follow up feed, 'do we all agree?' (turn 5), echoing to reinforce the correct answer and making it available to the whole class (turn 5).

For the remaining part of this lesson, it is evident from the excerpt that the teacher used an authoritative approach, and shows that there was poor engagement as in chances for students to speak out their ideas, to think about what the teacher presented and to exercise more control over the talk, and learning was limited. Again, there was a strong transmission of ideas from the teacher and limitation in elaborative questions for the students to explain their views (turn 5).

7.12 L6 Episode 6.1: chemical rate of reaction (computer modelling using spreadsheets)

7.12.1 L6 Episode 6.1: Handing over responsibility to students in C&TA class

In the next session of the laboratory investigation of the effect of concentration, the teacher introduced and substituted the real experimental data with virtual environmental data using computer spreadsheets as a modeling tool in a non-interactive/authoritative way (NI/A). The teacher engaged students in group discussions through non-interactive/dialogic (NI/D) to make predictions, hypothesized or asked, 'what if?' and or 'what about? He also asked questions and analysed results by changing the concentration value while they observed its effect on reaction time or rate through graphical display.

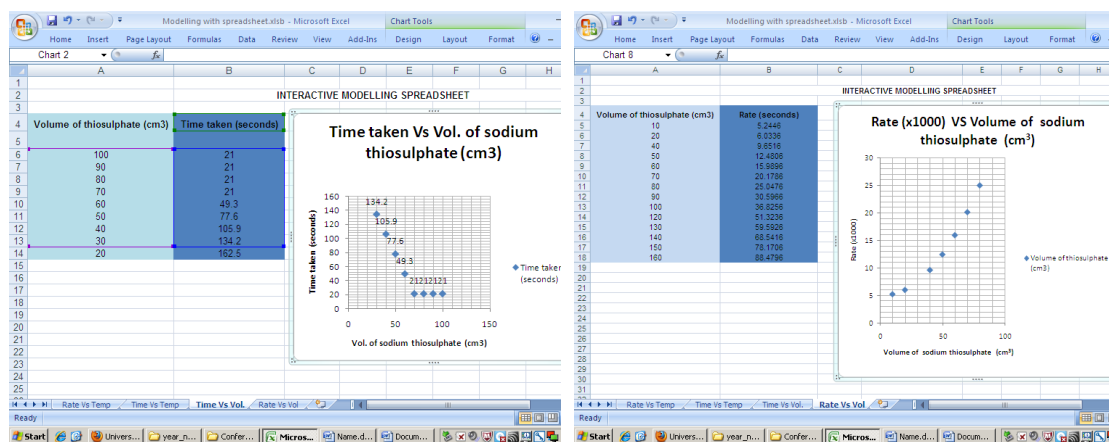


Figure 7-5: Graphical interactive spreadsheets for investigation of effect of concentration on chemical rate of reaction (Source: designed and developed by Moses Odongo, with researcher)

Students responded as part of a group to teacher prompts through a mixture of communicative approaches, as follows:

Table 7-35: Episode 6.1. Whole classroom interaction

Turn	Codes	Remarks
1T: Ok, in today's lesson we shall follow similar procedure like how we deal with temperature effect on rate of reaction using spreadsheet. We are expected to model the effect of concentration using the computer spreadsheet. You will work in group. Ok, I want you to pay attention to the shape of the graph? Here we will assume we are done another experiment. You will change the value of concentration the way you want! While changing the values, leave the time alone, vary temperature only while observing it effect on time...	I(r) I(i)	
2T: How does time changes when you increase the reaction concentration?	I (e)	
3S: The time decrease	R (aeq)	
4T: Yes...	E(i)	
the time decreases with increase in the reaction concentration	Echoes	
...and how does the concentration graphically change with time can you explain this?	I (e)	
5S: As the concentration increases, the time for the reaction reduces...decreases	R (aeq)	
6T: Good...also note that the shape of the graph remains the same whether you carry out your experiment beginning with higher concentrations and concluding with the lower concentration or you start with lower concentration and increasing concentration. For example, when you start from 10 through 90 or from 90 through to 10 the graph remains the same. Increasing the volume goes with its corresponding time or rate. The plot of your graph show that the time against concentration graph is still a curve depicting increase in concentration leads to decrease in time for the reaction. And the plot of 1/time (rate) against concentration shows that rate increases with increase in the concentration of the reactants. You have to understand that the shape of the graph for example; time (y-axis) against volume (x-axis), it has to be a curve (going down left to right); rate (y-axis) against volume (x-axis), it has to be a curve (going upwards from left to right). For time (y-axis) against temperature (x-axis), it has to be a curve (going down left to right); rate (y-axis) against temperature (x-axis), it has to be a curve (going upwards from left to right) 'Let these curves be in our minds'	E(i) I(r) I(s)	

Generated chain patterns of interaction: [I(r)-I(i)-]-[I(e)-R(aeq)-E(i)-Echoes]-
[I(e)-R (aeq)-E(i)]-[I(r)-I(s)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through I-pattern (**non-interactive/authoritative**) when the teacher was introducing the lesson; I-R-E-pattern (**interactive/authoritative**) where the teacher's move was towards the effect of temperature on chemical rate of reaction and concluded the lesson using I-pattern (**non-interactive/authoritative**) to summarise the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-36.

The key features of this episode of the lesson are summarized as the table below.

Table 7-36: Episode 6.1. Key features of the teaching process (Handing over responsibility to students)

Teaching purpose	To interpret graphically how concentration affects rate of reaction
Content	Graphical interpretation of the relationship between concentration and time/rate of chemical reaction
Communicative Approach	Non-interactive/authoritative; Interactive/authoritative and Non-interactive/authoritative
Patterns of interaction	[I]-[I-R-E]-[I-R-E]-[I]
Forms of teacher intervention	Reviewing, introducing, exploring, echoing and summarising key ideas

Commentary: In this lesson, the teacher used a non-interactive/authoritative (NI/A) approach, reviewing how computer spreadsheets were used in the previous lesson to model the effect of temperature on rate of reaction, and introducing that the effect of concentration of reactants on rate of reaction will be modeled in similar way (turn 1). He then engaged students in group discussions in a non-interactive/dialogic way (turn1).

The teacher then interacted authoritatively exploring and guiding students to apply and expand their ideas about the relationship between concentration of reactants and time/rate of reaction, by asking a question - 'how does time change when you increase the reaction concentration?' (turn 2), and waiting for students to answer. He used strategies such as evaluating, sharing ideas and echoing (turn 4) to reinforce the correct answer and making these ideas available to the whole class.

He then presented a summary of the relationship between concentration of reactants time, and rate of chemical rate of reaction in a non-interactive/authoritative (NI/A) way (turn 5).

Furthermore, the use of computer modelling using spreadsheets was found to be quite effective, and helped to engage in hypothesizing or asking 'what if?' and 'what about?'. This helped in enhancing students' understanding of the relationship between concentration of reactants time and rate of chemical reaction.

7.12.2 For L6 Episode 6.1: Handing over responsibility to students in NTA class

In the next lesson, the teacher used a non-interactive/authoritative approach to carry out an experimental demonstration on how to investigate the effect of concentration

using a solution of sodium thiosulphate and HCl. He performed a demonstration to show students the experimental procedures, determination of plot scales, reading and recording a stop clock as follows.

7.12.3 Supporting students' internalisation

Table 7-37: For Episode 6.1. Whole classroom interaction

	Turn	Code s	Remarks
1T:	<p>In our last experiment we looked at the effect of temperature on the rate of reaction between a solution of sodium thiosulphate and Hydrochloric acid. Today we shall also use the solution of sodium thiosulphate and Hydrochloric acid to determine how concentration affects the rate of reaction between sodium thiosulphate and Hydrochloric acid Reaction equation is still the same (Writes the equation on the board)</p> $\text{Sodium sulphate} + \text{hydrochloric acid} \longrightarrow \text{Sodium chloride} + \text{water} + \text{sulphur dioxide} + \text{sulphur}$ <p>Teacher continues with explanations, 'again here the sulphur produced makes the solution appears cloudy. It takes some time for the sulphur to appear and its appearance depends on the concentration at which the reaction is taking place. We shall determine the rate at which sulphur appears at different concentrations and compare concentrations at which it takes a shorter time. Is that clear? This time we shall not use the thermometer because as we said last time when dealing with concentration, we keep the temperature constant. We shall need the stop clock again to measure ...the time the sulphur will take to appear. We shall also need measuring cylinders and beakers. Are we together and is that clear? So let's take down these procedures write down the procedures on the blackboard</p> <p>Procedure:</p> <ol style="list-style-type: none"> Mark a cross with blue or black ink on a piece of paper. Measure 50 cm³ of 0.2M sodium thiosulphate solution into 250 cm³ beaker. Add 10 cm³ of 2M hydrochloric acid to the thiosulphate and at once start the stop clock. Shake gently for the solutions to mix well and place over the cross. Watch the cross through the solution from above the beaker. Stop the clock when the cross disappears. Record the time taken for the yellow precipitate of sulphur to appear in the table below. Pour away the mixture and rinse the beaker thoroughly, then place 40 cm³ of thiosulphate and 10 cm³ of distilled water into it. Add 10 cm³ of the acid and follow the procedure above, again recording the time taken for the cross to disappear. Repeat procedure (b) for the rest of the mixtures as shown in the table below. Complete the table. And answer the following questions below <p>I will carry out the first experiment to show you how to perform and I will expect you to follow the procedure to do the remaining set... I am going to measure into the beaker 50cm³ of 0.2M sodium thiosulphate and place it over the cross (X) on the paper, I will also measure 10 cm³ of 2M hydrochloric acid, then add the two together and start the stop clock. When the cross disappears, I will stop the clock and record the time taken for the yellow precipitate of sulphur to appear. I would like you to do the remaining sets of the experiments, please make sure you follow the procedures well.</p> <p>Questions</p> <ol style="list-style-type: none"> Plot a graph of volume of thiosulphate (y-axis) against time (axis) How does the concentration of thiosulphate affect the time for the cross to disappear? What is the effect of concentration of thiosulphate on the rate of this cross to disappear? Why do we plot volume rather than concentration of thiosulphate in (2)? Plot a graph of volume of thiosulphate against 1/ time. 	<p>I (r)</p> <p>I (i)</p> <p>I (cu)</p> <p>I (s)</p> <p>I (cu)</p> <p>Cmm</p>	

	6. Calculate the gradient (slope) of the graph in (6) and state its units.		
2T:	Please, you have to hand in your work at the end of the lesson for marking....Everyone should hand in his or her work.... When we meet next time we shall be look another factor which rate of reaction. We shall look at the effect of surface area of reactants to rate of reaction.	Cmm I (i)	

Generated chain patterns of interaction: [I(r)-I(i)-I(cu)-I(s)-I(cu)-Cmm-Cmm-I(i)]

The generated chain patterns of interaction in this episode show that the classroom talk was developed through I-pattern (**non-interactive/authoritative**) when the teacher was introducing the lesson and summarizing the key ideas. The forms of teacher intervention used to support students' understanding are indicated in brackets and presented in table 7-38.

The key features of this episode of the lesson are summarized as in the table below.

Table 7-38: For Episode 6.1. Key features of the teaching process (Handing over responsibility to students)

Teaching purpose	To interpret graphically how concentration affects rate of reaction
Content	Graphical interpretation of the relationship between concentration and time/rate of chemical reaction
Communicative Approach	Non-interactive/authoritative
Patterns of interaction	No interaction
Forms of teacher intervention	Reviewing, introducing, using classroom management moves and summarising ideas

Commentary: In this lesson, the teacher used a non-interactive/authoritative (NI/A) approach, reviewing the previous lesson about using the solution of sodium thiosulphate and hydrochloric acid to investigate the effect of temperature on rate of reaction and introducing that the effect of concentration of reactants on rate of reaction will be investigated using a solution of sodium thiosulphate and hydrochloric acid (turn 1).

It is observed from the above excerpt that the teacher used non-interactive/authoritative, guiding students to apply and expand their ideas about the relationship between concentration of reactants and time/rate of reaction. It is evident that the teacher used a didactic approach and there was passiveness on the side of students during the lesson. Thus, there was no teacher and student interaction lead through questions, except a little move by the teacher to check

whether students were following his explanations, such as 'is that clear?, it is clear?', and the use of classroom management move, for example, 'take down these procedures' and 'I expect you to hand in your work for making' (turn 2).

7.13 Key differences arising from C&TA and NTA teaching approaches

This section brings together the summaries of the two teaching approaches in order to draw significant differences in the two approaches. The presentation of the differences is done lesson by lesson drawing from the key features of the lesson episode as summarized at the end of each lesson analysis by the class in the previous sections. It focuses on the teaching purpose and communicative approaches (CA) used, drawn directly from the generated patterns of class talk/interaction. Descriptive frequencies, percentages, graphics and commentaries have been used to show the key differences in the use of CA in the experimental class (C&TA) and comparison class (NTA).

The description of the key differences between C&TA and NTA is done lesson by lesson, based on the reviews of the coding schemes and the characterisation of talks presented in **section 7.2** and **section 7.4** respectively.

7.13.1 L1 Episode 1.2.1. Comparison between experimental class and comparison class patterns of interaction and communicative approach (CA)

The findings in **table 7-39** show that in the experimental class (C&TA class), 60 % of the teaching was conducted using **I/A**, compared to 22.2 % in the comparison class (NTA class). The teaching purpose in this episode aims at developing ideas about rate of reaction. The teaching intention requires an approach which allows the joint development of this idea which could only be achieved by using **I/A**, whereby the teacher leads the students through a sequence of instructional questions and answers with the aim of reaching one specific point of view, in this case defining rate of reaction. **I/A** allows the teacher to intervene to work on alternative conceptions (through *shaping, selecting and marking ideas*) for some aspects of the content, with a view to developing further the scientific ideas, which supported the students' understanding of the definition of rate of reaction.

The findings also show that 13.3 % of the teaching was also conducted using the **I/D** approach in the experimental class (C&TA). This approach is used to elicit and explore students' ideas about a particular issue (in this case the definition of rate of reaction) and it aims to inform the teacher about students' ideas and provide opportunity for misconceptions to be addressed.

Furthermore, it is evident from the results that 77.8 % of the teaching in the comparison class (NTA class) was conducted using **N/A**, compared to 26.7 % in the experimental class (C&TA class), to present and maintain the development of students' understanding; reviews students' progress and summaries key ideas of the definition of rate of reaction. The results show NTA teacher's forms of interventions consisted of questions (initiation) to confirm understanding [**I**(cu)] whether students followed his explanations with limited initiation of explorative questions [**I**(e)], use of classroom management moves (**Cmm**) and students' response mainly to confirm understanding [**R**(cu)] with limited responses to explorative questions [**R** (aeq)].

Table 7-39: Teaching definition of the term ‘rate of reaction’

	Experimental class			Comparison class		
Chain patterns of interaction	[I] (i)-[I] (e)-R (aeq)-F-[I] (e)-R (aeq)-Ei - [I] (e)-R(aeq)-E (i)-Echoes]-[I(e)-R (aeq)-E (i)]-[I (s)] [I (r)]- (I)e-R(aeq)-E (i)-M (i)]-[I (e)-R (aeq)-N(F)- [I] (e)-R (aeq)-E(i)]-[I] (e)-R(aeq)-I(i) & I(e)-R (aeq)-I (e)-R (aeq)-E (i)- Echoes]- [I] (e)-R (aeq)-E(i)]-[I(e)-R(aeq)-E (i)]- [I(s)]			[I (e)-R (aeq)-Ev/Echoes]-[I (cu)-R (cu)-Echoes- I (cu)-I (s)-I (cu)-Cmm-I (cu)-I(cu)-I(e)-I (s)-I (cu)-I (i)-I (s)-I (cu)-R (cu)]-[I] (e)-R(aeq)-E(i)]-[I] (s)-I (cu)-R (cu)-I(s)-I(e)-N-I (s)-I (cu)-R (cu)-I (cu)-R (cu)-I (cu)-R (cu)-I(e)-R (aeq)-I(r)-I(i)-M]		
Patterns of interaction	[I]-[I-R-F]-[I-R-E]-[I-R-E]-[I-R-E]-[I-R-E]-[I]-[I]-[I-R-E]-[I-R-F]-[I-R-E]-[I-R-E]-[I-R-E]-[I-R-E]-[I]			[I-R-E]-[I]-[I]-[I]-[I-R-E]-[I]-[I]-[I]		
Frequency of Communicative approach (CA) in class talk	CA	Frequency	Percent	CA	Frequency	Percent
	[I]-NI/A	4	26.7%	[I]-NI/A	7	77.8%
	[I-R-E]-I/A	9	60%	[I-R-E]-I/A	2	22.2%
	[I-R-F]-I/D	2	13%	[I-R-F]-I/D	0	
	[N]-NI/D	0		[N]-NI/D	0	

7.13.2 L1 Episode 1.3.1: Comparison between experimental class and comparison class patterns of interaction and communicative approach (CA)

The findings in **table 7-40** show that in the experimental class (C&TA class) the teacher’s use of CA was equally distributed between NI/A, I/A and I/D (28.6 %), compared to the teaching in the comparison class (NTA class) which was conducted only using NI/A (100 %). The results show that C&TA was also conducted using NI/D and this comprised of 14.2 %. This means that 14.2 % of the teaching in C&TA was carried out using small group work to give the students an opportunity to develop their understanding of the proper orientation of reacting particles.

The results show that the C&TA teacher used **I/A** (28.6 %) to introduce and develop ideas about the proper orientation of reacting particles through *shaping, selecting, marking ideas, evaluating ideas* and this supported the students’ understanding of the proper orientation of reacting particles.

Also, the results indicate that the C&TA teacher used **I/D** (28.6 %) to elicit and explore students’ ideas about the proper orientation of reacting particles using a series of ‘genuine’ questions, *offering listening* to different ideas, and echoes to emphasize the point, reinforce the correct answer, and acknowledge an answer as acceptable and worked on different points of view. Furthermore, it was evident that

C&TA teacher used **NI/A** (28.6 %) to maintain the development of students' understanding of proper orientation of reacting particles; reviews students' progress and summarize key ideas about the proper orientation of reacting particles. The results show that the NTA teacher employed only **NI/A** to teach the concept of proper orientation of reacting particles. Also, results show that the NTA teacher's forms of interventions consisted of questions (initiation) to confirm the understanding [I(cu) and students' responses, mainly to confirm understanding [R(cu)].

Table 7-40: Teaching proper orientation of reacting particles

	Experimental class			Comparison class		
Chain patterns of interaction	[I (i)]-[I (e)-R (aeq)-E(i)-S(i)]-[I (e)-R (aeq)-N(F)]-[I(e)-R(aeq)-Ev-M(i)-Echoes]-[Ie-R (aeq)-R (aeq)-Echoes & N (F)]-[Ie-R (aeq)]-[I(r)-I (s)]			[I (i)-I(s)-I(cu)-R (cu)]		
Patterns of interaction	[I]-[I-R-E]-[I-R-F]-[I-R-E]-[I-R-F]-[I]			No interaction		
Frequency of Communicative approach (CA) in class talk	CA	Frequency	Percent	CA	Frequency	Percent
	[I]- NI/A	2	28.6%	[I]- NI/A	2	100%
	[I-R-E]- I/A	2	28.6%	[I-R-E]- I/A	0	
	[I-R-F]- I/D	2	28.6%	[I-R-F]- I/D	0	
	[N]- NI/D **	1	14.2%	[N]- NI/D	0	

** Occurrence in group discussion

7.13.3 L1 Episode 1.3.2: Comparison between experimental class and comparison class patterns of interaction and communicative approach (CA)

The results in **table 7-41** show that in the experimental class (C&TA class) the teacher used 75 % **NI/A** and 25 % **NI/D**, to teach the concept of activation energy, E_a compared to the comparison class (NTA) where the teacher used 100 % **NI/A**. The results mean that the C&TA teacher used **NI/A** (75 %) to present and maintain the development of students' understanding of activation energy, E_a ; reviews students' progress and summarize key ideas about activation energy, E_a . It also means that 25 % **NI/D** of the teaching in the C&TA class was carried out in small groups to give the students an opportunity to develop their understanding of the activation energy, E_a . The use of computer simulations in the C&TA class aided understanding as students were able to see that when the energy level was high, the reaction takes place within a short time; and that when energy level was low, the reaction takes a longer time to occur.

Also from the **table 7-41** the results show that the NTA teacher employed only **NI/A** to present the concept of activation energy, E_a . The NTA teacher's forms of

intervention were checking students' understanding [I(cu)], students' response to confirm understanding [R(cu)] and classroom management moves (Cmm). As such, this approach was not supportive to the students' understanding as indicated by the post-test, that only 3.1 % of NTA students were able to provide a correct explanation of activation energy, Ea.

Table 7-41: Teaching activation energy, Ea and how this affects the number of effective collisions and formation of the products in a reaction

	Experimental class			Comparison class		
Chain patterns of interaction	[I(r)-I (i)-I(s)]			[I (i)-I (cu)-R(cu)-I(i)-Cmm]		
Patterns of interaction	[I]-[I]-[I]			[I]-[I]		
Frequency of Communicative approach (CA) in class talk	CA	Frequency	Percent	CA	Frequency	Percent
	[I]-N/A	3	75%	[I]-N/A	2	100%
	[I-R-E]-I/A	0		[I-R-E]-I/A	0	
	[I-R-F]-I/D	0		[I-R-F]-I/D	0	
	[N]-N/D **	1	25%	[N]-N/D	0	

** Occurrence in group discussion

7.13.4 L1 Episode 1.3.2: Comparison between experimental class and comparison class patterns of interaction and communicative approach (CA)

The findings of the teaching in **table 7-42** show that in the experimental class (C&TA class), the teacher's use of CA comprised of N/A (16.7 %), I/A (58.3 %), I/D (16.7 %) and N/D (8.3 %) compared to the teaching in the comparison class (NTA class) which was conducted using N/A (75 %) and I/A (25 %).

The results mean that 8.3 % of the teaching in C&TA was carried out in small groups to give the students an opportunity to develop their understanding of the effect of temperature on chemical rate of reaction.

Also, from **table 7-42**, the results show that the C&TA teacher used I/A (58.3 %) to introduce and develop ideas about the effect of temperature on chemical rate of reaction through *shaping, selecting, marking ideas, evaluating ideas* and this supported the students' understanding of the effect of temperature on chemical rate of reaction. It is evident from the results that NTA teacher used 25 % I/A with a limited use of initiation of explorative questions (Ie) and limited students' responses to explorative questions [R (aeq)].

Furthermore, results indicate that the C&TA teacher used **I/D** (16.7 %) to elicit and explore students' ideas about the effect of temperature on chemical rate of reaction using a series of 'genuine' questions, *offering listening* to different ideas, echoes, to emphasize the point, reinforce the correct answer, acknowledge of an answer as acceptable, and worked on different points of view. It was also evident that the C&TA teacher used **NI/A** (16.7 %) to present and maintain the development of students' understanding of the effect of temperature on chemical rate of reaction; reviews students' progress and summarize key ideas about the effect of temperature on chemical rate of reaction. The results show that the NTA teacher employed **NI/A** (75 %) and **I/A** (25 %) to teach the concept of the effect of temperature on chemical rate of reaction.

Table 7-42: Teaching effect of temperature on chemical rate of reaction

	Experimental class			Comparison class		
Chain patterns of interaction	[[I (e)-R (aeq)-E (i)-Echoes]- [I (e)-R (aeq)-R (aeq)-R (aeq)-E (i)-Echoes]-[I (e)-R (aeq)-N(F)-M (i)]-[I (e)-R (aeq)-R (aeq)-R (aeq)-Ev-S (i)]-[I (e)-R (aeq)-R (aeq)-N(F)]-[I (e)-R (aeq)-Ev-M (i)]-[I (e)-R (aeq)-R (aeq)-R (aeq)-Ev-S (pi) & S (i)]-[I (e)-R (aeq)-R (aeq)-Ev-S (pi) & S (i)]-[I (e)-R (aeq)-R (aeq)-E(i)] -[I (r)-I (s)]			[I (i)]-[I (e)-R (aeq)-I (e)-R (aeq)-E (i)]-[I (s)-I (i)]		
Patterns of interaction	[I-R-E]-[I-R-E]-[I-R-F]-[I-R-E]-[I-R-F]-[I-R-E]-[I-R-E]-[I-R-E]-[I-R-E]-[I-R-E]-[I]			[I]-[I-R-E]-[I]-[I]		
Frequency of Communicative approach (CA) in class talk	CA	Frequency	Percent	CA	Frequency	Percent
	[I]-NI/A	2	16.7%	[I]-NI/A	3	75%
	[I-R-E]-I/A	7	58.3%	[I-R-E]-I/A	1	25%
	[I-R-F]-I/D	2	16.7%	[I-R-F]-I/D	0	
	[N]-NI/D **	1	8.3%	[N]-NI/D	0	

** Occurrence in group discussion

7.13.5 L2 Episode 2.1-2.2: Comparison between experimental class and comparison class patterns of interaction and communicative approach (CA)

The findings in **table 7-43** show that in the experimental class (C&TA class) the teacher's use of CA comprised of **NI/A** (25 %), **I/A** (37.5 %), **I/D** (25 %) and **NI/D** (12.5 %), compared to the teaching in the comparison class (NTA class) which was conducted using **NI/A** (85.7 %) and **I/A** (14.3 %).

The results mean that 12.5 % of the teaching in C&TA was carried out in small groups to give the students an opportunity to develop their understanding of the graphical interpretation of the effect of temperature on chemical rate of reaction.

Also, from **table 7-43**, the results show that the C&TA teacher used **I/A** (37.5 %) to introduce and develop ideas about the graphical interpretation of the effect of temperature on chemical rate of reaction through shaping, selecting, marking ideas, evaluating ideas, and this supported the students' understanding of the graphical interpretation of the effect of temperature on chemical rate of reaction. It is evident from the results that the NTA teacher used 14.3 % **I/A**.

Furthermore, results indicate that the C&TA teacher used **I/D** (25 %) to elicit and explore students' ideas about graphical interpretation of the effect of temperature on chemical rate of reaction using a series of 'genuine' questions, *offering listening* to different ideas, echoes to emphasize the point, reinforce the correct answer, acknowledge an answer as acceptable, and worked on different points of view. It was evident that the C&TA teacher used **N/A** (16.7 %) to present and maintain the development of students' understanding of the graphical interpretation of the effect of temperature on chemical rate of reaction; reviews students' progress and summarize key ideas about the graphical interpretation of the effect of temperature on chemical rate of reaction.

The results show that the NTA teacher employed **N/A** (85.7 %) and **I/A** (14.3 %) to teach the concept of the effect of temperature on chemical rate of reaction. The results show that the NTA teacher's forms of interventions consisted mainly of questions (initiation) to confirm understanding [**I**(cu)] whether students were following his explanations with limited initiation of explorative questions [**I**(e)], use of classroom management moves (**Cmm**) and students' response to confirm understanding [**R**(cu)] with limited responses to explorative questions [**R** (aeq)].

Table 7-43: Teaching graphical interpretation of the effect of temperature on chemical rate of reaction

	Experimental class			Comparison class		
Chain patterns of interaction	[I (e)-R (aeq)-E (i)-Echoes]-[I (e)-R (aeq)-E (i) & Echoes -I (e)-R (aeq)-E(i)]-[I (s)]-[I (e)-R (aeq)-N (F)]-[I (e)-R (aeq)-Ev/ Echoes] - [I (e)-R (aeq)-M(i)-I (e)-R (aeq)-E (i)] - [I (s)]			[Cmm-Cmm-I (cu)-R (cu)-Cmm-I (s)]-[I (e)-R (aeq)-E (i)/I (cu)]-I (cu) -I(i)-I (s)-I (cu)-R (cu)-Cmm-I (i)& I (cu)-I (i)-I (s) & I (cu)-R (cu)]		
Patterns of interaction	[I-R-E]-[I]-[I-R-F]-[I-R-E]-[I-R-F]-[I-R-E]-[I]			[I]-[I-R-E]-[I]-[I]-[I]-[I]-[I]		
Frequency of Communicative approach (CA) in class talk	CA	Frequency	Percent	CA	Frequency	Percent
	[I]-N/A	2	25%	[I]-N/A	6	85.7%
	[I-R-E]-I/A	3	37.5%	[I-R-E]-I/A	1	14.3%
	[I-R-F]-I/D	2	25%	[I-R-F]-I/D	0	
	[N]-N/D **	1	12.5%	[N]-N/D	0	

** Occurrence in group discussion

7.13.6 L3 Episode 3.1: Comparison between experimental class and comparison class patterns of interaction and communicative approach (CA)

The findings in **table 7-44** show that in the experimental class (C&TA class), the teacher's use of CA comprised of **N/A** (40 %), **I/A** (40 %) and **N/D** (20 %) compared to the teaching in the comparison class (NTA class) which was conducted only using **N/A**.

The results mean that 20 % of the teaching in C&TA was carried out in small groups to give the students an opportunity to further develop their understanding of the graphical interpretation of the effect of temperature on chemical rate of reaction.

Also, from **table 7-44**, the results show that the C&TA teacher used **I/A** (40 %) to introduce and develop ideas about the graphical interpretation of the effect of temperature on chemical rate of reaction through shaping, selecting, marking ideas, evaluating ideas and this supported the students' understanding of the graphical interpretation of the effect of temperature on chemical rate of reaction.

Furthermore, results indicate that the C&TA teacher used **N/A** (40 %) to present and maintain the development of students' understanding of the graphical interpretation of the effect of temperature on chemical rate of reaction; reviews

students' progress and summarize key ideas about the graphical interpretation of the effect of temperature on chemical rate of reaction. The results show that the NTA teacher employed only **N/A** to further teach the concept of graphical interpretation of the effect of temperature on chemical rate of reaction. The NTA teacher's forms of interventions consisted of questions (initiation) to confirm understanding [**I**(cu)], use of classroom management moves (**Cmm**) and students' response mainly to confirm understanding [**R**(cu)].

Table 7-44: Teaching graphical interpretation of the effect of temperature on chemical rate of reaction (handing over responsibility to students)

	Experimental class			Comparison class		
Chain patterns of interaction	[I (e)-R (aeq)-E (i)- Echoes]-[I (e)-R			[I(r)-I(i)-I (cu)-R(cu)-I (i)-I (cu)-R(cu) – I(i)-I(s)-Cmm]		
Patterns of interaction	[I-R-E]- [I-R-E]-[I]			[I]-[I]-[I]-[I]-[I] (No interaction)		
Frequency of Communicative approach (CA) in class talk	CA	Frequency	Percent	CA	Frequency	Percent
	[I]- N/A	2	40%	[I]- N/A	5	100%
	[I-R-E]- I/A	2	40%	[I-R-E]- I/A	0	
	[I-R-F]- I/D	0		[I-R-F]- I/D	0	
	[N]- NI/D **	1	20%	[N]- NI/D	0	

** Occurrence in group discussion

7.13.7 L4 Episode 4.1: Comparison between experimental class and comparison class patterns of interaction and communicative approach (CA)

The findings in **table 7-45** show that in the experimental class (C&TA class), the teacher's use of CA comprised of **N/A** (21.43 %), **I/A** (14.29 %), **I/D** (57.14 %) and **NI/D** (7.14 %), compared to the teaching in the comparison class (NTA class) which was conducted using **N/A** (100 %).

The results mean that 7.14 % of the teaching in C&TA was carried out in small groups to give the students an opportunity to develop their understanding of the effect of concentration on chemical rate of reaction.

Also, from **table 7-45**, the results show that the C&TA teacher used **I/A** (14.29 %) to introduce and develop ideas about the effect of concentration on chemical rate of reaction through *shaping, selecting, marking ideas, evaluating ideas* and this

supported the students' understanding of the effect of concentration on chemical rate of reaction.

Furthermore, results indicate that the C&TA teacher used **I/D** (57.14 %) to elicit and explore students' ideas about the effect of concentration on chemical rate of reaction using a series of 'genuine' questions, *offering listening* to different ideas, echoes to emphasize the point, reinforce the correct answer, acknowledge an answer as acceptable, and worked on different points of view.

It was also evident that C&TA teacher used **NI/A** (21.43 %) to maintain the development of students' understanding of the effect of concentration on chemical rate of reaction; reviews students' progress and summarize key ideas about the effect of concentration on chemical rate of reaction. The results show that the NTA teacher employed only **NI/A** to teach the concept of the effect of concentration on chemical rate of reaction. The NTA teacher's forms of intervention consisted of limited explorative questions (Ie), limited students' responses to explorative questions [R (aeq)] and classroom management moves (**Cmm**).

Table 7-45: Teaching the effect of concentration on chemical rate of reaction

	Experimental class			Comparison class		
Chain patterns of interaction	[I(e)-R(aeq)-N(F)-R(aeq)-R(aeq)-R(aeq)-R(aeq)-N(F)]- [I(e)-R(aeq)-N-R(aeq)-N (F)]-[I(e)-R(aeq)-N(F) - I(e)-R (aeq)-I(e)-R (aeq)- I(e)-R(aeq)-I(e)-R (aeq)-N (F)]- [I(e)-R (aeq)-R (aeq)-R (aeq)-R (aeq)-R (aeq)-R (aeq)-R (aeq)-N (F)] - [I(e)-R (aeq)-N (F)]- [I(e)-R (aeq)-I(e)-R (aeq)-Ie-R (aeq)-N-R (aeq)-N-R (aeq)-N(F)] -[I(e)-R(aeq)-N (F)] -[I (e)-R (aeq)- E(i) & M-] [I(i) & I(e)- R (aeq)-E (i)]- [I (s)-I(r)-I(s)-]			I(i)-Cmm-I(e)-R (aeq)-I(e)-R (aeq)- I(e)-Cmm-I (s)]		
Patterns of interaction	[I-R-F]-[I-R-F]-[I-R-F]-[I-R-F]-[I-R-F] - [I-R-F] -[I-R-F] -[I-R-F]-[I-R-E]-[I-R-E]- [I]			[I] - [I-R...] [I] (No interaction)		
Frequency of communicative approach (CA) in class talk	CA	Frequency	Percent	CA	Frequency	Percent
	[I]-NI/A	3	21.43%	[I]-NI/A (F=2)	2	100%
	[I-R-E]-I/A	2	14.29%	[I-R-...]	0	
	[I-R-F]-I/D	8	57.14%	[I-R-F]-I/D	0	
	[N]-NI/D**	1	7.14%	[N]-NI/D	0	

** Occurrence in group discussion

7.13.8 L5 Episode 5.1: Comparison between experimental class and comparison class patterns of interaction and communicative approach (CA)

The findings in **table 7-46** show that in the experimental class (C&TA class) the teacher's use of CA comprised of **N/A** (7.69 %), **I/A** (23.08 %), **I/D** (61.4 %) and **NI/D** (7.69 %) compared to the teaching in the comparison class (NTA class), which was conducted using **N/A** (75 %) and **I/A** (25 %).

The results mean that 7.69 % of the teaching in C&TA was carried out in small groups to give the students an opportunity to develop their understanding of the graphical interpretation of the effect of concentration on chemical rate of reaction.

Also from **table 7-46**, the results show that C&TA teacher used **I/A** (23.08 %) to introduce and develop ideas about the graphical interpretation of effect of concentration on chemical rate of reaction through *shaping, selecting, marking ideas, evaluating ideas*, and this supported the students' understanding of the graphical interpretation of effect of concentration on chemical rate of reaction.

Furthermore, results indicate that the C&TA teacher used **I/D** (61.4 %) to elicit and explore students' ideas about the graphical interpretation of effect of concentration on chemical rate of reaction using a series of 'genuine' questions, *offering listening* to different ideas, echoes to emphasize the point, reinforce the correct answer, acknowledge an answer as acceptable, and worked on different points of view.

The results further show that the C&TA teacher used **N/A** (7.69 %) to maintain the development of students' understanding of the effect of concentration on chemical rate of reaction; reviews students' progress and summarize key ideas about the effect of concentration on chemical rate of reaction. The results show that the NTA teacher employed **N/A** (75 %) and **I/A** (25 %) to teach the concept of the graphical interpretation of effect of concentration on chemical rate of reaction. The NTA teacher's forms of intervention consisted of questions (initiation) to confirm understanding (Icu), classroom management moves (**Cmm**), limited explorative questions [**I(e)**], limited students' responses to explorative questions [**R(aeq)**] and students' responses to confirm understanding [**R(cu)**].

Table 7-46: Teaching graphical interpretation of the effect of concentration on chemical rate of reaction

	Experimental class			Comparison class		
Chain patterns of interaction	[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-N-R(aeq)-N(F)]-[I(e)-R(aeq)-I(e)-R(aeq)-E(i)]-[I(e)-R(aeq)-N-R(aeq)-N(F)]-[I(e)-R(aeq)-N]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-I(e)-R(aeq)-E(i)-I(s)]-[I(e)-R(aeq)-I(e)-R(aeq)-S(i)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-N(F)]-[I(e)-R(aeq)-E(i)] & M]-[I(r)-I(s)-I(i)]			[I(e)-R(aeq)-Ev/Echoes]-[I(cu)-R(cu)-Echoes & I(cu)-I(s)-I(cu)-Cmm-I(cu)-I(cu)-I(e)-I(s)-I(cu)-R(cu)]		
Patterns of interaction	[I-R-F]-[I-R-F]-[I-R-E]-[I-R-F]-[I-R-F]-[I-R-F]-[I-R-E]-[I-R-F]-[I-R-F]-[I-R-F]-[I-R-F]-[I-R-E]-[I]			[I-R-E]-[I]-[I]-[I]		
Frequency of communicative approach (CA) in class talk	CA	Frequency	Percent	CA	Frequency	Percent
	[I]-N/A	1	7.7%	[I]-N/A	3	75%
	[I-R-E]-I/A	3	23.1%	[I-R-E]-I/A	1	25%
	[I-R-F]-I/D	8	61.5%	[I-R-F]-I/D	0	
	[N]-N/D**	1	7.7	[N]-N/D	0	

** Occurrence in group discussion

7.13.9 L6 Episode 6.1: Comparison between experimental class and comparison class patterns of interaction and communicative approach (CA)

The findings in **table 7-47** show that in the experimental class (C&TA class) the teacher's use of CA comprised of **N/A** (57.14 %), **I/A** (28.57 %) and **N/D** (14.29 %), compared to the teaching in the comparison class (NTA class) which was conducted only using **N/A**.

The results mean that 14.29 % of the teaching in C&TA was carried out in small groups to give the students an opportunity to further develop their understanding of the graphical interpretation of the effect of concentration on chemical rate of reaction.

Also from **table 7-47**, the results show that the C&TA teacher used **I/A** (28.57 %) to introduce and develop ideas about the graphical interpretation of the effect of concentration on chemical rate of reaction through shaping, selecting, marking ideas, evaluating ideas and this supported the students' understanding of the graphical interpretation of the effect of concentration on chemical rate of reaction.

Furthermore, results indicate that the C&TA teacher used **N/A** (57.14 %) to present and maintain the development of students' understanding of the graphical

interpretation of the effect of concentration on chemical rate of reaction; reviews students' progress and summarize key ideas about the graphical interpretation of the effect of concentration on chemical rate of reaction. The results show that the NTA teacher employed only **NI/A** to further teach the concept of graphical interpretation of the effect of concentration on chemical rate of reaction. The NTA teacher's forms of intervention consisted of questions (initiations) to confirm understanding [I(cu)] and classroom management moves (**Cmm**).

Table 7-47: Teaching graphical interpretation of the effect of concentration on chemical rate of reaction (handing over responsibility to students)

	Experimental class			Comparison class		
Chain patterns of interaction	[I(r)-I(i)-]-[I(e)-R(aeq)-E(i)-Echoes]- [I(e)-R (aeq)-E(i)]-[I(r)-I(s)]			[I(r)-I(i)-I(cu)-I(s)-I(cu)-Cmm-Cmm- I(i)]		
Patterns of interaction	[I]- [I]-[I-R-E]-[I-R-E]-[I]-[I]			[I]-[I]-[I]-[I] (No interaction)		
Frequency of communicative approach (CA) in class talk	CA	Frequency	Percent	CA	Frequency	Percent
	[I]- NI/A	4	57.14%	[I]- NI/A	4	100%
	[I-R-E]- I/A	2	28.57%	[I-R-E]- I/A	0	
	[I-R-F]- I/D	0		[I-R-F]- I/D	0	
	[N]- NI/D **	1	14.29%	[N]- NI/D	0	

** Occurrence in group discussion

7.13.10 Overall summary of classroom talk analysis

Overall, the results demonstrate that by employing mixed CA, the C&TA class was able to support students' understanding of the chemical rate of reaction concept more compared to the NTA class, as confirmed by post-results in the previous sections.

The table 7-48 and figure 7-6 below show that overall the key features of the C&TA teaching sequence, which supported the students' understanding of chemical rate of reaction, consisted of teacher lead questions through **I/A** (35.3 %) to introduce and develop key ideas; students' response to explorative questions (**R** (aeq) through **I/D** (28.2 %) to elicit and explore students' ideas and engagement of students in small group work through **NI/D** (9.4 %) and reviewing (summarising) key scientific points through **NI/A** (27.1 %). In comparison to NTA teaching, it was clear that there was a tendency of the teacher to present the scientific views to the students through **NI/A** (87.2 %), and limited use of **I/A** (12.8 %). It was evident that NTA teachings were carried without an explorative approach through **I/D**, and small group work through **NI/D**. As such the NTA students were not actively involved in their learning process

and the teacher was not informed of the students' ideas about the concepts of chemical rate of reaction.

Table 7-48: Overall results of classroom talk

Communicative approach (CA)	NI/A	I/A	I/D	NI/D
Experimental class	23 (27.1 %)	30 (35.3%)	24 (28.2%)	8 (9.4%)
Comparison class	34 (87.2%)	5 (12.8%)	0 (0%)	0 (0%)

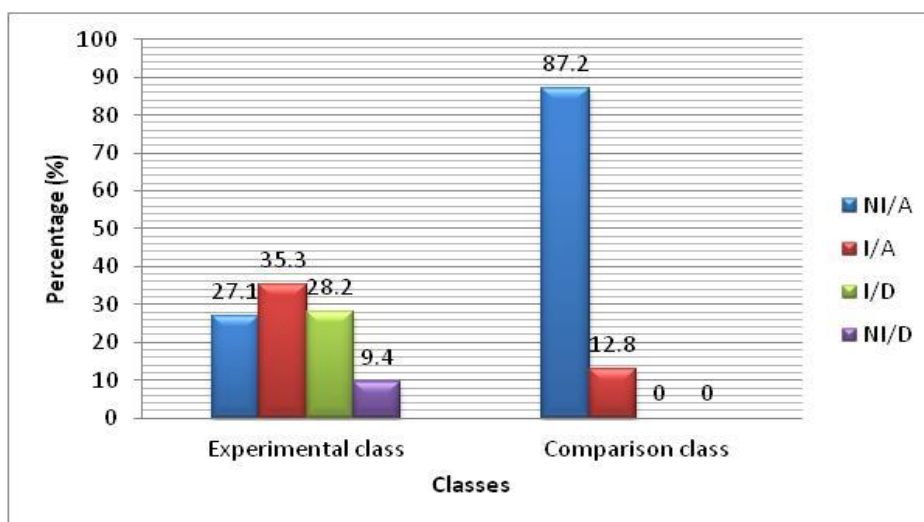


Figure 7-6: Overall percentage use of CA by Experimental and Comparison classes across all six lessons

Tables of key features of the lessons provide evidence on the use of varieties of CA teaching strategies to support students' understanding in C&TA class. These included the teacher's forms of intervention such as exploring ideas, marking key ideas, shaping students' ideas, evaluating, echoing to emphasize the key ideas, sharing ideas, reviewing and summarising key scientific ideas to support students' understanding of chemical rate of reaction.

These forms of strategies were less frequently employed by the NTA teaching as the NTA lessons were more characterised by the use of **NI/A** (a didactic approach) and strong transmission of ideas from the teacher. The teacher's forms of intervention were mainly classroom management moves (**Cmm**). For example, take down notes, draw up the diagrams, hurry-up, and initiation to confirm understanding (**Icu**), such as: 'are we together?', 'It is clear?', 'Is that clear?' were very prominent in the NTA class. This approach offers poor engagement, as chances for students to verbalise their ideas are limited and does not then inform the teacher of the students' level of understanding and knowledge development, hence teacher's support to promote students' understanding is often missed out. This might also

explain why the NTA class students achieved lower scores in applying scientific explanations to aspects of chemical rate of reaction.

It is clear that the students' responses from the C&TA class were responses to explorative questions [R(aeq)] which required students to think before responding, whereas students' responses from the NTA class largely were responses to confirm [R(cu)] that they were following what the teacher said.

Overall, it can be seen that the teaching in the experimental class (C&TA class) was more supportive to the students' learning compared to the teaching in the comparison class (NTA class).

In the next section, I present the actual teaching patterns in reference to the C&TA planned teaching patterns, so as to make an evaluation about the teaching, in order to judge to what extent the C&TA actual teaching patterns consisted of, with the design of C&TA teaching patterns.

7.14 Comparison between the Planned C&TA and Actual Teaching (AT)

Patterns

In this section, I present comparisons between the planned C&TA teaching sequence (see **section 4.15**) and Actual Teaching (AT) patterns in order to ascertain whether the teacher followed the design of C&TA teaching patterns.

	Lessons teaching patterns	Pattern altered / included
	L1: Episode 1.2.1 Definition /determination of rate of chemical reaction	
Planned C&TA	NI/A & I/A	
Actual Teaching (AT)	NI/A- I/A & I/D	Included: I/D
NTA Actual Teaching	I/A & NI/A	
	L1: Episode 1.3.1 Proper orientation of reacting particles	
Planned C&TA	NI/D- I/A & NI/A	
Actual Teaching (AT)	NI/D- NI/A-I/A & I/D	Included: I/D
NTA Actual Teaching	NI/A	
	L1: Episode 1.3.2 Determination of activation energy, E_a	
Planned C&TA	NI/D-I/A & NI/A	
Actual Teaching (AT)	NI/A & NI/D	
NTA Actual Teaching	NI/A	
	L1: Episode 1.3.2 Effect of temperature on chemical reaction (collision theory)	
Planned C&TA	NI/D-I/A & NI/A	
Actual Teaching (AT)	NI/D-I/A-I/D & NI/A	Included: I/D
NTA Actual Teaching	NI/A & I/A	
	L2: Episode 2.1-2.2 Graphical interpretation of temp. effect on chemical rate of reaction: Real laboratory investigation	
Planned C&TA	NI/A-I/A-NI/D & NI/A	
Actual Teaching (AT)	NI/A-NI/D-I/D & I/A	Included: I/D
NTA Actual Teaching	NI/A & I/A	
	L3: Episode 3.1 Graphical interpretation of temp. effect on chemical rate of reaction: Virtual laboratory investigation-computer modelling	
Planned C&TA	I/A-NI/D-I/A & NI/A	
Actual Teaching (AT)	NI/A-NI/D & I/A	
NTA Actual Teaching	NI/A & I/A (more real laboratory investigation)	
	L4: Episode 4.1 Effect of concentration on chemical reaction (collision theory)	
Planned C&TA	I/D-NI/A-I/D-NI/D-I/A & NI/A	
Actual Teaching (AT)	NI/A-NI/D-I/D & I/A	
NTA Actual Teaching	NI/A	
	L5: Episode 5.1 Graphical interpretation of concentration effect on chemical rate of reaction: Real laboratory investigation	

Planned C&TA	NI/A-I/A-NI/D & NI/A	
Actual Teaching (AT)	NI/A-NI/D-I/D&I/A	Altered and included: I/D
NTA Actual Teaching	I/A & NI/A	
	L6: Episode 6.1 Graphical interpretation of concentration effect on chemical rate of reaction: Virtual laboratory investigation-computer modelling	
Planned C&TA	I/A-NI/D-I/A & NI/A	
Actual Teaching (AT)	NI/A-NI/D & I/A	
NTA Actual Teaching	NI/A (more real laboratory investigation)	

Comparing the details of the planned C&TA teaching sequence presented in **Chapter Four** and Actual teaching patterns, it can be seen that the teacher, to a large extent, followed the sequence of interactions.

7.15 Summary evidence to answer research question 2 (RQ2)

1. The evidence from analysis showed that C&TA teaching had more use of interactive/authoritative (I/A) and non-interactive/dialogic (NI/D) than the NTA teaching sequence. There was a total absence of non-interactive/dialogic (NI/D) patterns in the NTA class which indicated a lack of group work and discussions supported by the teacher. As pointed out earlier, this led to poor engagement as chances for NTA students to speak out their ideas and to think were limited, subsequently resulting in low level of understanding and low performance in the post-test, compared to the C&TA class.
2. The implementation of the C&TA provides some evidence that the teacher worked together with his students in ways that were generally in line with the C&TA teaching sequence.
3. The use of computer simulations, modelling spread sheets and worksheets provided opportunities for the students to discuss and share their ideas in groups. The computer simulations made abstract ideas of chemical reaction clearer and more understandable to the C&TA class. In addition, the computer modelling spread sheet helped to develop and maintain students' understanding of the relationship between temperature, concentration of reactants and time or rate of chemical reaction to come to a stop or finish. This was more interactive as they worked together in their respective groups.
4. Furthermore, the session on the whole classroom interaction, where different groups presented ideas about the content proved helpful as the teacher used the opportunity to address students' misconceptions of many aspects of chemical rate of reaction.

CHAPTER EIGHT

8 ANALYSIS AND PRESENTATION OF INTERVIEW RESULTS

8.1 Introduction

This chapter presents evidence to support research questions 3 and 4. Chapter Eight covers the C&TA teacher and students' perceptions after each lesson and at the end of the intervention. The results presented were obtained through transcriptions and analyses of interviews with the C&TA teacher and students.

8.2 The teacher and students' perceptions after each lesson

In this sub-section, I present results of the follow up interviews taken immediately after each lesson on the students' understanding and the teacher's perception of the lesson.

8.3 Lesson 1 episode 1.2-1.3 Chemical rate of reaction- Effect of temperature on rate of reaction

8.3.1 The teacher's perception

After the lesson, the teacher said that although he had not evaluated fully, the lesson was very interesting. He explained that the process was interesting because students were able to clearly observe the behavior of atoms with the computer simulations, and that the class was '*enjoyable really...*'. In terms of what did work out, he said that some students were probably not able to get on with the computer usage, but there was no hard time.

The C&TA teacher said in terms of students' understanding, using C&TA had done much indeed. He said that students were able to see what happens to reacting particles when temperature increases or decreases. He pointed out that, '*actually not only the students but including myself...we got to know what actually takes place when temperature is increased or decreased*'. He went on to say that the simulated energy diagram level was good because students would clearly see that when temperature increases, kinetic energy, KE also increases. This means that as temperature increases, more molecules will have higher KE, thus the fraction of molecules that have high enough KE to exceed the minimum energy (activation energy, E_a) needed for a reaction also increases, and this really was useful in bringing out the relationships between temperature, activation energy, E_a and rate of reaction.

According to the teacher, the lesson was understood by most students.

8.3.2 Students target group's perceptions

During the interview after the end of the lesson, the students (eight) in the target group were able to correctly define rate of reaction. They stated that:

'Is the amount of products formed per unit of time?'

They observed that using the simulations made it more understandable:

'I found no big challenge actually, because at least it was more understandable, more than just watching when they are adding reactants and you do not see anything taking place. Yet they tell you this is produced, new products are formed and there is nothing you are seeing taking place.'

'I liked the testing part of it, where you see the atoms colliding to form products... this made it easier to remember.'

The students were also able to correctly state and explain the effect of temperature on rate of reaction. For example:

'the increase in temperature leads to the increase in the rate of reaction, hence more collisions between atoms and more products are formed.'

'The decreases in temperature leads to low rate of reaction hence less products are formed.'

'When the temperature is increased, the rate of reaction is also increasing at the same time, hence making more products ...and the random movement of the molecules made the collisions faster.'

The students said that the lesson was more practical and enjoyable.

8.4 Lesson 2 episode 2.1-22 Effect of temperature on rate of reaction (Laboratory experiment investigation)

8.4.1 The teacher's perception

The teacher said the lesson was good and students were able to follow the instructions and carry out the practical work. He observed that there was general involvement of the students, and it was clear that members in groups had shared responsibility, measuring volume of reacting solutions, recording reaction time, heating, and at least everyone was seen to be involved. In terms of understanding, he said the lesson was well understood by students. Referring to the groups' responses, he said the explanations students gave were correct, meaning that they understood the lesson.

8.4.2 Students target group's perceptions

At the end of this lesson, the target group of students were able to use the ideas from the computer to explain what was happening in the solution during the experiment to determine rate of reaction. The following is what they had to say:

'I think the computer thing brings the ideas of what was happening in the solution because last time we saw the molecules colliding in the computer, so now we knew what was taking place in the solution.'

'the chemicals ...the chemicals also tend to move...the chemical themselves move because when you heat the solution...take for example, when you boil water...the water starts to move...those atoms between water molecules they are the ones that get heat up...they are the ones that starts moving...so, I think you just apply that to the solution...if the temperature increases, the solution also tend to...move.'

'the way I see it, there in the computer we were using A and BC on the reactant side but on the product side we were getting AB and C. That is why here we got water, gas and yellow precipitate. The water and gas are in the form of C while the yellow precipitate was the AB we were getting there in the computer'

The students also said the lesson was good and interesting, and that working in groups was helpful, as one student explained:

'It is better, if you are in groups for example, like you have an idea, you know how to state it but you do not know how to explain, other members can help in giving the explanations. So when you combine your ideas you end up with good explanations and answers.'

They all said that the lesson was good, interesting and they were able to understand the concept.

8.5 Lesson 3 episode 3.1: Effect of temperature on rate of reaction (Modelling with computer spreadsheets)

8.5.1 The teacher's perception

For this lesson, the teacher said that, "the lesson was ok!" He stated that it was time saving, saved chemicals, and it brought out the same ideas that students would get if they had done another practical. He also said that, it was clear to students because the graphs had similar shapes, as they had plotted and he believed they understood the relationship between temperature and rate of reaction.

8.5.2 Students target group's perceptions

After the lesson, the target group of students were able to use graphs to explain the relationship between temperature and time/rate of reaction. The following is what they had to say:

'I think, the idea of practice with computer allows you to see the relationship between temperature and rate of reaction...it was just a summary of what we had learnt because I understood things from the previous lesson.'

'I saw that when you increase the temperature, the rate also increases.'

'For me it was ok...everything was programmed well. I enjoyed because you could try with any number...change temperatures but the shape of the graphs would still remain just like how we plotted in the practical exercise.'

It was evident that students also enjoyed and understood the lesson, as remarked by one student:

'For me it was also good because I learnt so many ideas from there and made me happy!'

This indicated that students had understood how changing temperature affects time or rate of reaction to come to a stop or finish.

8.6 Lesson 4 episode 4.1: Effect of concentration on rate of reaction (Computer simulations)

8.6.1 The teacher's perception

For this lesson, the teacher said that some students confused the explanation for concentration effect on the rate of reaction with the explanation of temperature effect. The idea of using kinetic energy, K.E., which is used to explain temperature effect, was believed to also apply to concentration, but later they understood that it only applied to temperature. He said this was attributed to the computer which proved useful, after he explained to them using the simulations, 'that increasing the numbers of particles does not increase the speed of moving particles'. He said students were able to see and that helped them to understand, and many were able to explain correctly that the more the numbers of particles, the closer they are to each other, so they collide easily and react often, hence an increase in rate of reaction.

Commenting on the group work, the teacher said:

'actually...since during classroom interactions, you could see that the responses the group members agreed on were correct...I think it was an indication that members discussed and came up with correct answers.'

8.6.2 Students target group's perceptions

The students stated that this lesson was challenging and confusing. However, they said later they were able to understand. When I asked them to explain, the following is what they had to say.

For Challenge

'...I got confused when I used less numbers of atoms, there was no change...and the speed was the same....and when I used more atoms, I saw the same speed but I saw products being formed, then I was confused.'

'...I was also disturbed because of that kinetic energy, K.E. I thought that when you increase the concentration, K.E increases but after that I saw it...I had a problem with it actually, when I increase the concentration and maintained the temperature and I found that the K.E was constant also...I was mixed up!'

For Understanding:

'It was interesting because, I got to learn that the temperature is the only factor affecting the rate of reaction...that can make those atoms move faster. I thought maybe there are other factors like pressure that can affect the speed but I learnt it is only temperature.'

'For me it was challenging but interesting because I was used to temperature because when you increase the temperature, it increases the rate of reaction but the same also happen for concentration but explanation for the concentration was different from that of temperature...that made me confused.'

'For me, it was ok...because for the temperature, the explanation could not be applied for the concentration...there the number of atoms were moving at a faster rate but here the atoms were moving at a constant rate, but when you increase the concentration...collisions increases and products were formed faster. It was quite interesting for me!'

When I asked them to explain the effect of concentration of reactants on time/rate of reaction, they were able to respond with a correct explanation indicating that at the end of the lesson they understood. These were some of their explanations:

'when you increase the number of particles, they become very compact, there is very high chances of the particles meeting because they have a small distance between them to meet each other but when they are less,

they will have a large distance between them and they take time to meet and there will be very few products formed when the particles are less.'

'When you increase the particles, they will start colliding because the collision field is decreased...so they collide more frequently and form products.'

8.7 Lesson 5 episode 5.1: Lesson 5: Effect of concentration on rate of reaction (Laboratory experiment investigation)

8.7.1 The teacher's perception

The teacher stated that the relationship between volume, moles and rate were challenging. He said relating numbers of moles in a given volume is always challenging anyway, and that some students found it challenging to understand how volume and moles links to concentration. He said after explaining that it became clear and students were able to follow.

When I asked whether students were able to draw ideas from what they saw on the computers, he answered as follows:

'Quite a number of students were able to draw ideas from the computer to explain ...and you could see that they actually were aware of what was going on in the solution.'

8.7.2 Students target group's perceptions

The interview with the target group revealed that this lesson was challenging and complicated before the teacher's intervention. These are what they had to say:

'It was somehow complicated ...I do not know, maybe because it was our first time to carry out such experiment... but we found it a bit complicated.'

'...before, the teacher came in to explain, it was complicated.'

When I asked whether they were able to use the ideas from the computer to explain what was happening in the solution during the experiment to determine rate of reaction, one student responded as follows:

'...like when we were looking at the computer...like when you increase the number of particles on the screen, you see clearly that the distance between the particles reduces. So when you are doing the experiment practically...uhm you kind of have that knowledge of what you saw on the computer. It makes you understand what is going on in the solution.'

From the lesson observation, the concept of volume and time of the reaction was confusing to the class. So when I asked how they overcame the challenge of the concept and whether they were able to explain, these were the students' responses:

'when the volume is increase, you are also increasing the concentration and when you increase the concentration, it means you are increasing the number of the particles...and when the numbers of particles are increased, it makes them to collide at a faster rate in the process... and the products are formed at a faster rate...'

'Actually, when you increase the volume, you have increased the concentration in that you have increased the number of particles. The moment you increase the particles, you have reduced the space between the particles and when you have reduced the space between the particles, you are making the particles to collide easily per unit time and hence the rate of reaction is increased.'

These responses are correct and indicate that the students understood the lesson.

8.8 Lesson 6 episode 6.1: Effect of concentration on rate of reaction (Modelling with computer spreadsheets)

8.8.1 The teacher's perception

For this lesson, the teacher said the lesson was good. He said it provided students with opportunities to explore the relationship between concentration and rate of reaction. He mentioned that it gave students more insight and he believed students had a proper understanding of the effect of concentration on rate of reaction. He further said that the most important thing is that students are able to practice with spreadsheets, without having to conduct another practical, which was useful.

8.8.2 Students target group's perceptions

After the lesson, the target group students were able to use graphs to explain the relationship between concentration and time/rate of reaction, although some expressed meeting challenges of operating the computers. Here are some examples of what they had to say:

For Challenges:

'Today's lesson was not like the best...because my computer was disturbing...by the time I reached on the graphs I was confused.'

For Understanding:

'For me it was ok...everything was programmed well. So I did not have any problem.'

'From what I learnt, if you put the volume at 2, the rate would also increase by 2....'

'For me I think, it was just a summary of what we had learnt because I understand things from the previous lesson. So for me it was just summary that involved some practice...I would say exercise!'

Again, here we see that students expressed that they were able to practice, hypothesize and try out their ideas about what happens to the rate of reaction when concentration of a reactant increases. Thus, students were able to broaden their understanding of the effect of concentration.

8.9 The teacher and students' perceptions at the end of the C&TA intervention

In this sub-section, I present the results of the interviews on the teacher and students' perceptions on major benefits, challenges and comparisons between C&TA and NTA. The results are presented thematically basing on an analysis of the teacher and students' views about C&TA, using the coding schemes presented in **Chapter Five**.

8.9.1 Benefits of using C&TA teaching sequence

Major benefits of the use of C&TA have been presented thematically according to the teacher's and students' perspectives.

8.9.2 Teacher's perceptions

According to the teacher, using the C&TA teaching sequence helps to:

Increase attentiveness and engagement

'With computers in front of students they were all eager to see what it was they were learning. You see when you enter the computer lab and the students all fight for computers to ensure that they are going to do the things themselves. Once in front of the computer they are able to move together with the teacher'.

Make abstract concepts clearer and understandable. For example, the teacher said:

'It has given me a lot of understanding of how we can make such abstract information to be made simpler especially to these juniors. In fact some of us had never even thought that particles really collide when they are many and we also thought that every collision leads to formation of product, but sometimes it does not.

As a teacher I learnt that in chemical reaction there are factors that affect rates of reaction, which include temperature, concentration, and surface

area. That...in all these cases particles are colliding because the collision theory is employ. That...not every collision leads into a product unless particles are well arranged, what we called proper orientation they could not form products. So we come to learn some of these ideas, and it was very interesting'.

He further commented that the teacher–student discussions were a very good approach in teaching some of the abstract ideas.

Save time in the laboratory. For instance, the teacher said the spreadsheets brought out the same ideas as expected in the laboratory setting:

“Using computers and group discussion is very useful in addressing alternative ideas, for example the use of spreadsheets revealed that changing the values of given experimental values does not change the kind of graph- it remains as it is in the normal setting, you may not think of it unless you conduct another experiment which requires a lot of preparations and is time consuming, this approach saves time!”

Modeling with spreadsheets saves chemicals and brings out the ideas about same concepts which would be obtained by using other sets of laboratory investigations of temperature and concentration effects on chemical rate of reaction.

Working on computers brings about conceptual change. The teacher reported that a learner or user could not forget the concept that easily. This is proof of the benefits of ‘do it yourself and learn it by heart’.

Build confidence and interpersonal skills in learners. Allowing students to discuss their both their good and wrong ideas gave them confidence. The teacher said ‘the learners can come to learn of where they have made errors and this also helps to create in them scientific thinking and arguments’.

8.9.3 Students’ perceptions

It was evident that using C&TA teaching sequence had:

Motivational effect on students

‘Yes... we enjoyed the lessons. When the first lesson was introduced to the class in the computer lab, there were people with a negative attitude to chemistry, because every time things were written on the blackboard and we usually mainly do as a whole class. In most cases people just sit behind and they do not participate. But during the discussion, we were put in a small group everyone participated, taking down what was being studied’.

Increased class participation

According to the focus group interview students appreciated C&TA lessons and there was evidence of active learning: For example, a student said:

'In a small group, there is a way everyone gets to participate; each person has to write the reaction'.

Increase attentiveness and engagement

'In groups there is high concentration by students, someone concentrates much more than as the whole class and someone gets to understand if his / her friend explain to him what is happening and he himself can see it happening. There someone gets to understand it better than other classes. People have got it very well because they have done it practically'.

Support slow learners

The evidence from the experimental class shows that various aspects of achievement can be improved by integrating simulations into topics that students find conceptually difficult. The simulations were found to benefit students with low reasoning abilities in particular, enabling them to cope with learning scientific concepts and principles which require relatively high cognitive skills. For example, a student pointed out that:

'People learn differently, other people get things from the blackboard. Like some of us who take time... to like get things from the blackboard, may be the other method of studying from the computer was a little better...much better!'

Using computer simulations brings clarity to abstract concepts and therefore betters students' understanding. Students observed that computers created a real scenario of what at first appeared idealistic. One particular participant pointed out that if only this is what was done right from the beginning with all topics that have practical tasks then they would have each at least understood the working of chemistry.

Working on computers brings about conceptual change

'It did not only help us in chemical rate of reaction but other topics which need this kinetic theory. Now we are able relate to it and hence better our understanding of chemistry reactions'.

Another student testified that when he was going to sit for the post-test he had not picked any book to read, he just did it by himself, so it stuck in his mind. He went on to say that however when the teacher would come every day, write information on the blackboard for them to go and read, that actually made it hard for him to understand, because he had to refer to the book every now and again, but when he did it himself there it just stuck in his mind, even if he had not read anything.

Students further noted that using computers to study was a way of gaining more compared to learning on the blackboard because on the computer, they said one could see something practically, but when on the blackboard one just assumed and said it may be something like this... but on the computer one was able to see the molecules of reactants. They further argued that when working with the computer you could see the particles during simulations, but when you were dealing with chemicals you could not see the particles inside. Thus, when working with the computer one is able to visualize the particles colliding with each other. So when one combines knowledge from the computer with chemical knowledge, they can easily understand what is happening during chemical reactions during real experiments.

C&TA helps to improve working relationships between students. The group interviewees observed that when working in groups, secretaries chosen had to be friendly, pay attention to the discussion and have good abilities because as one gave his or her view, you got to understand more. They further noted that if one did not understand, they could go and actually ask their peers to explain this to them. One particular respondent argued that it gave confidence and respect to contributors as they aired their views, and the others listened. Another declared that:

'When working with fellow students, they have to tell you their ideas and since you are not only two, someone will be in position at least to explain to you. If you do not understand the idea, s/he will help you bring it to the language you understand'.

C&TA bridges the gap between the teacher and students

This brings the students closer to the teacher because, whenever, the students are on computers observing the phenomena, there is also teacher-student interaction taking place.

For example, a student observed that:

'some students were not free with teachers; they had the attitude that the teacher was unfriendly, but during C&TA lesson, they interacted with their friends, the normal people they chatted with her everyday and would go through these friends to get their queries to the teacher'.

'C&TA should continue, because, before, I had a negative attitude towards the teacher (Mr. Y) and the subject but now I have began to like the teacher and the subject, chemistry'.

In so doing the teacher would pay particular attention to such a group, which bridges that gap between the learner and the teacher. Thus, the teacher helps students to understand the learning phenomena and it helps students in class to pay attention to the teacher.

Discussions in groups are helpful to students

Students interviewed were quick to explain that sometimes when they missed out some points explained by the teacher, during the discussion friends were able to remind each other. One learner noted that:

'For example the concept of kinetic energy is not involved in concentration but in temperature. Sometimes when holding the discussion, some students may use it to explain the effect of concentration. This became more apparent that it is only involved in the temperature when pointed out during discussions. So it becomes ... like don'ts and dos... don'ts and dos... so you get it right away'.

C&TA promotes peer learning

It was articulated that some people were naturally selfish; when asked they could not easily share their knowledge in class. But when working in groups, team spirit overcame their selfish character. They were able to discuss and share ideas freely as the goals of the group members were to present correct answers and gain the marks. They asserted that selfish people were forced to air their views while working in groups or they would feel ashamed that they were not making any contribution. In other words, group work helped some students develop a sense of responsibility; the feelings of letting other people down prompted them to work to ensure success. This is the zone of proximal development (ZPD), peers becoming compelled to assist others to learn.

8.10 Summary of the teacher and students' perceptions on benefits of using C&TA

- Makes abstract concepts clearer and understandable
- Saves school science chemicals
- Saves time from conducting laborious science experiments
- Brings about conceptual change
- Motivates students
- Supports slow learners
- Helps to improve working relationship between the teacher and students / learners
- Promotes peer learning through group discussions

8.11 Challenges of using C&TA teaching sequence

Challenges of the use of C&TA have been presented according to the teacher and students' perspectives.

8.11.1 Teacher's perceptions

Lack of computer skills and competence

Using computers required one to have skills and was a challenge, unless one had somebody to help them operate the machine. The teacher admitted that operating the smart board had been a challenge, apart from that, other areas had been normal.

Lack of evaluation knowledge of the learning software

Simulations had presented a challenge in that when investigating the effect of temperature on rate, there was the possibility of using single collision and many collisions. However, using many collisions was more suitable for investigating the effect of concentration. This was because when using many collisions it was confusing as it would appear as if the atoms were moving quickly, a phenomenon only affected by change in temperature. So, it was up to the teacher to make this distinction clear that when investigating temperature, the use of single collision and the use of many collisions for investigating the effect of concentration.

8.11.2 Students' perceptions

The interview results show that there was negotiation and agreement failure over the correct answers. One learner acknowledged that:

'It is good to work in groups, all of you bringing out views, but the problem is when one fails to get the point you are trying to bring out...is like...no, this is not happening yet you are all coming to the conclusion that this is what is happening! (Challenge concerning what is correct and wrong). Negotiation is required to reach the agreed correct answer'.

Lack of objective direction during discussion within the group

Sometimes group discussions are ineffectively directed by the student group leader. For example, students observed that while in groups, there was usually a sense of every person being knowledgeable, yet each had different ideas. No one wanted to give up on their own idea. Everyone pushed for their answer to be the correct one. Thus disagreements over ideas were perceived as a put-down. However, when probed during the interview on whether the teacher was very helpful in guiding

them, students acknowledged that in such circumstances the teacher came in to help to resolve their disagreements. This approach makes scientific ideas clearer to the learners.

Unequal contributions of ideas

There is a tendency of some students to sit back during group discussion. In class, when students are working in groups, there is a feeling of letting others do things / work. One respondent raised the issue of others tending to sit back leaving the work to the secretary (someone writing down agreed upon ideas) on the worksheet. It was noted that the task of taking down the record of what was discussed was left only to the secretary, and the other participants tended to sit back and take whatever the active students had said. This may be beneficial if the groups are mixed, the slow or weak learners could possibly learn from the active or high ability students. The students argued that on the other hand, often this was not good for students with wandering minds, as they would fail to benefit from the discussion. One student argued that 'It cannot work out for some people in groups...some people need individual study'.

Uneven progress in achievement

The students pointed out that there was also a tendency of bright students moving forward faster than the slower learners. They argued that bright students preferred 'chap'...'chap' (Quick...quick), and that at times they might not have been very helpful to the slower or weaker learners.

It is worth noting that whether the post-test data shows this is beyond the scope of the current study. Further study needs to be conducted to clarify this claim.

8.12 Summary of the teacher and students perceptions challenges of using C&TA

- C&TA requires teacher's technical competence on how to operate the computers and the smart board
- Simulations used in C&TA required clear understanding of the key concept words, temperature and concentration, in order to choose the right model for the temperature or concentration
- Reaching agreement on what is correct and incorrect during the discussions required negotiation skills of the group participants (students)
- Lack of objective direction was evident as hindrances to discussions

- Unequal contributions as other students tend to sit back during group discussions
- Working in groups with slower learners was noted as sometimes being counterproductive to the quicker or gifted learners.

8.13 Perceptions of the teacher and students comparing the C&TA and NTA teachings

This section presents evidence that relates to research question 4 (RQ4). The section presents a comparison of the teacher and students' perceptions of the C&TA and NTA teachings.

8.13.1 Teacher's perceptions

C&TA increases students' attentiveness in class

The teacher pointed out that:

'This may not only apply to chemical rate of reaction, but if it can also be widen to other topics in chemistry, then this would make chemistry a more interesting subjects'.

The teacher said that at that moment, students considered chemistry to be a very difficult subject and earlier class participation had been 50 %, but with the use of C&TA 98 % of the class was with him. He said this could be seen by students' high level of participation and responses during the lessons.

C&TA enhances students' understanding

In terms of students' understanding, "using C&TA has done much indeed", appraised the teacher. He said students had been able to see the behaviour of reacting particles and had understood the concept of chemical rate of reaction. He went on to admit that, in fact, it had not been only the students, but himself as well. He said:

'We got to know what actually takes place when temperature or concentration is increased or decreased. We were able to see reacting particles behaving differently under different conditions. I think that is the point we just talk about but the students had never seen it happening'.

C&TA bridges the gap between the teacher and students

It brings the students closer to the teacher because whenever the students are on computers observing the phenomena, there is also teacher-student interaction taking place. The teacher said '*C&TA helps students to understand the learning phenomena and it helps students in class to pay attention to the teacher'.*

C&TA helps to connect chemistry to daily life

For example, when looking at the effect of concentration, when the students increased the particles, the volume was reducing. So when one relates this to normal daily life, it becomes very simple. The teacher illustrated this as follows:

'If you tell a student this is a room, we are two, and the number is increased to 30, what is bound to happen? The student will be able to tell you in relation to what s/he saw on the computer. This method tries to create a very good connection in explaining chemistry concepts using day to day life experiences'.

According to the teacher, using C&TA made chemistry real, as he commented "I have come to realise that chemistry is not taught in air, it is actually something that exists because of these simulations".

The teacher further argues that:

'If this is a start, let it not stop here! Develop more teaching sequence in chemistry as this would make chemistry an interesting subject. Let have simulations for surface area as we have had for temperature and concentration'.

8.13.2 The students' perceptions

Changing the environment, from classroom to computer laboratory, is exciting and motivates learners about what they are going to learn. It was said that one could grasp what they were seeing seriously because when one saw something they could not forget it. One learner admitted that in the NTA classroom setting, they could even 'doze' (sleep) when looking at the teacher. He further asserted that this was not possible in C&TA lessons where it would be difficult for someone to sleep. He emphasized that "*it is like your attention is higher!*"

C&TA is student-centered and NTA is teacher-centered

'When the teacher is in class, he is the only one in control but when you get the computer, each one is on his / her computer, all of us are actively participating but when the teacher stands there and starts teaching, that is when you hear some people dosing (sleeping)...such situation but when you hold your computer mouse and you are determined in what you are doing and I do not think that you forget what you have done! But when the teacher teaches, actually you forget.'

'It is working, because, sometimes teachers finds himself/herself talking alone in NTA but when we all participating and everyone is on his or her computer, when the teacher is talking we follow what he is explaining and we tend to understand well than when the teacher is using blackboard.'

C&TA support learning more than NTA

'I tend to learn better, I get more than when in NTA.'

'C&TA ...is good; it has reduced the rate of cramming...improved students' understandings.'

'NTA encourage rote learning, you cannot explain concepts...but C&TA you are able to remember what you saw on the computer, explaining and describing becomes very simple.'

'Using computer is not tiresome like reading the book because when you read, you read a page in 1 hour but when using the computer you take a short time to understand and analysis all the stuff and get it very well while seeing it than using the book.'

'I think practical method of using computers of study was away of gaining more than the way of learning on the black board because on the computer you see something practically, but when you are on the blackboard you just assume and say may be something is like this... but there on the computer you see the molecules of particles...yeah!

'It feel better when using the computer, I see what is happening, what is to be done... (Plotting graphs, interpreting graphs...) and grasp the concept... easily grasps concepts and it sticks to my head but when the teacher is just giving notes, explaining, I do not understand what is talking about...(students try to envision abstract ideas) sometimes, I keep on reading notes and reading notes but I do not get the exact thing...concept'

C&TA improves the teacher's morale

'When we use C&TA we are able to contribute and the teacher gets the morale of continuing to teach. When students ask the teacher we saw this, but we did not understand, you are able to see the teacher feeling, he / she is part of the students.'

"In NTA lessons, sometimes the teacher ask questions and students just look on as if the students are **on no talk strike**" said a student in an experimental class during the interview. Students further commented subsequently that the teacher felt bored and just write notes and leaves, because he felt the students did not want to pick up the ideas.

Encourages students to make prior research and preparations

This was particularly during practical work where clear expectations helped to sustain students' focus, as two students said:

"With this practical thing I have to know...I have to know this yellow precipitate... It is like when you come to the laboratory, I am going to be grouped so I have to read... so that when we go there I do not have to be blank when everyone else has read. So you find yourself getting the book to read... so that when you come to the laboratory you are ready to work as a group".

'You feel bad when the rest are contributing and you are just looking on. There is prior preparation by students so they also contribute ...next time let me read so that I also contribute so the participation was higher'.

The results show that the students were encouraged to prepare so that when in discussion group, each one was able to contribute ideas on the topic being discussed.

8.14 Summary evidence to answer research questions 3 and 4 (RQ3 and RQ4)

The findings in this chapter have provided some evidence that:

- The C&TA offers opportunities to think and support students' understanding of chemical rate of reaction.
- Makes lessons more practical, interesting and enjoyable to students and improves the teacher's morale.
- Major benefits of the use of computer simulations and modelling were that it: improves working relationship between the teacher and students / learners, promotes peer learning through group discussions, encourages active class participation, encourages students to make prior research and preparations before the lessons, enhances students' understandings of chemical rate of reaction, bridges the gap between the teacher and students and it brings the students closer to the teacher and helps students in class to pay attention to the teacher, saves school science chemicals and saves time from conducting laborious science experiments.
- Major challenges of the use of C&TA were found to be teacher ICT competence, knowledge of software, negotiation skills over correct answers by students during group discussions and unequal contributions of ideas.
- The analyses has revealed that the teacher and students have recommended that C&TA is a good method of teaching and learning,

therefore it should continue and also be adopted by other subjects, for example, Biology.

In the next chapter, the discussions drawn from the findings in this thesis are presented.

CHAPTER NINE

9 DISCUSSION

9.1 Introduction

This chapter discusses findings regarding the main research investigation presented in Chapters Six, Seven and Eight. The first section deals with research question one (RQ1), focusing on evidence that students who received C&TA understand better the concepts of chemical rate of reaction in comparison to students who followed the NTA. The second section deals with research question two (RQ2) focusing on parts of the teaching sequence which are effective in supporting learning, and which are less effective. The third section deals with research question three (RQ3) focusing on the benefits and challenges of using C&TA. The fourth section deals with research question four (RQ4), focusing on perceptions of the teacher and students about the C&TA teaching sequence. The discussion of the findings will also cover the unanticipated findings.

In the subsequent **sections 9.2 to 9.6**, I will discuss the key findings of this study.

9.2 RQ1: The advantage of C&TA over NTA

The statistical analyses presented in Chapter Six show that there was strong evidence that C&TA had a strong effect compared to NTA in enhancing students' understanding across all the five areas of chemical rate of reaction, cited in the literature review in Chapter Two. Students' performance on related aspects of chemical rate of reaction as reported in Chapter Six show that even with respect to particular component aspects, which are considered less demanding to conceptualise, the C&TA class performed better than the NTA class.

The findings of this study demonstrate that following C&TA support students' understanding of chemical rate of reaction in Ugandan secondary school science classrooms. Therefore, generally speaking, the findings reported in this thesis further mirror and add to the findings that using research evidence-informed teaching, 'The Leeds Approach', as outlined in Chapter Four, supports students' learning of science more compared to usual or normal teaching. Examples of such studies which have used a research evidence-informed teaching approach include the results of 13 case studies in the United Kingdom on teaching Chemistry, Biology and Physics by Leach, et al. (2006). The results from the 13 case studies show similarities with the findings of this study and suggests further that it is plausible to make a generalizable observation that using designed teaching intervention along

with talk approach (in this case C&TA) supports students' understanding. Another study, which draws on the research design-based teaching along with communicative approaches, is the work of Ahmad (2010), which found that after the intervention, experimental class students demonstrated a better conceptual scientific understanding of electrochemistry. Similarly, a study by Alzaghbi (2010), on teaching about plant nutrition in Saudi Arabia shows that the experimental class performed significantly better than the comparison class.

In reference to the use of computer tools in supporting learning, the findings presented in Chapter Six in this thesis support the results of many experimental studies demonstrating that computer simulations and modeling can enhance students' understandings of abstract ideas, and can improve students' achievement in science (Mellar & Bliss, 1994; Yildiz & Atkins, 1993; Parush et al. 2002; Morgil et al. 2005 and Stern et al., 2008).

The findings of this study are similar to the work of Calik (2010) as highlighted in Chapter Two, in which students who followed the computer animated chemical rate of reaction lesson had an improved understanding. Furthermore, the results align with the findings of Papageorgiu et al., (2008) and Arcdac & Ali (2002) in which using computers along with group discussions were found to support students' understanding.

An analysis of classroom interactions (**sections 7.7 to 7.12.3**) appears to show that C&TA was more engaging and supportive to students' understanding of chemical rate of reaction concepts than the NTA. We shall return to the discussion of the results of classroom interactions in **section 9.3.8**.

The evidence from the after lesson interviews shows that not only the students, but also the teacher understood the chemical rate of reaction concept (see **section 9.3.2** for details). The interview results on conceptual understanding at the end of each lesson show that students' understood the chemical rate of reaction concepts across all the six lessons. As reported in Chapter Eight, students were able to answer and explain correctly the concepts covered in each lesson when asked at the end of each lesson.

The evidence from the post-test shows that students who followed the C&TA teaching sequence drew upon the scientific view collision (kinetic) theory /

orientation of reacting particles or atoms, temperature, activation energy, E_a and concentration on chemical rate of reaction, more correctly than those in the NTA class did. This is because the NTA did not offer enough support for students to make links between the collision theory, explanations and actual behaviour of atoms involved in chemical reactions. I think that it is plausible that the students' understanding arose from the use of the computer simulations in the C&TA class (see **section 9.3.2** for more details). The simulations supported students in making links between theories and actual behaviour of atoms involved in chemical reaction. The evidence from this study shows that the use of computers in the teaching is more nuanced. Previously, computers were viewed as 'a good thing' in a rather uncritical way. This study has showed that computers are particularly good for 'showing' processes at the molecular level that 'are not there to be seen' due to size and scale, and also the speed at which individual collisions occur.

Furthermore, the post-test analysis presented in **figure 6-5** shows that the intervention had an effect of the same magnitude across the ability range. The evidence from the results of the interview with the focus group shows that students acknowledged that C&TA supported learning for students with different abilities. For example, a student said:

'People learn differently, other people get things from the blackboard. Like some of us who take time... to like get things from the blackboard, may be the other method of studying from the computer was a little better...much better!'

This evidence perhaps suggests that C&TA could be used as an alternative teaching approach to didactic teaching in science classrooms in Uganda since it seems to offer support to students' learning irrespective of their abilities.

This study also reveals that by following the NTA, many students failed to offer detailed explanations consistent with the scientific ideas in all the five difficult areas of chemical rate of reaction. Therefore, although the C&TA is better in supporting students' understanding of chemical rate of reaction, this study adds to the evidence that understanding chemical rate of reaction is difficult for learners under a 'normal teaching approach'.

To summarise, students who received C&TA understand better in comparison to students who followed the 'normal teaching approach'.

In the next section, I present unanticipated findings which emerged from the post-test analysis.

9.2.1 Performance by gender

The evidence from the analysis indicates that female students benefited more from the intervention than male students (see **figure 6-6** in **chapter 6**), although the difference was small (by 1.7 marks on average). I wish to acknowledge that I was not able to conduct individual interviews probing the understanding of students' ideas on the written post-test to support this claim, which I suggest would merit more research.

Reviews of literature related to gender as well as the teaching and learning of science, reveal existing gender imbalances in science (Biology, Physics and Chemistry). For example, Mullis et al., (2000), reports that Third International Mathematics and Science Study (TIMSS) Report of the International Association for the Evaluation of Educational Achievement (IEA) revealed that, in science, unequal gender attainment was even more pronounced than in Mathematics. They pointed out that significant gender differences in favour of male students were found in science achievements in half of the TIMSS countries, including the US and Canada.

Similarly, analysis of Mullis et al., (2008) of TIMSS 2007 report showed that in fourth grade, eighth grade and the final year of secondary education in many countries males scored significantly higher than females in various science subjects, particularly in Earth Science, Physics and Chemistry.

Further research evidence indicates a pronounced gender gap in the number of females taking science subjects at A-Level (Wynarczyk, 2007a; 2008; Wynarczyk & Hale, 2008).

Bearing in mind that studies have shown that there are many reasons for females (girls) opting out of science, for instance, they may not like it (Joyce, 2000; Dawson, 2000), or they may opt into something else, or they may be under pressure not to choose a subject that is viewed as masculine (Rodger and Duffield, 2000), or they may be given messages through teaching that science is for boys rather than girls. It is possible to suggest that the results of this study show that C&TA might help to support and inspire (Brown, 2002) females to take up and attain more highly in science subjects (Papert, 1993; Jonassen, 2000; Brunner and Bennet, 2002;

Edwards, 2002; Yelland, 2002). However, this is a case study with only one school, more research with a longitudinal scope would be needed to determine the broader scale of the impact of C&TA in enhancing female students' understanding of science concepts, and this is beyond the scope of this present study.

In the next section, I discuss the salient features of the C&TA that might have caused better student learning.

9.3 RQ2: Aspects of the teaching sequence which were effective in supporting learning and which were less effective

The findings in Chapter Six provide some evidence that the students in the C&TA class demonstrated a better understanding in all the five learning areas. The findings illustrated that many students in the C&TA class were able to generate detailed explanations based on factual recall.

The findings in Chapter Six, however, were not sufficient to highlight the aspects of the C&TA teaching sequence that made it possible for students in the C&TA class to perform better in the five learning areas compared to the NTA class. As a result, an analysis of the actual teaching presented in Chapter Seven in reference to the content of the C&TA teaching sequence was used to make an evaluation about the teaching and to judge to what extent the teaching has successfully followed the teaching sequence (see Chapter Four).

The evidence from the interviews presented in Chapter Eight highlight the teacher's and students' perceptions of aspects of C&TA that were important in supporting learning. For that reason, evaluation of the effectiveness of C&TA teaching sequence was multi-layered. It included comparing the post-test scores and the aspects in the C&TA teaching sequence with the NTA sequence (for example, patterns of interaction, communicative approaches, forms of teacher intervention, computer simulations and modelling, laboratory investigations, teaching goals, group discussion and the worksheets).

Therefore, the features of the C&TA teaching sequence and how they have contributed to the students' performance in the post will be outlined in this section. The aspects are outlined under two broad themes. The first is related to the C&TA aspects that supported students' understanding of chemical rate of reaction at the three fundamental theoretical models for teaching and understanding chemistry as

mentioned in Chapter Two. The second is based upon communicative approach (Mortimer and Scott, 2003), and Leach and Scott's social constructivist perspective on teaching science (Leach and Scott, 2002) in formal settings used to inform the design of the C&TA teaching sequence (also see Chapter Four for details).

9.3.1 Teaching and understanding chemistry contents: Chemical rate of reaction

To put into perspective the aspects of C&TA teaching sequence which supported the students' understanding of chemical rate of reaction, how chemistry is taught and learned, is revisited. In Chapter Two, we saw that chemistry contents and teaching takes place at three levels: microscopic (abstract ideas), macroscopic level (physical phenomena) and symbolic level (using equations, formulae and mathematical representation); Johnstone (1982; 1991).

From the review of literature (in Chapter Two), students normally operate on the macroscopic level and do not simply follow links between the macroscopic and microscopic levels (Nahum et al. 2004). Nahum et al. (2004) argues that because of this, chemical concepts become "very abstract and students find it difficult to explain chemical phenomena" (p.302). This implies that understanding chemistry requires students to conceptualise behaviour of molecules at a molecular level (microscopic) in order for them to be able to explain at the macroscopic and symbolic levels. The C&TA design provided computer simulations, computer modelling and real laboratory lessons to enable students to make links between models and explanations, and the actual behaviour of atoms or molecules or ions involved in the chemical reactions (which are not 'there to be seen' in the 'real world').

9.3.2 Teaching and learning microscopic (abstract phenomena) of chemical rate of reaction: Computer simulations

The evidence from the post-test results show that C&TA teaching sequence support students' understanding of behaviour of atoms or molecules or ions during chemical rate of reaction at microscopic level using computer simulations. The detailed analysis of the interviews presented in Chapter Eight suggests that both the teacher and students acknowledged that computer simulations made abstract ideas of chemical reaction clearer and more understandable to the C&TA class. For example, one student stated:

'I liked the testing part of it, where you see the atoms colliding to form products... this made it easier to remember'.

While the teacher observes that:

'In terms of students' understanding C&TA [computer simulations] had done much indeed! Actually not only the students but including myself...we got to know what actually takes place when temperature is increased or decreased'.

In fact, lesson 1 episode 1.3, Computer Simulations - provided opportunities for the students to virtually see the orientation of the reacting particles during collision and how it affected the reactions. Simulations were able to depict that when the temperature of the system increases, KE also increases. This means that as temperature increases, more molecules will have higher KE, thus the fraction of molecules that have high enough KE to exceed the minimum energy (Activation energy, E_a) needed for a reaction also increases and simulations were also used to support students' understanding of the microscopic behaviour of molecules of reactants when temperature is increased or decreased (see **figure 7-2**). In lesson 4 episode 4.1, simulations were used to demonstrate the microscopic behaviours of atoms when concentrations of reactants were altered during chemical reaction. Therefore, simulations were supportive in enhancing students' understanding (see also Rodrigues, 2007; Papageorgiou et al., 2008) in comparison to the NTA class where there were no such opportunities for students to study microscopic behaviours of atoms during chemical reactions. Stieff and Wilensky (2003) support this, arguing that "using computers in chemistry lessons contrasts with the traditional chemistry lectures that rely almost entirely on verbal explanation of concepts meaning students have little opportunity to 'observe' molecular interaction".

Thus, it could be argued that the teaching and learning which follow C&TA might be helpful in supporting students to make links between collision theory, how it is used to explain the behavior of reacting atoms or ions or molecules and their effects on chemical rate of reaction when temperatures or concentration of reactants are altered.

In the C&TA class, evidence showed that the students were able to use collision theory (ideas about microscopic behaviour of reacting atoms) to explain correctly these concepts of chemical rate of reaction, compared to the NTA class in the post-test as shown in Chapter Six.

9.3.3 Teaching and learning macroscopic (physical phenomena) of chemical rate of reaction: Real laboratory investigation

Understanding macroscopic concepts of chemical rate of reaction involves real laboratory investigations, analyses and interpretations of factors that affect chemical rate of reaction. In this study, two factors were investigated: effects of temperature, and concentration of reactants on the chemical rate of reaction. Lesson 2, episode 2.1 and lesson 5, episodes 5.1 (see **Appendix 7** for detailed descriptions) were important in helping students link microscopic ideas to macroscopic (physical phenomena) and symbolic representation. The interview results with the teacher show that when asked whether the students were able to draw ideas from what they saw on the computers, the teacher responded as follows:

'Quite a number of students were able to draw ideas from computers to explain and you could see that they actually were aware of what was going on in the solution'.

The students' interview results confirm the teacher's view above. For example, one student was able to link microscopic ideas to macroscopic phenomena:

'The way I see it, there in the computer [microscopic phenomena] we were using A and BC on the reactant side but on the product side we were getting AB and C. That is why here [reactants solution] we got water, gas and yellow precipitate. The water and gas are in the form of C while the yellow precipitate was the AB we were getting there in the computer'.

These data suggest that C&TA has the potential to help students make links between the microscopic behavior of atoms or ions or molecules involved in chemical reaction. Whereas C&TA supports and assists students to make links between theories and explain what happens in solution during chemical reaction, C&TA also recognizes the importance of laboratory investigations as core to the teaching and learning of school science.

Thus, the evidence from the findings of this study further suggests that C&TA has the potential to be used as a teaching and learning tool which supports students' understanding of the theoretical model and explanations of the behavior of reacting particles (atoms, ions or molecules) as well as offering the students laboratory skills and familiarizing them with the behavior of science phenomena in the real (material) world.

9.3.4 Teaching and learning macroscopic (physical phenomena) of chemical rate of reaction: Using computer modelling (spreadsheets)

In the C&TA class, L3 episode 3.1 and L6 episode 6.1 supplemented real laboratory investigations with a virtual computer environment. Computer modelling provided a virtual environment for the students to perform investigations (Mcfarlane and Sakellarios, 2002) on the relationship between temperature and chemical rate of reaction (**figure 7-3**), and between concentration and chemical rate of reaction (**figure 7-5**). The post-test results show that the C&TA students' understanding was supported more compared to the NTA students as reflected by their performances in **table 6-8** and **table 6-10** in Chapter Six.

The focus of these lessons was more on investigating the relationship between temperature (L3, episode 3.1), concentration (L6, episode 6.1) and chemical rate of reaction graphically. It was meant to shift away from the laborious laboratory investigation and focus more on hypothesizing, analysing the results or trends and exploring relationships between variables at a sophisticated level (Bennett, 2003 and Hennessy, 2006), promote critical thinking and develop the ability to ask 'what if' questions (Mellar & Bliss, 1994); improve cognitive understanding (Yildiz & Atkins, 1993); and better students' concept retention (Parush et al. 2002). The analysis of the teacher and target group interviews indicated that using computer spreadsheets supported and enhanced students' understanding. For example, students said:

'I think the idea of practice with computer allows you to see the relationship between temperature and rate of reaction...it was just a summary of what we had learnt because I understood things from the previous lesson'.

'I saw that when you increase the temperature, the rate also increases'.

'For me it was ok, everything was programmed well. I enjoyed because you could try with any number... change temperatures but the shape of the graphs would still remain just like how we plotted in the practical exercise'.

It can be concluded that understandings were further enhanced using computer modelling. Thus, this evidence further suggests that C&TA allows students to build links between the real world and events, and the world of theory or model which has the potential to create a better understanding (also see Tiberghien, 2002; Parush et al. 2002). For example, the C&TA teacher in an interview stated that '*computer modelling brought out the same ideas students would get if they had done another practical*'. He also said that it was clear to students because the graphs had similar

shapes to those that students had plotted, and he believed that students understood the relationship between temperature and rate of reaction.

Hence, the evidence from the findings of this study suggests that C&TA could be used to supplement real laboratory investigations. This could help to reduce the cost of running the school science laboratories as well as supporting students' learning more, especially in Uganda where most schools struggle to provide science requirements, chemicals (non-reusable) and equipment.

9.3.5 Teaching and learning symbolic representations of chemical rate of reaction: Using worksheets

The worksheets in the C&TA teaching sequence provided space for group practice and conceptualisation of behaviour of molecules at a molecular level (microscopic), and also relate to the macroscopic level and representing chemical rate of reaction ideas using chemical symbols, equations, formulae and through graphical display (see **appendix 7**). Worksheets provided sets of learning activities for students. While investigating behaviour of reacting atoms at microscopic level using computer simulations, worksheets provided activities and spaces for students to write their predictions, observations and explanation for their observations. For laboratory investigation, worksheets provided students with activities, procedures for experiments, space for writing (record), observations and explanations. All activities were supported by worksheets on which students recorded their discussion results which were then reported to the whole class by a representative. In fact, the results of classroom interactions presented in Chapter Seven were generated from worksheet activities. That is, worksheets were used to focus the students' attention to the material at hand. Inclusion of learning tasks and questions in C&TA teaching sequence denied student passivity during lessons. Through the completion of the worksheet activities and simultaneous discussion in C&TA class, worksheets provided students with opportunities to develop their understanding (also see Alzaghibi, 2010; Calik et al. 2010) of the chemical rate of reaction.

9.3.6 Presentation of content through identification of teaching goals

In Chapter Four, I identified the "Learning Demands" from the literature review and also by analysing the chemistry curriculum. I concluded that the chemistry curriculum teaching goals were not sufficient enough to support students' understanding since it used the macroscopic model to explain the microscopic

behaviour of reacting particles involved in chemical reaction. So, I developed teaching goals based on the microscopic behaviour of reacting particles to explain the chemical rate of reaction which students find difficult to understand. Therefore, the teaching goals were significantly different from teaching goals in the Ugandan national chemistry curriculum for secondary schools.

After the C&TA intervention, the evidence from the analysis shows that C&TA teaching goals were achieved and were supportive to the students' understanding of chemical rate of reaction compared to the NTA ones. The post-test results show that the teaching goals and learning outcomes in the C&TA teaching sequence were achieved as follows:

1. To define / determine of rate of reaction (74.3 % of students).
2. To explain, using the collision theory, the effect of temperature on chemical rate of reaction (61 % of students).
3. To explain the term activation energy, and how this affects the number of effective collisions and formation of the products in a reaction (60 % of students).

However, the evidence from the post-test shows that the following teaching goals achieved low learning outcomes as follows:

1. To explain the term 'proper orientation' of reacting particles (44.8 % of students)
2. To explain using the collision theory the effect of concentration of reactants on chemical rate of reaction (27.6 % of students).

The results in **table 6-6** and **figure 6-8** for item 3diii, which is about teaching the proper orientation of reacting particles, and the results in **table 6-11** and **figure 6-13** for item 2diii, which is about teaching the effect of concentration of reactants on chemical rate of reaction show that performance of the students in the C&TA class was rather weak, but better than that of the NTA class.

This implies that the teaching activities used in lesson 1 episode 1.3, lesson 4 episode 4.1 and lesson 5 episode 5.1 were not effective enough to assist students to conceptualise the concept of proper orientation of reacting particles and the effect of concentration on the chemical rate of reaction. It also suggests that the sequences of the content in L1 episode 1.3, L4 episode 4.1 and L5 episode 5.1 may not be appropriate and may need to be reviewed.

For example, from my observation of lesson 5 episode 5.1 on the effect of concentration on chemical rate of reaction, students had problems with conceptualising concentrations in terms of moles per unit volume. That is, understanding that by measuring the volume of the mixture we can deduce the amount of solute [moles / concentration] present in a given solution. Particularly understanding that for a given solution, moles [concentration] increases with volume of solution measured. Their thinking was that 'increasing volume, increases space between atoms, so molecules would take longer to collide and hence rate of reaction would be low'.

The extract below shows students' views after the lesson:

S: it [effect of concentration of chemical rate of reaction] was somehow complicated ...I do not know may be because it was our first time to carry out such experiment but some students found it a bit complicated

R: and you? How did you find it?

S: before, the teacher came in to explain, it was complicated!

The evidence from classroom analysis shows that in L4 episode 4.1, the microscopic ideas were not linked to the macroscopic ideas as was evident by students' misconceptions (see **section 7.10.3**). The interview results after the L4 episode 4.1 show that the students expressed that understanding the effect of concentration (at microscopic level) was challenging. For example:

'I got confused when I used less numbers of atoms, there was no change and the speed was the same and when I used more atoms, I saw the same speed but I saw products being formed, then I was confused'.

'I was also disturbed because of that kinetic energy, K.E. I thought that when you increase the concentration, K.E increases but after that I saw it, I had a problem with it actually, when I increase the concentration and maintained the temperature and I found that the K.E was constant also, I was mixed up!'

The interview with the teacher (see **section 8.6.1**) shows that some students confused the explanation for concentration effect on the rate of reaction with the explanation of temperature effect. The idea of using kinetic energy, KE, which is used to explain the temperature effect, was believed to also apply to concentration. He, however, said later that the students were able understand that KE only applied to temperature when he explained it to them using the computer simulations.

The reason for the weak performances in these two areas might be due to the great differences between school science and everyday ways of reasoning, due to little

overlap between the concepts and associated epistemology and ontology of school science and everyday views (see Leach, et al., 2006). The great differences tend to make these concepts difficult to learn and teach.

The results suggest that when designing teaching sequence for chemical rate of reaction, the focus should be more on the students' learning challenges of linking theory about the microscopic behaviour of reacting atoms or particles to chemical physical phenomena. It also suggests that the current Ugandan national curriculum teaching goals on chemical rate of reaction need to be revised to focus more on teaching and understanding the links between theory and physical chemical reactions. This would better students' understanding of the chemical rate of reaction concept. Nevertheless, the results show that the teaching goals in this study have the potential to be used to support students' understanding of the chemical rate of reaction in Uganda, and perhaps in other countries in Sub-Saharan Africa.

9.3.7 Teaching process / implementation

The teaching process design in the C&TA class went through three key phases outlined in **section 2.6.2**. The analysis of classroom interactions (see **sections 7.7 to 7.12.3**) shows that the teacher was to a good extent able to follow the three phases: staging the scientific story, supporting students' internalisation and handing over responsibility to students (Leach & Scott, 2002; Mortimer & Scott, 2003). Staging the scientific story was used by the teacher to open up discussion and then working with the students to help them develop an understanding of the concepts introduced. These understandings were further developed by working and supporting students' internalisation through exchanges with the small groups and the whole class. The whole classroom interaction, where different groups presented ideas about the content, proved very helpful as the teacher used the opportunity to address students' misconceptions of many aspects of chemical rate of reaction as will be described in **section 9.3.8**.

L3 episode 3.1 and L6 episode 6 were used to provide opportunities for the students themselves (hand over responsibility) to try out new ideas through discussion both with the teacher and with other students in groups. Unlike the other four lessons, L3 episode 3.1 and L6 episode 6.1 did not have worksheets for students' written observations and exercises. These lessons were designed for students to practice and discuss the concepts of chemical rate of reaction by themselves.

The evidence from the classroom analysis shows that by thinking carefully about how content is structured for its introduction to students in classrooms (through the sequencing of activities), and how it is 'staged' in the classroom (see Leach and Scott, 2000; 2002) through talk and the use of computers, it is possible and practical for a teacher in Uganda to teach using computers in a more interactive/dialogic way, which is an unfamiliar pedagogical strategy. The outcomes of the C&TA teaching process show that it has potential to be used as a teaching sequence model upon which other science lessons could be developed and used in Uganda's school classrooms. Adopting C&TA teaching strategy by other science subjects might help to improve the quality of science teaching and learning in Uganda.

9.3.8 Aspects of the social constructivist perspective and communicative approach that supported students' learning

Other aspects of the C&TA teaching sequence that contributed to the students' performance relates to the social constructivist perspective and communicative approach on teaching science adopted in this research study.

The C&TA teaching sequence draws on the social constructivist perspective on teaching and learning science which is also an unfamiliar approach to Ugandan teachers. It recognises that teaching is cumulative over time in that it involves bringing together every day and scientific views (social constructivism theory), using talk to make meanings, with teachers guiding and providing scientific knowledge and students talking science for themselves relating to their ideas and ways of thinking (Lemke, 1990; Leach & Scott, 2003). Drawing from this assumption that 'talk' is important, the C&TA teaching sequence provided the framework on how the teacher initiates interaction and works with students to develop ideas of chemical rate of reaction in the classroom, based upon a communicative approach (Mortimer and Scott, 2003), and Leach and Scott's social constructivist perspective on teaching science. The importance of communicative approaches in supporting students' learning has been discussed in **section 2.6.12**.

Evidence and commentary sections in Chapter Seven have provided some insights about actual teachings that were implemented in the C&TA class and the NTA class.

The findings in Chapter Seven provide some evidence that the C&TA teacher worked together with his students in ways that were generally in line with the C&TA

teaching sequence (see **section 7.14**). The findings show that it is possible for a teacher in my country to teach using computers in a more interactive/dialogic way, with relatively little training and make significant improvement to students' learning of science concepts. The results in **table 7-48** and **figure 7-6** show evidence of the overall use of communicative approaches in the C&TA and NTA teaching sequences.

The findings indicated that in the C&TA class, there was more use of interactive/authoritative (**I/A**) to introduce and develop key ideas, non-interactive/dialogic (**NI/D**) to engage students in groups as they develop their understanding, interactive/dialogic (**I/D**) to elicit and explore students' ideas and non-interactive/authoritative (**NI/A**) to review ideas, summarise key concepts and maintain the development of students' understanding of chemical rate of reaction.

The C&TA class, L1 episode 1.2.1, showed that the actual teaching was carried out using more interactive/authoritative, non-interactive/authoritative, and to a small extent the teacher was able to initiate dialogic talk with students through interactive/dialogic. **Table 7-39** shows the percentage proportion of the **CA** used to support students learning of rate of reaction. In L1 episode 1.3.1, the C&TA teacher's interaction with students was uniformly distributed between non-interactive/authoritative, interactive/authoritative and interactive/dialogic (see **table 6-55** for details). Whilst in lesson 1 episode 1.3.2, the teacher initiated limited group interaction with students and focused more on presenting, reviewing and summarising key ideas about activation energy in a non-interactive/authoritative way. **Table 7-41** shows a high percentage proportion of a non-interactive/authoritative approach. The teaching focus was more on supporting students' understanding activation energy, E_a . This approach was recommended as Mortimer and Scott (2003, pg.71) argue that "the social language of school science is itself authoritative in nature". In L2 episode 1.3.2, it is further shown that in teaching the concept of the effect of temperature on chemical rate of reaction, the teacher was able to initiate interactive/dialogic, used non-interactive/dialogic in groups but focused more on supporting students to make sense of the effect of temperature on chemical rate of reaction through interactive/authoritative approach. A combination of **CA** used in L2 episode 1.3.2 was significant in supporting students' understanding. **Table 7-42** shows a percentage proportion of **CA** used. A similar combination of **CA** approaches was also applied in L2 episodes 2.1 and 2.2 (for details see **table 7-43**).

L3 episode 3.1 (table 6-59 and figure 6-25 and L6 episode 6.1, table 6-62 and figure 6-28) were about handing over responsibility to students. The **CA** patterns show that the teachings were carried out using non-interactive/authoritative, interactive/authoritative and non-interactive/dialogic. The results of the two lessons show a high percentage of proportions of non-interactive/dialogic approach. This implies that the lessons were more focussed on students' group discussions to support the development and maintenance of their understandings of the effect of temperature and concentration of reactants on chemical rate of reaction.

The purpose of these lessons was to provide opportunities for students to try out and practice the scientific ideas about the relationship between temperature, concentration and chemical rate of reaction for themselves, making those ideas their own and for the teacher to gradually hand over responsibility to students for their independent working (also see Wood et al. 1976; Mortimer & Scott, 2003).

L4 episode 4.1 (**table 7-45**) and L5 episode 5.1 (**table 7-46**) all show that the teachings were carried out through non-interactive/authoritative, non-interactive/dialogic, interactive/authoritative and more through interactive/dialogic. The results show that by engaging students through an interactive/dialogic approach the teacher was able to identify students' ideas which were not consistent with the scientific views (misconceptions). He was then able to address these misconceptions using a non-interactive/authoritative approach focusing more on supporting students to make sense of the scientific ideas.

For example the exchange in episode 4.1:

16S: the molecules are seen to be moving at a high speed due to high [increase] concentration.

53T: When you increase particles to 10 for example, I have not increase speed...so when you are increasing the concentration, you are increasing the number of particles in a given volume. When particles are many, collisions per second with each other are easier. So the speed at which the particles are colliding has not been increased. Speed is only associated with gain in kinetic energy and this, class! It only happens when temperature is increased not with concentration.

Here you can see that through dialogic talk, the teacher was able to identify a student's view and was able to help students understand that increasing concentration does not result in molecules gaining speed.

In comparison to the NTA class the evidence shows that the teacher took the central role of teaching, and the students were passive during the lessons. The transcripts

analysis of the audio-video of his lessons confirmed a very strong transmissive approach (87.2 % use of **NI/A**), a characteristic typical of NTA. In most cases he was 'passing on knowledge' to the learners with a very widespread dependence on using whole-class dictation of written notes. It is, however, true that the NTA teacher to a certain extent (12.8 % use of **I/A**) frequently attempted to check on his students' ability to interpret and explain the scientific ideas. This was typical for each lesson as reported in Chapter Seven.

The analysis of the NTA classroom talk shows that the 'normal teaching approach' is less supportive to students' understanding, which when judged in terms of the range of the communicative approaches considered in this thesis generally appears to have a low robust consolidation of meaningful learning.

In light of this finding, it is possible to suggest that C&TA offers a better pedagogical approach which could be adopted to support and promote science learning compared to NTA. This might help to support the Ministry of Education's attempts and effort in promoting science education in Uganda. In addition, other countries in Sub-Saharan Africa may also benefit from the use of this approach in their schools to promote science education.

9.3.9 Group discussion

Although group discussion work with small classroom sizes of 25 to 30 students (see, for example, Mortimer and Scott, 2003), the evidence from this study shows that it supports students' learning in large classes of 70 to 120 students. Group discussion is an unfamiliar approach to learning in Ugandan classrooms and perhaps in classrooms in other countries in Sub-Saharan Africa, because of large class sizes. The findings of this study show that C&TA offered opportunities for students to talk through their developing understandings both with the teacher and with each other in large classes. As mentioned in section **9.8**, students recorded their discussion of views (ideas) and a representative from each group reported the results of their discussion to the whole class. The evidence from the interview results show that students stated that the support they received from their peers and teacher facilitated their understanding and enhanced their learning (as described in more detail in later sections). This concurs with Vygotsky, (1978); Mortimer and Scott (2003); Ogborn et al. (1996) and Sutton (1992; 1995) who all advocate that supporting student's understanding is important in learning. Similarly, Lemke 1990 argues that getting students to talk science is a way that students can learn science.

This approach also follows the argument that learning science involves learning the social language of 'school science' (Leach & Scott, 2002; Mortimer & Scott, 2003). Therefore, the evidence from this study suggests that C&TA has the potential to allow teachers in Uganda, and other countries in the Sub-Saharan Africa, to support students' learning in large classes more than compared to the NTA.

9.3.10 Forms of teacher intervention

In the C&TA class, analyses of whole classroom interaction (supporting students' internalisation) show that the C&TA teacher invited students to put their ideas to the whole class through explorative questions. The results of the classroom interaction show that the teacher was able to learn the students' views and was able to intervene to support students' learning. The forms of the teacher's support included exploring ideas, echoing, marking key ideas, selecting ideas, shaping ideas, evaluating, reviewing and summarising ideas. These forms of teacher intervention are presented in tables showing key features of the teaching process. Sections **7.7 to 7.12.3** show detailed accounts of whole classroom interactions, and the tables show the different forms of the teacher's support for each lesson. The forms of teacher intervention were significant in supporting students' understanding of chemical rate of reaction and contributed to students' performance in the post-test in which the C&TA class performed better than the NTA class.

While the analyses of the NTA classroom interactions show that the teaching took the usual approach of talk, chalk and practical exercises. The talk was teacher centred characterised mainly by the use of classroom management moves, such as presentation of information, directives (write down or draw the diagram), use of questions tailored to find out whether students were following what the teacher was saying. The questions used were of the forms: 'Are we together?' and 'Is it clear?' These questions were less engaging and did not encourage students to think during the lessons. As is evident in most of the NTA lessons, there were 'limited' classroom interactions and no opportunity for students' group discussion, and as such students' learning was less engaging and lacked the teacher's support.

Therefore, the evidence from the C&TA classroom analyses suggests that engaging students is important in informing the teacher of the students' views and their understandings. As a result, it allows the teacher to address students' learning challenges and helps them to understand the science concepts. This aspect of the teaching is not being adequately employed in the current NTA practice in Uganda as

revealed in this study. As such, teachers are not normally aware of the students' views and the teachers are not in a position to challenge and support students' understanding of science concepts. Therefore, this study shows that C&TA has the potential to change the current NTA practice and promote interactive and engaging lessons in Uganda's school science classrooms.

9.4 Summary on aspects of the teaching sequence which were effective in supporting learning

The C&TA teaching sequence was effective because it supported students' understanding of the chemical rate of reaction at microscopic level using computer simulations; at macroscopic level using real experiments and computer modelling; at symbolic representations using computer simulations and modelling. Worksheets were used to provide learning activities and discussions.

The C&TA teaching design provided opportunities for students to work in small groups exploring their ideas using computer simulations, hypothesis or asking 'what if?' questions while using computer modeling and performing experiments to investigate relationships between activation energy, E_a , temperature, concentration and chemical rate of reaction. In addition, C&TA provided platforms for group discussions which supported students' learning.

The C&TA teaching goals and learning outcomes in the lesson sequence were effective in addressing the learning demands and hence supported students' learning of chemical rate of reaction.

As is evident in the results of the teaching activities, the wider use of communicative approaches (CA) supported students' understanding of the chemical rate of reaction concept more, compared to the NTA class. This explains in general terms the over effectiveness of the C&TA teaching sequence in supporting students' understanding.

Sections **9.13** and **9.14** provide further details of the teacher's and students' perspective on the effectiveness of C&TA in supporting learning.

9.5 RQ3: Benefits and challenges of using C&TA

In this section, I present the discussion of the findings on the benefits and challenges of using the C&TA teaching design.

9.5.1 Benefits of using C&TA

The study has indicated that schools could benefit from the use of C&TA in a number of ways. We have seen in Chapter Six that C&TA supports students' understanding more than NTA. The interview results point out the teacher and students' views that C&TA makes abstract ideas understandable. This latter finding is also supported within the relevant literature (Osborne and Hennessey, 2003; Hennessey, 2006; Mcfarlane and Sakellarios, 2002 /2009), which explains that simulations increase the salience of the underlying abstract concepts which cannot be physically illustrated - in this case the behaviour of atoms during a chemical reaction. In this study, using simulations made it clearer and more understandable to the teacher and students what happens to atoms during a chemical reaction when the temperature and concentration of the reactants increases (refer to **section 9.3.2**).

Calik et al. (2010) reached a similar conclusion when they investigated the change in students' alternative conceptions for the 'rate of reaction' concepts using computer animations as an intervention to make abstract phenomena understandable to students.

Using computer spreadsheets as a modelling environment provided a virtual environment for the students to perform investigations (also see Mcfarlane and Sakellarios, 2002) on the relationship between temperature or concentration and chemical rate of reaction. This saved time as the students were released from laborious manual experimental processes and focused more on hypothesising (for example, by asking what if temperature or concentration of a reactant is changed), interpretations, discussions and analysis of results (Mellar & Bliss, 1994; Bennett, 2003; Osborne & Hennessy, 2003). Thus, C&TA enabled students to build links between the real world and events, and the world of theory or model which bettered their understanding.

The interview results pointed out that computer modeling saved the school science laboratory from further use of chemicals to conduct more investigations as there was no need to conduct additional sets of laboratory investigations (also see **section 9.3.4**).

In this study, computer modeling also provided opportunities for the students to try out and practice scientific ideas by themselves, make those ideas their own and for

the teacher to gradually hand over responsibility to his students (Mortimer & Scott, 2003).

The use of C&TA helped to increase motivation, interest and confidence in both the teacher and students. C&TA can inspire individuals as was observed by a participant student, *'there is high concentration by students while working in groups, and someone concentrates much more than as the whole class'*. Such attributes were also accounted for as benefits of using computers in science teaching and learning by Barton (2004) and Wellington (2004).

The study confirmed the earlier claims that computer simulations improved students cognitive gain or permanent conceptual change (Atkins, 1996 and Parush et al., 2002) as was acknowledged by the C&TA teacher "you cannot forget the concept" after working with computer simulations. In a similar line of argument, a student from the C&TA class observed:

'When I was going to sit for the test examination (post-test), I did not get any book to read because something I just did it practically, so it stuck in my mind. He further went on to say, but when the teacher comes every day, gives the stuff there on the blackboard to go and read, that actually disturbs me a lot! ...because I have to refer to the book every time and again, but when you do it practically here it just sticks into your mind even if you do not read anything'

Furthermore, the interview analysis presented in Chapter Eight suggests that the C&TA perhaps offers alternative learning methods to slow learners. For example, one student said:

'People learn differently, other people get things from the blackboard. Like some of us who take time...to like get things from the blackboard, may be the other method of studying from the computer was a little better...much better'.

The study also revealed that C&TA improved teacher-student relationships. We saw in Chapter Eight that the student expressed a dislike for her teacher and chemistry as a subject, but this improved after the C&TA lessons. This is likely to be because C&TA provides a supportive classroom environment where free interactions between teacher-student and student-student are encouraged. This finding is supported by the social constructivist theory adopted in this study which stresses the role of the teacher in setting up the learning environment in such a way as to

enable dialogue, interaction and the acquisition of new knowledge (Mortimer & Scott, 2003).

Another significant benefit of C&TA was its role in promoting peer learning. There was evidence of peer support during discussions as students observed that sometimes when one misses a point from the teacher, other students would help to explain the same. Students said the C&TA lessons were good and interesting, and that working in groups was helpful - as one student explained:

'It is better, if you are in groups for example, like you have an idea, you know how to state it but you do not know how to explain, other members can help in giving the explanations. So when you combine your ideas you end up with good explanations and answers'.

This kind of peer support is in line with scaffolding of learning in the ZPD (Vygotsky, 1978). For example, some students thought the concept of kinetic energy associated with temperature effect on rate of reaction was also applicable to the explanation of the concentration effect. Such misconceptions became clearer during group discussions as one student put, *"it becomes ... like don'ts and dos...so you get it right away"*. It appears here that peers who were more competent supported other students to internalise concepts such as kinetic energy as only used to explain temperature effect on rate of reaction. This further confirms the effectiveness of the C&TA teaching sequence in supporting learning.

Having looked at the benefits, let us turn our attention to challenges encountered in using C&TA in teaching and learning.

9.5.2 Challenges of using C&TA

Drawing from the results of the interviews presented in Chapter Eight the study identified following challenges:

First and foremost, since the teaching sequence involved the use of computers and learning software, it was noted that the teacher needed to have sufficient technical competence, as cited by Newton and Rogers (2003) on how to operate the computers and smart boards.

Secondly, learning software evaluation skills was considered necessary. In this study, the teacher needed to be knowledgeable in choosing the right simulations (also see Newton & Rogers, 2003; Osborne & Hennessy, 2003) to address a particular learning difficulty.

Thirdly, negotiation and reaching an agreement on what ideas are correct and incorrect during group discussion posed a challenge to many students. Although this initially sounded negative, in light of this study, it was considered constructive as through the process of negotiation, students became more involved and became attentive listeners, making sense of the points of view of others, and compared their personal meanings to those embedded within the theories of their peers (Lorsbach & Tobin, 1992). Discussions of similarities and differences in the ideas made it possible for them to reach a consensus about the correct ideas within students groups. It also offered the teacher an opportunity to address the different ideas held by students. In this way, students were helped to understand the scientific ideas.

In addition, the interview results indicated that tension about whose ideas are correct comes up during group discussion and dialogic talk. As Vygotsky (1978) pointed out, the notion of individuals making sense of what is being discussed on the social plane of the classroom require the teacher to step in to direct the group discussion and classroom talk. Similarly, Mortimer and Scott's (2003) framework adopted in this study argues that in such circumstances, the teacher helps the learners to make sense of the scientific ideas. As we have seen in Chapter Eight, the focus group participants acknowledged the role played by their teacher in guiding and supporting them to understand concepts. In this case, the teacher's action was in line with the design of the C&TA teaching sequence.

Furthermore, the interview results revealed that there is a tendency for an unequal contribution of ideas, as some students tended to sit back during group discussions. This has most likely occurred due to the teacher not enforcing ground rules in classroom talks (Wegerif & Mercer, 1996, p.58). This can be solved by encouraging everyone in the group to adhere to ground rules during the C&TA lessons. Everyone must talk or make a contribution during the group discussion session.

Finally, it was noted that group discussions were sometimes less beneficial to fast or gifted learners. For example, the interview results show that bright students preferred '*chap*'...'*chap*' (*quick*...*quick*) learning approaches. This critique sounded from the students' perceptions as a deterrent to the progress of gifted learners, in the view of this study, it was one way of making slow (weak) students benefit from active and gifted students through peer support.

9.6 RQ4: Perceptions of the teacher and students comparing C&TA and NTA teachings

The general perceptions from the interviews presented in Chapter Eight show that the C&TA is a good method of teaching and learning compared to the 'normal teaching approach'. For example, one student said that *'the use of C&TA should continue and should be adopted by other subjects'*. While the teacher said:

'If this is a start, let it not stop here! Develop more teaching sequences in chemistry as this would make chemistry an interesting subject. Let's have simulations for surface area as we have had for temperature and concentration'.

The teacher's statement seems to suggest a willingness to change his approach from the NTA to the C&TA, while the student's suggestion indicates a belief that the C&TA might help to support learning in other subjects. I think this offers a new front for future research to explore the potential of C&TA in different science subjects which subsequently might help to improve science teaching and learning in Uganda. The evidence from interview results also indicated that the C&TA teacher and students unanimously agreed that there was high class participation. The teacher interview results show that the students considered chemistry to be a very difficult subject. His view concurs with the reported literature in Chapter Two of this thesis. He explained that class participation had been 50 % which improved to nearly 98 % during the C&TA teaching intervention. He said this was indicated by students' high level of participation and responses during the lessons.

Similarly, the students stated that they were more able to participate and contribute ideas during the C&TA class sessions than during the NTA class sessions. A girl in the focus group stressed the need to prepare through intensive reading in order to be able to contribute ideas during group discussion and dialogic talk. She asserted *'you feel bad when the rest are contributing ideas and you are just looking on'*.

From the students' perspective, there was evidence of feelings of participation in all of the lessons, particularly during practical work, and clear expectations helped to sustain students' focus. For example, one student observed:

'With this practical thing I have to know...I have to know this yellow precipitate... It is like when you come to the laboratory, I am going to be grouped so I have to read... so that when we go there I do not have to be blank when everyone else has read. So you find yourself getting the book to

read... so that when you come to the laboratory you are ready to work as a group'.

Her peers similarly asserted that *'in small groups, there is a way everyone gets to participate; each person has to write the reaction'*. The teacher pointed out that this increased students' attentiveness in most of the C&TA lessons.

All these views suggest that the C&TA teaching sequence offers interactive and engaging learning opportunities to students. I think that it is plausible that through interaction and engagement in the learning process, the quality of teaching and learning in Uganda's science classrooms can be improved by adopting C&TA teaching as a model of science teaching.

Furthermore, the evidence shows that C&TA has the potential to change the role of the teachers in science classrooms. For example, students stated that C&TA is a different approach and that people have been tuned into or are used to one method, the normal teaching (NTA), where the teacher talks and the learners just look at him. One student stated that in normal teaching the teacher was the only one in control, the teacher stood there, started teaching and this is when you could hear some people 'dozing' (sleeping), but in the computer class, the students paid attention to the teacher as he taught and they were all actively participating; each one on their computer, holding onto the computer mouse and determined in what they were doing. This evidence perhaps suggests that there is a need to re-think the teacher pedagogical approach from the current NTA characterised by 'talk and chalk', or the lecture method to a more interactive approach, such as the C&TA if the quality of science teaching and learning is to be improved in Uganda's secondary schools.

In the context of this study, group discussion is an unfamiliar approach. The students are used to the lecture method. However, the evidence in Chapter Eight also shows that the C&TA students stated that since they were working in groups, they were able to understand each other's weakness. The students stated that while in groups they were able to know an individual could not easily understand something, and so they tried to explain these areas to that person, so that they were all on the same footing. Learner helping learner is the 'scaffolding learning approach', recommended by Vygotsky (1978) as an important support to novice learners. Responding to questions about individual students who naturally feared to ask, one student noted that such people were encouraged to ask as C&TA offered

them the opportunity to talk freely with their peers. Students further stated that when one had ideas which differed from others in the group, the other members in the group were able to clarify such ideas. Therefore, the students were able to refine their understandings of the concepts (in this case chemical rate of reaction) and rehearse ideas with peers.

Furthermore, the interview results showed that students were excited and motivated about what they were going to learn each time the lessons were conducted in the computer laboratory. One student said that he could grasp what he saw seriously because when one sees something, it is not easy to forget. Another student owned up that in a normal classroom setting and teaching, they could even 'doze' (sleep) when looking at the teacher. He further asserted that this was not possible in C&TA lessons; it was difficult for someone to sleep. He emphasized that "it is like your attention is higher."

In addition, the C&TA provides an opportunity for a one-on-one conversation, that is, between the learner and teacher. One learner stated that:

'You are on your computer and focused on what you are doing with the teacher as he supports your understanding. In normal teaching sometimes students get bored when the teacher is teaching because they are less involved.'

'I think, if you and the teacher now...some of us who have wandering mind you are here but your mind is way far not even close to this place (class). If that is the mind you have, when the teacher is teaching, you might look at the teacher and ...that he is boring then you starts fantasizing where you will be like in 10 years ..So you are like looking at him but your mind is not even close to the teacher. But when you are holding the computer mouse, as you scroll and then you start thinking back, you are like focus to what you are doing. That is one on one ...that when you are with the teacher, when you are involved doing things together then it is better'.

Since the C&TA lessons involved observing the reacting particles (phenomena), the students' attention was not drawn away, and because they are in a group of four people, they have to work, look at the particles critically, so that they can make correct conclusions. It is a better method of learning as students stated:

'Using the computer is not tiresome like reading the book because when you read, you read a page in one hour, but when using the computer you take a short time to understand and analyze all the stuff and get it very well while seeing it than when using the book.'

'We tend to learn better with computers and we get more than when learning using the normal method' one student acknowledged. He argued that this was possible because sometimes the teacher found himself/herself talking alone in NTA, but when they were all participating and everyone was on his or her computer, and the teacher talking, they could follow what he was explaining and they tended to understand better than when the teacher was using blackboard'.

The evidence in Chapter Eight reports that NTA encouraged rote learning. It was observed that explaining the chemical rate of reaction concepts were challenging but computer lessons made it easy to remember. So, explaining and describing chemical rate of reaction concepts became very simple. This account supports why the post-test results favoured the C&TA class compared to the NTA class.

Furthermore, the interview results report that learning with C&TA can facilitate learning better because it is possible visualize what is happening and what is to be done. For instance, plotting graphs and interpreting graphs. One student observed that C&TA enables him to easily grasp the concept:

'With computers, I easily grasp concepts and it sticks to my head but when the teacher is just giving notes, explaining, I do not understand what is talking about...sometimes, I keep on reading notes and reading notes but I do not get the exact thing...the concept.'

'Using a computer is not tiresome like reading the book because when you read, you read a page in one hour, but when using the computer you take a short time to understand and analyze all the stuff and get it very well while seeing it than when using the book'

Similarly, the teacher commented that:

'We got to know what actually takes place when temperature or concentration is increased or decreased. We were able to see reacting particles behaving differently under different conditions. I think that is the point we just talk about but the students had never seen it happening'.

As discussed in **section 9.3.3** and **section 9.3.4**, the C&TA present chemical phenomena in three dimensions, in such a way that students can understand them.

The findings of the interview show that there are benefits for the teacher inform of class support by the students. For instance, when the teacher asks questions and students are able to contribute ideas, the teacher becomes happy, unlike in the NTA lessons where most of the time the students remain quiet. For example, one student stated:

*'In NTA lesson, sometimes the teacher ask questions and students just look on as if the students are on **no talk strike**'* said a student in an experimental

class during the interview. Students further commented subsequently the teacher feels bored and just write notes and leaves because he feels the students do not want to pick ideas.'

'In a computer class we are able to contribute and the teacher gets the morale of continuing to teach. Students are able to ask the teacher, we saw this but we did not understand and you are able to see the teacher feeling s/he is part of the students.'

Furthermore, it was mentioned that C&TA reduces the level of learning through cramming, and can improve students' understandings. I think this because C&TA has the potential to make abstract ideas visible informs of simulations which help students to link such ideas to physical phenomena in Chemistry. It possible to suggest that such salient features of C&TA could support students learning in other science subjects, such as Biology or Physics.

However, there was some concern raised by the students that whereas C&TA is good, it should be supplemented with real experiments because science is hands-on and practical in nature. Their arguments support the basis upon which the C&TA teaching sequence was developed as argued earlier. That is, teaching which links microscopic, macroscopic (physical phenomena involving laboratory investigations) and the symbolic representation of reacting atoms or ions or molecules involved in chemical reaction. The evidence from the analysis has provided some proof that C&TA has the potential to be used to teach chemical rate of reaction concepts across the three levels (microscopic, macroscopic and symbolic representations) recognised by Johnstone (1982; 1991) as fundamental in understanding chemistry concepts.

9.7 Summary

This chapter has argued that the effectiveness of C&TA in supporting students' learning was attributed to the features of the C&TA teaching sequence. The lessons learned are that the computer simulations and modelling, social constructivist perspective on teaching and learning along with the communicative approaches seem to facilitate learning and engagement in a science classroom.

CHAPTER TEN

10 CONCLUSIONS

10.1 Introduction

In this chapter I give a brief summary of the full study, identify its contributions to science education, the limitations of the study and indicate implications for science education. I also give suggestions for further research and finally, I reflect on what I have gained from the research process.

In this study, I developed, implemented and evaluated a computer and talk approach (C&TA) teaching sequence to improve students' understanding of chemical rate of reaction. I carried out the study in Uganda at a time when Uganda's Ministry of Education and Sports (MoE&S) had declared science subjects compulsory for secondary school students, and issued a call to promote science teaching and learning (see **Appendix 21**). There has been some advocacy for science education to be seen as central to economic development, with a need to increase scientific literacy, creativity and innovative thinking. These aspirations were reported in the international ROSE project report (2005) in which Uganda came top of the group of countries that need science education and technology to become more developed.

As a practitioner in science education in Uganda for over a decade, I identified the use of computers as tools for teaching and learning science with more specification helping learners to link theories, models and explanations of physical phenomena. As Uganda moves towards a science and technology-based economy for development using computers to supplement laboratory investigations would also help in cutting down the running costs of school science laboratories as computers tools and programs are reusable. Therefore, my study was motivated by the aspiration to generate empirical data that could be considered, alongside other evidence, to promote and improve science education in Uganda. I choose the C&TA design as an alternative (better) method to support science content teaching and learning, based on research that science education plays a central role in the development of the country.

My findings fitted within the current understanding in the field of science teaching and how learning may be supported (e.g. Driver, et al. 1994; Leach and Scott, 2002; Mortimer and Scott, 2003; Mercer, et al. 2004, 2007, Ahmad, 2010; Alzaghibi, 2010). Many scholars have indicated that although the computer is considered an

important tool in science education as a bridge between abstract concepts and students' understanding, very few designed research-based teaching sequences have involved computer programs in supporting science teaching and learning internationally.

My research was a case study of two high schools in Uganda involving 247 students and two teachers. Data were collected before and after the implementation of the C&TA teaching intervention for seven months using a base-line test and a post-test, interviews and classroom observations.

This study has generally demonstrated that the C&TA teaching sequence supports students' understanding of chemical rate of reaction. In particular, it is argued that the comparable analysis applied here suits the problem well and fits with the experimental class (C&TA class) and comparison class (NTA class) in Uganda. The study focused on four research questions.

Research question 1 was to evaluate the understanding of the students who follow the C&TA in comparison to students who follow the NTA. The post-test mean score showed that the experimental class mean score was higher compared to the comparison class. The statistical analysis confirmed that there was a statistical difference in the post-test mean scores between the experimental class and the comparison class. Further analysis was conducted using the General Linear Model (GLM) procedure to compare the post-test scores based on base-line test, group and gender to determine if their effects predicted the final students' achievement levels, the post-test outcomes. The results show that there was a substantial main effect for groups, a confirmation that the intervention had a substantial positive effect on the post-test scores.

Research question 2 was to identify parts (aspects or features) of the teaching sequence which would prove effective in supporting students' learning and which would be less effective. The analyses showed that all parts of the teaching sequence appeared effective in supporting students' learning. The transcriptions and analyses of recorded audio-video episodes of classroom talks and interviews with the teacher and students after every lesson, showed that the C&TA teaching sequence was more effective than the normal teaching approach (NTA) in supporting the students' understanding of chemical rate of reaction.

Research question 3 was about the teacher's and students' perspectives on major benefits and challenges using C&TA, while research question 4 was about teacher and students perceptions about using C&TA in teaching. The transcriptions and analyses of the teacher and students views and opinions showed that major benefits of the use of computer simulations and modelling were that it helps learners to link theories, models and explanations of physical phenomena in the real world, motivates and arouses interest in learning Chemistry as a subject, saves school science chemicals, saves time from conducting laborious science experiments, improves working relationships between the teacher and students/learners, promotes peer learning through group discussions which are unfamiliar in Uganda's secondary school classrooms.

On the other hand, the challenges during the use of C&TA, were lack of teacher ICT competence, evaluation knowledge of the learning software, negotiation skills over correct answers by students during group discussions and unequal contributions of ideas during discussion.

The findings also revealed that the teacher's and students' general perceptions were that C&TA encourages active class participation, enhances students' understanding of chemical rate of reaction, improves relationships between the teacher and students, brings the students closer to the teacher and helps students in class to pay attention to the teacher.

Furthermore, the analysis of the interviews revealed that the teacher and students recommended that C&TA is a good method of teaching and learning, and therefore it should continue and should be adopted by other subjects.

From my study, I have identified what I consider to be its main contributions to knowledge, which I highlight in the next section.

10.2 Original contributions to knowledge about science education

In this section I highlight the key contributions of my study to teaching science concepts through designed teaching interventions.

10.2.1 Contribution to science education in Uganda

To begin with, in the Ugandan context, I have not come across any research study specifically on the C&TA or even general science education. Therefore, my study is the first I know of in Uganda, and indeed in Sub-Saharan Africa, that has

investigated the use of C&TA to enhance students' understanding of chemical rate of reaction, and as such offers an insight into what the C&TA can support, and the possible influences on such learning. I must acknowledge, however, that perhaps some similar studies exist but which (perhaps due to poor resources in Sub-Saharan Africa, generally) are not published, particularly in a way that could be accessible on the internet. Nevertheless, with regards to Uganda, my visits to all public university libraries and leading bookshops did not yield any. Based on this, I would say that my study contributes empirical research-based evidence that will be useful in the ongoing implementation of science for all students in their ordinary level in Uganda according to the MoE&S circular (see **Appendix 21**). In this light, my study is also very likely to be relevant to other countries in Sub-Saharan Africa which are promoting science education.

10.2.2 Contribution to developing teaching sequences: Teaching methodology

I believe my study also makes significant contributions to teaching approaches. It highlights the research evidence-informed teaching sequences as a viable option for science teaching and learning in Uganda, as well as other countries in Sub-Saharan Africa. I say this because research evidence-informed teaching sequences are uncommon in Uganda, and communicative approaches have never been formally used in teaching and learning.

I believe my study may contribute to better science teaching methods in the Ugandan context. It also contributes to these specific findings towards the development of pedagogical knowledge in the area of research evidence-informed teaching sequence regarding chemical rate of reaction, as well as content areas where students find it hard to conceptualise and arguably offers those areas a much needed meta-theoretical framework, not only in Uganda but other countries in Sub-Saharan Africa.

10.2.3 Contribution to teaching chemical rate of reaction

Research shows that chemical rate of reaction is one of the most difficult topics in chemical education (Gilbert et al. 2002; Cakmakci, 2005, 2010) and previous teaching sequences or approaches have been designed to teach this topic (see Chapter Two) with a relatively positive effect on students' understanding. In this study, I developed a unique computer plus talk teaching approach which focuses on the students' learning challenges as identified in literature and from the analysis of

learning demands in Chapter Four. The results of the teaching approach show that it supports students' understanding of chemical rate of reaction more than students who followed the normal teaching approach (NTA). I therefore concluded that C&TA is a better approach for teaching and learning chemical rate of reaction in terms of students' conceptual understanding across the three levels (microscopic, macroscopic and symbolic representations) recognised by Johnstone (1982; 1991) as fundamental in understanding chemistry concepts.

The findings also indicate that the C&TA teaching sequence had an effect of the same magnitude across the ability range. This is a significant finding and another important contribution of this study that merits more research.

10.3 Tentative benefits of this study

The subsequent sections present potential benefits for teacher training or continuous professional development and girls science education

10.3.1 Potential benefits for teacher trainings and continuous professional development (CPD) in Uganda

In terms of teacher training and Continuous Professional Development (CPD) which are currently being implemented through unprecedented and costly Government investment in ICT projects in schools, the equipping of teacher training colleges with laboratories and equipment so that the training of science teachers can be scaled up in order to improve the quality of science teaching, C&TA will provide an alternative method for improving science teaching and learning.

The findings of this study show that by thinking carefully about how content is structured for its introduction to students in classrooms (through the sequencing of activities), and how it is 'staged' in the classroom (see Leach and Scott, 2000; 2002) through talk and the use of computers, it is possible and practical for a teacher in Uganda to teach using computers in a more interactive/dialogic way, with relatively little training, making statistically and educationally significant improvements to students' learning without spending high amounts of money.

10.3.2 Potential benefits for girls' science education

The findings appear to indicate that the C&TA may particularly support female students' understanding of chemical rate of reaction. I wish to acknowledge that I was not able to conduct individual interviews probing the understanding of students'

ideas on the written post-test to support this claim which I suggest merits more research. Nonetheless, this method of teaching might encourage and inspire more female students to take up science subjects (for example, the differences between boys and girls taking up Biology, Chemistry and Physics is ever widening). Chemistry and Physics subjects have always been perceived as male dominated subjects in Uganda, and in many places around the world, thus this approach if adopted might help to change this perception.

10.3.3 Potential benefits for teaching large classes

In this study, the C&TA teaching sequence was developed based on the model for teaching small classes in the UK and other Western developed countries. The evidence from this study shows that C&TA has the potential to support group discussions, teaching and learning in large classes more than compared to the NTA. However, similar studies need to be conducted to ascertain whether C&TA is a viable solution for teaching large classes in Ugandan schools (also see O'Sullivan, 2006; Nakabugo, 2008; In-Press) as well as in schools in other countries in Sub-Saharan Africa.

10.4 Limitations of the study

The research methodologies employed in this study have limitations.

1. First and foremost, the sample size was small (two classes and two teachers), so the interpretation and generalisation of findings should be taken with caution. Thus, to generalise and confirm the role of communicative approach and computer tools (simulations and spread sheets) in generating the learning gains observed, supplementary trails of the C&TA teaching materials would be needed with a wider range of teachers (repeating on a larger scale). But, it is reasonable to assume based on the evidence of other numerous small case studies cited in **section 9.2** that it is plausible to generalise and conclude that C&TA supports students learning.
2. Secondly, the assessment of the learning outcomes was conducted using only a written post-test. Given that conceptual misunderstandings were noticed in students' written answers (incorrect responses), it would be better if such ideas were further investigated orally with a small number of individual students.
3. Thirdly, the teaching goals had some limitations in addressing students' learning in two areas: understanding the concepts of proper orientation of

reacting particles and explaining the effect of concentration of reactants using collision theory. Although the C&TA class performed slightly better than the NTA class, future teaching design should focus more on linking collision theory to proper orientation of reacting particles and the effect of concentration of reactants would improve students' achievement in the two areas.

4. Fourthly, the analysis carried out did not capture the views of the C&TA and NTA students that were inconsistent with the scientific views. This would have answered a question whether their views were similar to or different from those reported in the literature review of this study. As such, analysis would allow for new emerging difficult learning areas in chemical rate of reaction to be dealt with in designing any future evidence-based teaching sequence.
5. Fifthly, because of resource issues, the analysis of classroom interactions only dealt with teacher interaction with the whole class and did not include teacher talk to small student groups, as well as student-to-student talk group discussions (as was emphasised by the design of the teaching sequence). A focussed analysis of the teacher talk to small groups and student-to-student might reveal additional features about effectiveness of specific aspects of C&TA.
6. Sixthly, due to the time limitations of my study, I could not carry out detailed comparison analysis of actual teaching and planned C&TA teaching sequence to gain insight for possible refinement and improvement of the C&TA teaching design. However, much more could be done to help the teacher appreciate the use of the different communicative approaches and to recognise the different purposes of each form of communicative approaches in science teaching. As mentioned, this study is a case study but offers encouragement that the C&TA has considerable value for the learners. It needs replication using many schools to make a generalised conclusion of its effectiveness.
7. Seventhly, the possible impact of the scope of the training provided for the 'experimental' teacher, notably on the field's learning demands might impact on the quality of the teaching undertaken (independently of the impact of the computer simulations or communicative approach).
8. Last but not least, using C&TA requires time and resources. The computer simulation software used in the study was adopted from PhET Sims

software⁸. The modeling spreadsheets were designed and developed by the researcher as no software was available to serve the purpose in the context of this study. Training of the C&TA teacher on the use of the computer simulations and modeling also required time and resources. In spite of these limitations (lack of software) and challenges posed by the lack of computer competence, C&TA was effective in supporting the students' learning more than NTA.

⁸ <http://phet.colorado.edu/index.php>

10.5 Suggestions for future research

From the discussion of the study findings and the above limitations that were identified in the design and implementation of the present study, some suggestions that can be made for future research into the use of C&TA on enhancing students' understanding of chemical rate of reaction are as follows:

1. Similar research needs to be conducted in other secondary schools in Uganda so as to obtain a broader picture of the effect of C&TA on enhancing students' understanding chemical rate of reaction and other subject content areas.
2. Further research could be carried out to investigate a variety of activities that were not covered in this study, particularly on the student-to-student talk during group interactions, and teacher talk to small student groups.
3. Further research needs to be conducted to determine the broader scale of the impact of C&TA in enhancing female students' understanding of chemical rate of reaction (or science concepts) and across the ability range.
4. Future research should consider alongside the post-test, an analysis of individual interviews probing the understanding of students' ideas on the written post-test in order to support the post-test claims. This could allow the issue of causality to be addressed. For instance, what might have caused the positive results of the C&TA class compared to the NTA ones? Or is looking for 'cause' an impossible thing to do?
5. Future research should consider the use of diagnostic tests to determine the students' conceptual understanding about chemical rate of reaction before the intervention, then designing the teaching sequence to address the students' misconceptions. The long term focus should be on redesigning and re-researching to obtain refined and replicable C&TA teaching sequence that can work in a wide context.

10.6 Implications of the study for science education in Uganda

The C&TA teaching sequence requires additional examination and development, including further investigation of its application in a wider range of science education contexts. Nevertheless, this study has policy implications for science teaching and learning in Uganda.

1. The findings of the study suggest that teaching of chemical rate of reaction or kinetic energy should focus more on linking collision theory to proper orientation of reacting particles, activation energy, E_a , effect of temperature

and concentration of reactants in order to support students' learning of chemical rate of reaction.

2. This study supports a change in science teaching methodologies from the current didactic state in Uganda to more interactive methods where learners actively participate in their own learning, so as to improve science teaching and learning. However, given the fact that the teaching approach adopted in this study is new to the Ugandan context, preparing teachers to implement the teaching as intended was an essential requirement. As indicated in this study, teachers' expertise should not be overlooked. Although the teacher welcomed and appreciated the use of C&TA, he was in need of further support in some basic computer knowledge and skills, use of **CA** in teaching and learning.
3. This study provides some guidance regarding how effective science teaching and learning should be conducted but much remains to be learned on the part of science teachers, science educators and curriculum developers.
4. This study also provides insight into what should be included in the process of teacher training and pedagogical development. It also raises questions about teacher professional development that have implications for the use of computers and social-constructivist approaches to science education, communicative approaches of teaching and learning, curriculum reforms and implementations. For the teacher's professional development, analyzing the training needs of the Uganda science teachers might help to determine the pedagogical starting points and then the teacher's continuous professional development (CPD) can be planned accordingly.
5. As the Uganda Ministry of Education and Sports (MoE&S) has moved towards making science compulsory, this study has shown that both teachers and students can benefit from the use of C&TA. However, improving practice is more than offering instructional materials or professional development. The MoE&S through National Curriculum Development Centre (NCDC) should consider adopting a research evidence-informed teaching approach focusing on learning areas that students find difficult when designing the teaching sequences so as to improve science teaching and learning.

10.7 Final reflections

The process of my doctoral study has been a long, challenging and sometimes lonely academic journey that has covered a period of three years of my life. I now near the end of the course of my research project.

As a chemistry teacher at a high school, I had always been interested in making chemistry learning better and more enjoyable to my students. After graduating with an M.Ed in ICT in Education, I realised ICT can be used to make abstract ideas understandable. I used the ICT knowledge acquired to gain background information which I gradually developed into my research problem. This was also a challenging process in itself. A quest to find solutions to students' learning challenges posed by the abstract nature of the chemical rate of reaction concepts eventually became my research project. I developed a research-based teaching sequence on chemical rate of reaction using a computer and talk approach, which was implemented in Uganda and evaluated by making comparisons with the 'normal' teaching approach.

As an individual, this process has equipped me with insightful knowledge and skills in designing research evidence-informed teaching sequences and more generally research. I have gained insight of classroom discourse analysis and have also gained personal development in academic writing and independent thinking.

Finally to society, I am humbled by the fact that the above efforts have become part of the initiatives to improve science education, especially in Uganda and other countries aspiring to promote science teaching as a basis for their economic development. Therefore, it is hoped that these findings have the impact on policy that I believe they deserve and that will be rewarded for this long journey.

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APPENDICES

Appendix 1: AREA Faculty Research Ethics Committee, University of Leeds

Research Support
3 Cavendish Road
University of Leeds
Leeds LS2 9JT
Tel: 0113 3434873
e-mail: j.m.blaikie@adm.leeds.ac.uk



Moses Odongo
Science Education, School of Education
University of Leeds
Leeds, LS2 9JT

**AREA Faculty Research Ethics Committee
University of Leeds**

10 December 2010

Dear Moses

Title of study: Developing, implementing and evaluating a computer and talk teaching sequence to improve students' understanding of chemical rates of reaction. A Case for Uganda

Ethics reference number: AREA 09-118

Amendment number: 2

Amendment date: 06/12/10

Amendment description: Further clarification

The above project was reviewed by the AREA Faculty Research Ethics Committee at its virtual meeting of 9th December 2010.

The following documentation was considered:

Document	Version	Date
Response to Ethical Review Committee Queries.doc	2	06/12/10
Informed Consent_Headteacher_Teacher_Form.doc	3	06/12/10
Informed Consent_student Form.doc	3	06/12/10
Participant_Consent_Headteacher_Teacher Form.doc	3	06/12/10
Participant_Consent_Students_Form.doc	3	06/12/10

On the basis of the information provided, the Committee is happy to approve but would like to offer the following comments and advice.

- The consent form now has the following lines included:
"The Lessons will be video and audio recorded to collect data on classroom activities but will not be included in the filming. The information gathered will be anonymised and used for the purpose of this study only."

This appears to have a word missing. Perhaps it should read

*"The Lessons will be video and audio recorded to collect data on classroom activities but **students** will not be included in the filming."*

If this is included then the reviewers are happy with this part of the response.

- The data handling now has "if used" included in the text relating to storage on CD or pen drives. You have not provided a rationale for the situation when this would be the case. The reviewers' speculation was that this would occur when there was not an internet connection available to enable data to be stored on UoL computers. If this situation occurs data should only temporarily be kept on portable media and should be removed/ destroyed once data is securely uploaded to UoL systems, which should happen at the earliest possible opportunity.

Please let the FREC know if you make any changes to the research which may affect the research ethics approval you have received.

Yours sincerely

Jennifer Blaikie
Research Ethics Administrator
Research Support
On behalf of Dr Anthea Hucklesby
Chair, AREA Faculty Research Ethics Committee

CC: Faculty Research Office/ Student's supervisor(s)

**Appendix 2: Uganda National Council of Science and Technology
(UNCST) Approval Research Certificate**



Uganda National Council for Science and Technology

(Established by Act of Parliament of the Republic of Uganda)

Our Ref: IS 80

06/05/2011

Mr. Moses Odongo
IACE
Makerere University
P.O Box 7062
Kampala

Dear Mr. Odongo,

RE: RESEARCH PROJECT, “DEVELOPING, IMPLEMENTING AND EVALUATING A COMPUTER AND TALK TEACHING SEQUENCE TO IMPROVE STUDENTS’ UNDERSTANDING OF CHEMICAL RATES OF REACTION: A CASE FOR UGANDA”

This is to inform you that the Uganda National Council for Science and Technology (UNCST) approved the above research proposal on **April 14, 2011**. The approval will expire on **April 14, 2012**. If it is necessary to continue with the research beyond the expiry date, a request for continuation should be made in writing to the Executive Secretary, UNCST.

Any problems of a serious nature related to the execution of your research project should be brought to the attention of the UNCST, and any changes to the research protocol should not be implemented without UNCST's approval except when necessary to eliminate apparent immediate hazards to the research participant(s).

This letter also serves as proof of UNCST approval and as a reminder for you to submit to UNCST timely progress reports and a final report on completion of the research project.

Yours sincerely,

Winfred Badanga
for: Executive Secretary

UGANDA NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

LOCATION/CORRESPONDENCE

*Plot 6 Kimera Road, Ntinda
P. O. Box 6884
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COMMUNICATION

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FAX: (256) 414-234579
EMAIL: info@uncst.go.ug
WEBSITE: <http://www.uncst.go.ug>**

Appendix 3: Informed Consent form. Information sheet [Head teacher / Teacher Form A]

Title of Project: Developing, implementing and evaluating a computer and talk teaching sequence to improve students' understanding of chemical rate of reaction. A Case for Uganda

Principal Investigator: Mr. Moses Odongo

Introduction

I invite you to take part in the implementation and evaluation of a computer and talk teaching sequence to improve students' understanding of chemical rate of reaction. Taking part in this study is entirely voluntary. I urge you to contact me about any questions about this study. If you decide to participate you must sign **Form B** to show that you want to take part.

Section 1: Purpose of the Research study

This research study is being done to find out whether the computer and talk approach improve the students' level of understanding of chemical rate of reaction in this Ugandan high school context in comparison with students following the 'normal' teaching.

Section 2: Procedures

This teaching sequence will involve the use of computers to simulate and model behaviours of molecules during chemical reactions and shall provide a platform for classroom discussions as students interact with the learning materials.

The lessons will thus involve both children and teacher talking freely about the chemistry concept, chemical rate of reaction.

Section 3: Time Duration of the Procedures and Study

The study will be conducted between the periods of January to June 2011. The period for teaching chemical rate of reaction is 24 periods for the whole content. The total period for chemistry lessons per week is 4, each lasting 40 minutes. Thus, the total time of teaching is 160 minutes per week. The teaching sequence for this study will not cover the whole 24 periods because it will focus on: Collision theory, activation energy, temperature and concentration of the reactants. Thus a total of six (6) lessons will be covered (see details in computer & talk teaching sequences document)

Section 4: Discomforts and Risks

There are no risks or harms in this study. This study is designed to improve the quality of teaching and better students' understanding of chemical rate of reaction.

Section 5: Participation

Taking part in this study is voluntary. If you choose to take part in this research your major responsibilities will include:

1. Overall supervision of the subject teacher (Head teacher)
2. Implementing a computer and talk teaching sequence for chemical rate of reaction in senior three classes (subject teacher)

Section 6: Confidentiality / anonymity

The information obtained will be kept strictly confidential to the researcher although the results of statistical and other analyses of data may be published in non-attributable and aggregated form.

Section 7: Contact Information for Questions or Concerns

You have the right to ask any questions you may have about this research. If you have questions, complaints and concerns feel free to contact me on:

E-mail: edmo@leeds.ac.uk or dng_mss@yahoo.ca

Telephone No.: +447553205419 or +256782460422

Section 8: Signature and Consent/Permission to be in the Research

Before making the decision regarding enrolment in this research you should have:

- Discussed this study with an investigator,
- Reviewed the information in this form on the teaching sequence
- Had the opportunity to ask any questions you may have.

Your signature on participant consent form [**Form B**] means that you have received this information, have asked the questions you have about the research and those questions

have been answered. You will receive a copy of the signed and dated form to keep for future reference.

Appendix 4: Participant Consent Form [Head teacher/Teacher Form B]

Title of Research Project: Developing, implementing and evaluating a computer and talk teaching sequence to improve students' understanding of chemical rate of reaction. A Case for Uganda

Name of Researcher: Mr. Moses Odongo

Tick the box if you agree with the statement to the left

- | | | |
|---|---|--------------------------|
| 1 | I confirm that I have read and understand the information sheet/ letter <i>[delete as applicable]</i> dated <i>[insert date]</i> explaining the above research project and I have had the opportunity to ask questions about the project. | <input type="checkbox"/> |
| 2 | I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline. | <input type="checkbox"/> |
| 3 | I understand that data collected from me will be kept strictly confidential. I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. | <input type="checkbox"/> |
| 4 | I agree for the data collected from me to be used in future research | <input type="checkbox"/> |
| 5 | I agree to take part in the above research project and will inform the principal investigator should my contact details change. | <input type="checkbox"/> |

Name of participant (Please tick: <i>Head teacher, teacher</i>)	Date	Signature	<input type="checkbox"/>
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Name of person taking consent (if different from lead researcher) <i>To be signed and dated in presence of the participant</i>	Date	Signature	
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Lead researcher <i>To be signed and dated in presence of the participant</i>	Date	Signature	
---	------	-----------	--

Name of the school _____

Appendix 5: Informed Consent form. Information sheet [Student Form A]

Title of Project: Developing, implementing and evaluating a computer and talk teaching sequence to improve students' understanding of chemical rate of reaction. A Case for Uganda

Principal Investigator: Mr. Moses Odongo

Introduction

I invite you to take part in the implementation and evaluation of a computer and talk teaching sequence to improve students' understanding of chemical rate of reaction. Taking part in this study is entirely voluntary. I urge you to contact me about any questions about this study. If you decide to participate you must sign **Form B** to show that you want to take part.

Section 1: Purpose of the Research study

This research study is being done to find out whether the computer and talk approach improve the students' level of understanding of chemical rate of reaction in this Ugandan high school context in comparison with students following the 'normal' teaching.

Section 2: Procedures

This teaching sequence will involve the use of computers to simulate and model behaviours of molecules during chemical reactions and shall provide a platform for classroom discussions as students interact with the learning materials.

The lessons will thus involve both children and teacher talking freely about the chemistry concept, chemical rate of reaction.

Section 3: Time Duration of the Procedures and Study

The study will be conducted between the periods of January to June 2011. The period for teaching chemical rate of reaction is 24 periods for the whole content. The total period for chemistry lessons per week is 4, each lasting 40 minutes. Thus, the total time of teaching is 160 minutes per week. The teaching sequence for this study will not cover the whole 24 periods because it will focus on: Collision theory, activation energy, temperature and concentration of the reactants. Thus a total of six (6) lessons will be covered (see details in computer & talk teaching sequences document)

Section 4: Discomforts and Risks

There are no risks or harms in this study. This study is designed to improve the quality of teaching and better students' understanding of chemical rate of reaction.

Section 5: Participation

Taking part in this study is part of your school program. Your responsibility will be to attend all regular class lessons on chemical rate of reaction.

Section 6: Confidentiality / anonymity

The information obtained will be kept strictly confidential to the researcher although the results of statistical and other analyses of data may be published in non-attributable and aggregated form.

Section 7: Contact Information for Questions or Concerns

You have the right to ask any questions you may have about this research. If you have questions, complaints and concerns feel free to contact me on:

E-mail: edmo@leeds.ac.uk or dng_mss@yahoo.ca

Telephone No.: +447553205419 or +256782460422

Section 8: Signature and Consent/Permission to be in the Research

Before making the decision regarding enrolment in this research you should have:

- Discussed this study with an investigator,
- Reviewed the information in this form on the teaching sequence
- Had the opportunity to ask any questions you may have.

Your signature on participant consent form [**Form B**] means that you have received this information, have asked the questions you have about the research and those questions have been answered. You will receive a copy of the signed and dated form to keep for future reference.

Appendix 6: Participant Consent Form [Student Form B]

Title of Research Project: Developing, implementing and evaluating a computer and talk teaching sequence to improve students' understanding of chemical rate of reaction. A Case for Uganda

Name of Researcher: Mr. Moses Odongo

Tick the box if you agree with the statement to the left

- | | | |
|---|---|--------------------------|
| 1 | I confirm that I have read and understand the information sheet/ letter <i>[delete as applicable]</i> dated <i>[insert date]</i> explaining the above research project and I have had the opportunity to ask questions about the project. | <input type="checkbox"/> |
| 2 | I understand that as a student my participation is to attend all the regular class lessons on chemical rate of reaction | <input type="checkbox"/> |
| 3 | I understand that data collected from me will be kept strictly confidential. I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. | <input type="checkbox"/> |
| 4 | I agree for the data collected from me to be used in future research | <input type="checkbox"/> |
| 5 | I agree to take part in the above research project and will inform the principal investigator should my contact details change. | <input type="checkbox"/> |

Name of participant <i>(Student)</i>	Date	Signature
Name of person taking consent <i>(if different from lead researcher)</i> <i>To be signed and dated in presence of the participant</i>	Date	Signature
Lead researcher <i>To be signed and dated in presence of the participant</i>	Date	Signature
Name of the school _____		

Appendix 7: Computer and talk teaching sequence for chemical rate of reaction

Background

This teaching sequence is designed for secondary school children aged 15-16 years in Uganda. The teaching sequence has been planned according to the Uganda National Curriculum for the Ordinary Level Chemistry (2008). The aim of the sequence is for the secondary school students to develop a clear understanding of the following concepts of chemical rate of reaction: Collision theory; activation energy; effect of temperature and concentration. It is designed to encourage classroom talk as students discuss the rate of reaction concepts with their peers while the teacher guides them through to make meaningful understanding using a computer based and talk approach.

Mode of interaction

The sequence has been designed to maximise students learning by incorporating various forms of classroom interaction. The sequence involves:

- ✓ Using different modes of interaction between the teacher and students in different episodes. The teacher will explore different approaches which will include: Interactive/Dialogic; Non-interactive/dialogic; Interactive-authoritative and Non-interactive/ authoritative.
- ✓ Providing opportunities for student-student talk in pairs and small groups.
- ✓ The sequence involves developing the idea of collision model for describing, explaining and predicting the chemical rate of reaction phenomena under change in temperature and concentration of reactants.

Lesson 1: chemical rate of reaction

Double period: 80 minutes

Teaching introduction

In this first lesson of the sequence links are made to the factors that affect chemical rate of reaction. The lesson begins with an interactive demonstration and talk about chemical reaction.

Sub-topics: Factors that affect rate of reaction; temperature effect on reaction

Learning objectives: By end of the lesson, the students should be able to:

1. Define correctly chemical rate of reaction
2. To review familiar ideas about the concept of collision theory
3. To set the target of developing a scientific model or collision model to explain chemical rate of reaction
4. Explain how changing temperature affects rate of reaction

Teaching materials

1. Computers
2. e-learning content (simulation on CD-ROM/DVD)
3. projector

What happens during this lesson

Episode 1.1: Chemical reaction

In this episode, the teacher performs precipitation reaction by adding barium chloride solution to dilute sulphuric. The class are sat round the teachers' table

The teacher poses some questions to start the discussion:

Ok, the precipitate was formed immediately...

What do you think is the white solid formed inside the test tube?

How do you think the reaction can be increased?

How do you think the reactions can be slow?



Interactive-dialogic

The teacher gets students in groups to make predictions/discussions

Students discuss and share their ideas in groups

The teacher continues the discussion to explore students' ideas about chemical reactions
At this point the teacher list down students' suggestions on the blackboard
For example; lists of factors which affect chemical rate of reactions

.....*By heating it...it will go quicker*
.....*If the acid is stronger....or concentration*
.....*Using a catalyst*
.....*Increasing surface area of the reactants*

**No suggestion is wrong!
This is a dialogic session**

The point here is to get students speak out their understanding of how temperature and concentration affects chemical rate of reaction.

The teacher then proceeds by saying...well these are some of the factors we will be studying in next lessons.

Episode 1.2: Chemical rate of reaction

Attention now turns to thinking about rate of reaction. Students will have done some work on collision theory under the topic; Kinetic theory of matter in senior one.

The point here is to review the ideas on collision theory as a starting point for introducing and explaining temperature effect and later concentration effects on the rate of reaction.

Review of Properties of the three state of matter. The teacher poses some questions to start the discussion on the properties of the three states of matter are solids, liquid and gas.
Properties of Solid: the forces that hold the particles are stronger; the particles are fixed in position-they do not move a part from vibrating.
Properties of liquid: the forces between the particles are weak; the particles are loose and move about freely
Properties of gas: Have no forces between the particles; the gaseous particles are completely separate; they move very fast and more freely than in liquids

Computer animation is to be used to demonstrate how the particles in a solid, liquid and gas move.

The point here is get student remember that particles in liquid or gas move at random, that is in any direction. That they collide with themselves or the walls of the container, they change direction. Furthermore, that their speed is governed by the temperature of the liquid or gas.

That, at higher temperature the particles gain higher kinetic energy and move faster.

At this point the teacher relates movement of particles to chemical rate of reaction and further discussions are to be dealt with in the subsequent episodes.

Definition of chemical rate of reaction

Non-Interactive / authoritative

In this episode, the teacher defines chemical rate of reaction (see definition: rate of reaction is the amount of product formed per unit time or the amount of reactants used up per unit time)

The teacher then poses a question

Ok, so what does this means?

Interactive / dialogic

Teacher prompts: *Who can tell us? Who can explain?*

The teacher then makes links to the students' suggestions: how to increase and decrease reaction (for example, increasing or decreasing temperature, increasing or decreasing concentration.....)

Non-interactive / authoritative

Episode 1.3: Explore using the computer simulation (sub-microscopic behaviour of molecules during chemical rate of reaction) see worksheet 1

In this episode, students fill in the worksheet 1 as they test their early predictions made under the episode 1.1 using computer simulations.

The teacher gets students to form groups and try out their predictions using a computer simulated model of rate of reaction.

Teacher ask students to begin with temperature

The teacher poses questions

-*so what happens when the temperature factor is*
- Increased during a chemical reaction*
 - Decreased during a chemical reaction*

Interactive-authoritative

The students.... *explore, record their observations, discuss and explain their observations*

The teacher prompts:

Interactive /dialogic

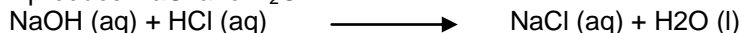
- Were your predictions correct?
- How did the simulation change your prediction?

Then teacher shares discussions and explanations with the whole class.

During whole class discussion, the teacher addresses the students' alternative conceptions by pointing out:

- That for reaction to occur, the molecules must possess enough energy and proper orientation of the reacting particles or atoms.

Proper orientation means atoms must be aligned in such a manner that they bond together. For example, consider the chemical reaction between NaOH and HCl to produce NaCl and H₂O

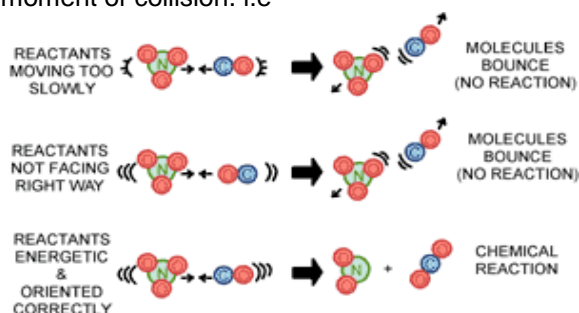


In this reaction, atom of Cl is transferred from HCl to Na atom and OH to H atom. The collision orientation most favourable for these occur are that, Cl atom from HCl must be near a Na atom from NaOH at the moment of collision.

Another example, consider the chemical reaction between NO₂ and CO to produce C O₂ and NO₂



In this reaction, atom of O is transferred from an NO₃ to a CO molecule. The collision orientation most favourable for these occur are that, O atom from NO₃ must be near a C atom from CO at the moment of collision. i.e



Proper orientation of reacting molecules (John, 2002)

- That when temperature increases the reactant molecules are moving rapidly and coming into contact with each other more often, this increases the reaction rate. Also that when temperature is increased the energy of the collisions is greater.
- That even when particles collide and with correct orientation, the reaction still might not occur because an activated complex or immediate product will not form if there is insufficient energy. That is, for a reaction to occur, the collision needs to be forceful enough to break the existing chemical bonds of the reactant.
- That there must be minimum amount of energy that reacting particles must have to form the activated complex and lead to reaction.
- That this minimum energy is called *activation energy*

Non-interactive / authoritative

Hints:

How does temperature affect the rate of a chemical reaction?

When two chemicals react, their molecules have to collide with each other with sufficient energy for the reaction to take place. This is collision theory. The two molecules will only react if they have enough energy. By heating the mixture, you will raise the energy levels of the molecules involved in the reaction. Increasing temperature means the molecules move faster. This is kinetic theory. If your reaction is between atoms rather than molecules you just substitute "atom" for "molecule" in your explanation (refer to Spiers & Stebbens, 1973; Atkinson, 1979; Holderness & Lambert, 1986).

Worksheet 1

For episode 1.3: Explore using the computer simulation (sub-microscopic behaviour of molecules during chemical rate of reaction)

Instructions

Working in a group, use the rate of reaction simulation on the CD-ROM or on the desktop of your computer to complete the table below by comparing your predictions to your observations

In this activity, complete the table below by comparing your predictions to observations.

- Predict what will happen to the rate of reaction when the temperature is changed
- Test your prediction with the simulation and record your observations

c) Discuss and explain your observations

Factor	Prediction	Test	Explain your observation
Increase temperature			
Decrease temperature			

Source: adopted and modified from <http://phet.colorado.edu/index.php>

Lesson 2: chemical rate of reaction

Double period: 80 minutes

Teaching introduction

In this lesson the students are required to conduct a practical experiment to determine rate of reaction. The lesson begins with the teacher conducting an experimental demonstration and talk about the procedures.

Learning objectives: By end of the lesson, the students should be able to;

1. Plot and correctly interpret graphically how temperature affects rate of reaction.
2. Use their knowledge of the collision theory to explain their observation

Teaching materials

1. Sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) and hydrochloric acid (HCl) solutions
2. Source of heat
3. Thermometers
4. Measuring cylinders
5. Beakers
6. Stop clock.

Review of Episode 1: The teacher reviews the previous lesson. The point here is to review how temperature affects chemical reactions as a starting point for introducing investigation of effect of temperature on chemical reaction experimentally in the school laboratory.

What happens during this lesson

The teacher: In the last lesson we saw that heating increases rate of reaction.

Ok, so let's now turn attention to how temperature affects rate of reaction by carrying out an experiment

Episode 2.1: Laboratory experiment to investigate the effect of temperature on the rate of reaction between sodium thiosulphate and hydrochloric acid (see worksheet 2)

This episode begins with the explanation on the experimental procedures

The teacher explains the experimental procedures

Non-interactive /authoritative

The teacher conducts an experimental demonstration to show the effect of temperature on the chemical rate of reaction.

The teacher gets students in groups to make predictions/discussion

The students work in groups, performing the following activities as they carry out the experiment. The students are to fill in their results in worksheet 2.

- a. Record temperatures
- b. Record time taken for the reaction to end
- c. Discuss their observations and present their explanations.



Interactive / dialogic

The teacher asks students:

- a. Why does the cross disappear in this experiment?
- b. Write an ionic equation for the reaction above

**No suggestion is wrong!
This is a dialogic session**

The point here is to have students explain their observation and represent symbolically the formation of the products at the end of the chemical reaction

Episode 2.2: Plot a graph of rate against temperature (the rate of a reaction may be found by dividing 1 by the time taken (1/t))

In this episode, the teacher ask students to plot a graph of rate against temperature

The students plot the graph and use the graph to:

Non-Interactive-dialogic

- Work out the rate of reaction or calculate the gradient (slope) of the graph and state its units.
- Explain the shape of the graph using the knowledge of the collision theory.

Then teacher shares discussions and explanations to the whole class. During whole class discussion, the teacher addresses the students' alternative conceptions by pointing out:

- That, rate of reaction is directly proportional to change in temperature-high temp. less time taken, the higher the rate of reaction;
- From collision theory: When temperature *increases* the reactant molecules are moving more rapidly and coming into contact with each other more often, which increase the reaction rate.

Non-interactive / authoritative

Worksheet 2

Episode 2.1: Laboratory experiment to investigate the effect of temperature on the rate of reaction between sodium thiosulphate and hydrochloric acid.

Instructions

Working in a group, carry out the experiment below, discuss your observations and present your explanations in the questions that follow.

Procedure: Mark a cross with blue or black ink on a piece of paper. Measure 50 cm³ of 0.2M sodium thiosulphate solution into 250 cm³ beaker. Add 10 cm³ of 2M hydrochloric acid to the thiosulphate and at once start the stop clock. Shake gently for the solutions to mix well and place over the cross. Watch the cross through the solution from above the beaker. Stop the clock when the cross disappears. Record the time taken for the yellow precipitate of sulphur to appear in the table below.

Table of results

Experiment No.	Vol. of Na ₂ S ₂ O ₃ (cm ³)	Vol. of HCl (cm ³)	Temperature (°C)	Time (s)	Time (1/t) (s ⁻¹)
1	50	10	Room temp (25 °c)		
2	50	10	30		
3	50	10	40		
4	50	10	50		
5	50	10	60		
6	50	10	70		

The equation for the reaction is

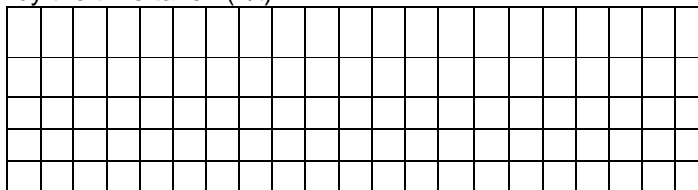


Questions

- Why does the cross disappear in this experiment

- Write an ionic equation for the reaction above

- Plot a graph of rate against temperature (the rate of a reaction may be found by dividing 1 by the time taken (1/t)



- From the graph, work out the rate of reaction or calculate the gradient (slope) of the graph and state its units.

- Use your knowledge of the collision theory to explain the shape of the graph.

Lesson 3: chemical rate of reaction (computer modelling using spreadsheets)**Double period: 80 minutes****Teaching introduction**

In this lesson the students are required to model effects of temperature change on rate of reaction. The lesson begins with the teacher demonstrating by changing temperature values asking students to make observations on its effect on the rate of reaction.

Sub-topics: Effect of temperature on rate of reaction**Learning objectives:** By end of the lesson, the student should be able to;

1. Make predictions and hypothesis or ask 'what if?'...and 'what about?'
2. Analysis graphically temperature changes against time.

Teaching materials

1. Computers
2. e-learning content (simulation on CD-ROM/DVD)
3. projector

What happens during this lesson**Episode 3.1: Virtual laboratory investigation of the effect of temperature on the rate of reaction**

In this episode, students are suppose to explore what might what might happen when the temperature of the reactions are altered.

The students are required to make changes of the temperature value while we observe its graphical display.

Teacher poses a question:

What do think the graph would look like?

Do think the curve would increase or decrease?

**Interactive-authoritative**

The teacher provide a second laboratory experiment where real experimental data are substituted with virtual environmental data using spreadsheets as a modeling tool.

The teacher gets students in groups to make predictions/discussions

Students discuss and share their ideas in groups

Non-Interactive-dialogic

The students: ... are to make prediction, hypothesizing or ask 'what if?' and or 'what about?' questions. Thus, focus more on analysing the results and hypothesizing.

The teacher will provide support as students try varied temperature values during modelling.the teacher shares students' results to the whole class.

The teacher then will provide opportunities for students to try out and practice the scientific ideas for themselves, to make those ideas their own and gradually take responsibility for their independent working.

The teacher prompts:

- a. *How does time changes when you increase the temperature?*
- b. *How does temperature graphically change with time?*

The point here is to have students try out their ideas, develop theory and test their theory and thus, focus more on analysing the results and hypothe

Non-Interactive / authoritative

Lesson 4: chemical rate of reaction**Double period: 80 minutes****Teaching introduction**

In this lesson the students are required to learn how concentration factor affect rate of reaction. The lesson begins with the teacher introducing the concept of effect of concentration on rate of reaction to the whole class (social plane).

Sub-topics: effect concentration on rate of reaction**Teaching objectives:** By end of the lesson, the students should be able to:

1. Explain correctly how concentration of the reactants affects rate of reaction

Teaching materials

1. Computers
2. e-learning content (simulation on CD-ROM/DVD)
3. projector

What happens during this lesson

Review of Episode 1: The teacher reviews the previous lesson. The teacher points out that, we have been dealing with temperature ...but... in that first lesson; we discussed ways of increasing chemical rate of reaction.

The teacher poses a question:

..Can anybody tell us what the other ways of increasing chemical rate of reaction were?

For example; the student:concentration

The teacher: *yes....concentration!*

Yes, we will discuss effect of concentration on the chemical rate of reaction in this lesson.

Interactive-dialogic

Episode 4.1: the effect of concentration on rate of reaction.

In this episode, the teacher explains the effect of concentration on rate of reaction (see explanation) Increasing the concentration of a substance in solution means that there will be more particles per dm^3 of that substance.

Non-Interactive / authoritative

The teacher:

So, how does concentration affect the rate of a reaction?



Interactive / dialogic

The teacher asks to students to make prediction, discuss and share their in groups.

Non-Interactive-dialogic

The point here is to get students speak out their understanding of how concentration affects chemical rate of reaction.

Episode 4.2: Explore using the computer simulation (sub-microscopic behaviour of molecules during chemical rate of reaction) see work sheet 3

In this episode, students fill in the worksheet 3 as they test their early predictions made under the episode 4.1 using computer simulations.

The teacher gets students to form groups and try out their predictions using a computer simulated model of rate of reaction.

Non-Interactive-dialogic

The teacher poses questions:

What happens when the concentration factor is:

- a. Increased during a chemical reaction?
- b. Decreased during a chemical reaction?

The students.... explore, record their observations and explain their observations

The teacher prompts

- a. *Were your predictions correct?*
- b. *How did the simulation change your prediction?*

Interactive-dialogic

Then teacher shares discussions and explanations to the whole class. During whole class discussion, the teacher addresses the students' alternative conceptions by pointing out:

- Increasing concentration of a reactant simply means there are more molecules coming into contact with each other more often, which increase the reaction rate.
- Thus, the more particles that there are in the same volume the closer to each other the particles will be. This means that the particles collide more frequently with each other and the rate of the reaction increases.

Non-Interactive / authoritative

Hints:

How does concentration affect the rate of a reaction?

Increasing the concentration of the reactants will increase the frequency of collisions between the two reactants. This is collision theory. Always discuss kinetic theory in an experiment where you vary the concentration. Although you keep the temperature constant, kinetic theory is relevant. This is because the molecules in the reaction mixture have a range of energy levels. When collisions occur, they do not always result in a reaction. If the two colliding molecules have sufficient energy they will react.

If reaction is between a substance in solution and a solid, you just vary the concentration of the solution. If the reaction is between two solutions, you have a slight problem. Do you vary the concentration of one of the reactants or vary the concentration of both? You might find that the rate of reaction is limited by the concentration of the weaker solution, and increasing the concentration of the other makes no difference. What you need to do for example, is to fix the concentration of HCl. Now you can increase the concentration of Na₂SO₃ solution to produce an increase in the rate of the reaction (refer to Spiers & Stebbens, 1973; Atkinson, 1979; Holderness & Lambert, 1986).

Worksheet 3

For Episode 4.2: Explore using the computer simulation (sub-microscopic behaviour of molecules during chemical rate of reaction)

Instructions

Working in groups, use the rate of reaction simulation on the CD-ROM or on the desktop of your computer to complete the table below by comparing your predictions to your observations

In this activity complete the table below by comparing your predictions to observations.

- a. Predict what will happen to the rate of reaction when the concentration is changed?
- b. Test your prediction with the simulation and record your observations
- c. Discuss and explain your observations

Factor	Prediction	Test	Explain you observation
Increase concentration			
Decrease concentration			

Source: adopted and modified from <http://phet.colorado.edu/index.php>

Lesson 5: chemical rate of reaction**Double period: 80 minutes****Teaching introduction**

In this lesson the students are required to conduct a practical experiment to determine rate of reaction. The lesson begins with the teacher conducting an experimental demonstration and talk about the procedures.

Sub-topics: Effect of concentration on rate of reaction**Teaching objectives:** Be end of the lesson, the students should be able to;

1. Plot and correctly interpret graphically how concentration affect rate of reaction.
2. Use their knowledge of the collision theory to explain their observation

Teaching materials

1. Sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) and hydrochloric acid (HCl) solutions
2. source of heat
3. thermometers
4. measuring cylinders
5. beakers
6. stop clock.

What happens during this lesson

Review of Episode 4: The teacher reviews the previous lesson. The point here is to review how concentration affects chemical reactions as a starting point for introducing investigation of effect of concentration on chemical reaction experimentally in the school laboratory

Episode 5.1: Laboratory experiment to investigate the effect of concentration on the rate of reaction between sodium thiosulphate and hydrochloric acid. (See worksheet 4)

In this episode, students are to carryout practical experiment to determine the effect of concentration on chemical rate of reaction.

The episode begins with the offering explanation on the experimental procedure.

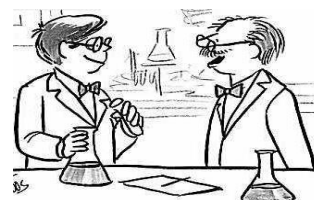
.....*Ok, so let's now turn attention to how increasing the concentration of the reactants affects rate of reaction by carrying out an experiment*

The teacher conducts an experimental demonstration to show the effect of increasing the concentration of the reactants on the chemical rate of reaction.

The students... *will then work in groups, performs the following as they carry out the experiment*

- a. Record concentration
- b. Record time taken for the reaction to end
- c. Discuss their observations and present their explanations.

Non-interactive / authoritative



Interactive-dialogic

The teacher poses questions:

- a. *Why does the cross disappear in this experiment?*
- b. *Write an ionic equation for the reaction above*

Interactive / authoritative

The point here is to have students explain their observation and represent symbolically the formation of the products at the end of the chemical reaction

Episode 5.2: Plot a graph of volume of thiosulphate (y-axis against time (x-axis)

In this episode, the teacher asks students to plot a graph of:

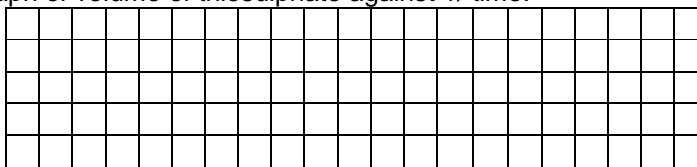
Non-Interactive-dialogic

10. What is the effect of concentration of thiosulphate on the rate of this cross to disappear?

11. Why do we plot volume rather than concentration of thiosulphate in (2)?

--

12. Plot a graph of volume of thiosulphate against 1/ time.



13. Calculate the gradient (slope) of the graph in (6) and state its units.

14. Use your knowledge of the collision theory to explain the shape of the graph.

Lesson 6: chemical rate of reaction (computer modelling using spreadsheets)

Double period: 80 minutes

Teaching introduction

In this lesson the students are required to model effects of concentrate change on rate of reaction. The lesson begins with the teacher demonstrating by changing concentration values and asking students to make observations on its effects on the rate of reactions and talk about the procedures.

Sub-topics: Effect of concentration on rate of reaction

Teaching objectives: Be end of the lesson, the student should be able to;

1. Make predictions and hypothesis or ask 'what if?'...and 'what about?'
2. Analysis graphically concentration changes against time.

Teaching materials

1. Computers
2. e-learning content (simulation on CD-ROM/DVD)
3. projector

What happens during this lesson

Episode 6.1: Virtual laboratory investigation of the effect of concentration on the rate of reaction

In this episode, students are to tryout what they think might happen when the concentration of the reactants are altered.

Students are required to make changes of concentration value while they observe its graphical display.

The teacher will substitute real experiment with virtual environment using spreadsheets as a modelling tool.

The teacher poses questions:

What do think the graph would look like?

Do you think the curve would increase or decrease?

The teacher gets students in groups to make predictions/discussions

Students discuss and share their ideas in groups



Interactive-dialogic

Here, the teacher will provide opportunities for students to try out and practice the scientific ideas for themselves, to make those ideas their own and gradually take responsibility for their independent working.

The students: *are to make prediction, hypothesizing or ask 'what if?' questions. Thus, focus more on analysing the results and hypothesizing.*

Non-interactive-dialogic

The teacher prompts

a. *How does time changes when you increase the concentration?*

b. *How does concentration graphically change with time?*

The teacher will provide support during modelling.

The teacher then will shares students' results to the whole class.

The point here is to have students try out their ideas, develop theory and test their theory and thus, focus more on analysing the results and hypothesizing.

Interactive-authoritative

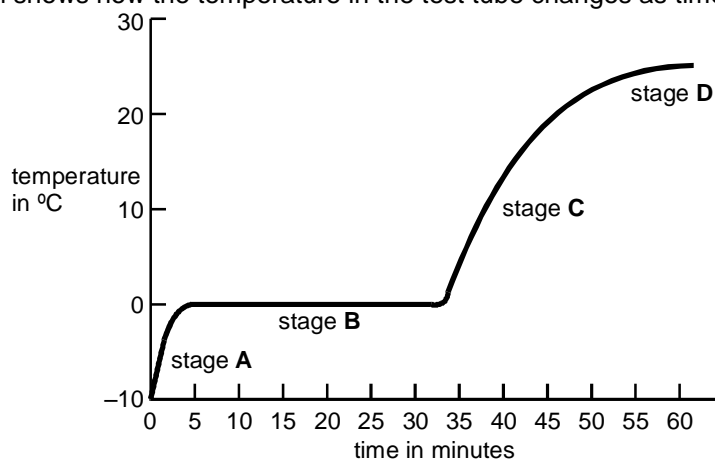
Appendix 8: Your understandings of particles and matter

Form: Senior Four

The following questions are about; states of matter and kinetic theory of matter

Answer **all** questions

1. A test tube of crushed ice is taken out of a freezer and left in a warm room. The graph shows how the temperature in the test tube changes as time goes by.



- (a) Explain as clearly as you can what is happening to the ice at stage **B**?

- (b) Why does the temperature of the water stop rising at 25°C (stage **D**)?

- (c) Four descriptions of the ways the molecules in ice or water could move are given below.

They vibrate around fixed points.

They move past each other and are close together.

They move in straight lines, colliding occasionally.

They all move in the same direction at the same speed.

- (i) How do the molecules move at stage **A**? Write **A** in the correct box above.
 (ii) How do the molecules move at stage **C**? Write **C** in the correct box above.

- d) Identify the states of matter in the different parts of the graph

i)

A _____

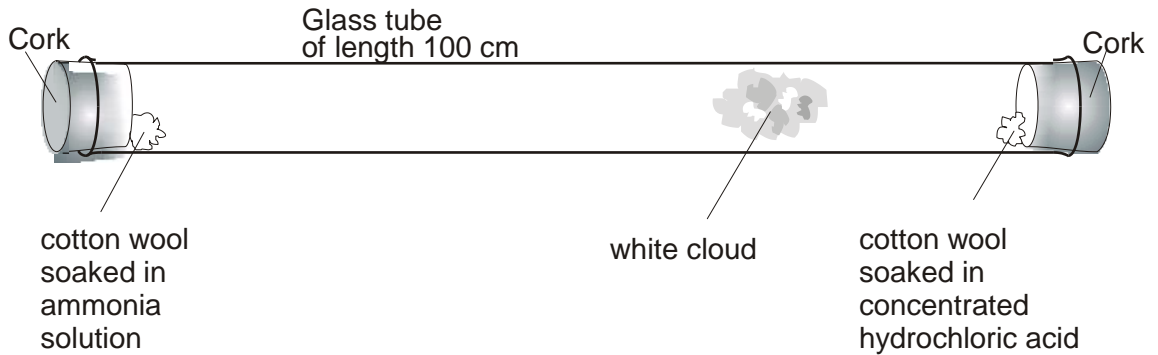
ii)

C _____

e) Draw diagrams to illustrate the arrangements of particles in the three states of matter above.

A	C

2. An experiment was set up as shown in the drawing. After several minutes white cloud of ammonium chloride, NH_4Cl , appeared as shown.



solution	gas given off	relative molecular mass
ammonia	ammonia	17
hydrochloric acid	hydrogen chloride	36.5

(a) Explain in as much detail as you can how the white cloud is formed.

(b) Explain why the cloud is formed nearer to the hydrochloric acid end of the tube than to the ammonia end.

(c) Explain why the cloud formed after several minutes, rather than immediately

d) Supposing the experiment with the tube was carried out in a hot chamber.
i. Would the white cloud be formed in a time (please tick the correct answer)

Shorter	
Longer	
Same time	

Explain why in as much detail as you can your answer in d (i) above

ii. What is this process called?

3. These questions are all about the atoms and particles which made up matter

	True	False
i. The particles in solids have a vibrating motion		
ii. When a solid is heated the particles expand to get bigger		
iii. The particles in a liquid are close together but do not touch each other		
iv. There is air in the spaces between the air molecules of this room		
v. The particles in a solid attract each other so that the solid keeps its shape		

End

Good Luck

Appendix 9: Your understandings of chemical rate of reaction

Form: Senior Four

Instruction

Attempt **all** questions

- John's chemistry teacher puts a beaker of sodium thiosulphate on a table near the window in the chemistry laboratory. John can clearly see a tree on the school compound through the beaker. The teacher adds hydrochloric acid to the beaker. After 120 seconds John cannot see the tree although he is looking carefully because the solution has gone cloudy
 - Explain why it has gone cloudy

The teacher repeats the experiment at different temperature with three other classes. The tree disappears from view at different times.

Class	Time for tree to disappear in seconds
A	120
B	200
C	150

- Which class carried out the experiment at the highest temperature?

The experiment was repeated at different temperatures

Temperature ($^{\circ}\text{C}$)	30	40	50	60	70
Time taken (s)	80	40	20	10	5

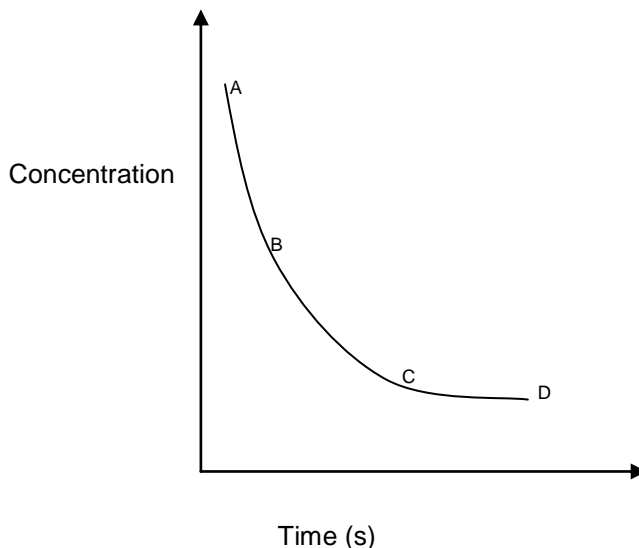
- Plot a graph of temperature ($^{\circ}\text{C}$) against time (s) in the table below.

- Use the graph to describe in as much detail as you can the effect of temperature on the time taken for the reaction to finish

- Use your knowledge of the collision theory to explain this as best as you can in terms of particles. (You might be able to think of more than one explanations for this)

- Mary conducted experiments to investigate the effect of changing the concentration of hydrochloric acid when it reacts with calcium carbonate.

The time taken for the reactions to stop were recorded and plotted against different concentrations of hydrochloric acid. The graph below was then obtained for reaction:
 $\text{CaCO}_3 (\text{s}) + 2\text{HCl} (\text{aq}) \longrightarrow \text{CaCl}_2 (\text{aq}) + \text{H}_2\text{O} (\text{l}) + \text{CO}_2 (\text{g})$



a) What would you see happening to calcium carbonate?

b) If 40 cm^3 of gas is collected in 10 seconds with 1M HCl acid. What is the rate of reaction?

c) How would the rate compare if you used 0.5M HCl acid?

d) Positions A, B, C and D are 4 points on the graph.

i) Which position does the calcium carbonate reacts fastest?

ii) Which position is the concentration of hydrochloric acid highest?

iii) Generally the reaction time is shorter if the concentration is higher, explain this as best as you can in terms of reacting particles

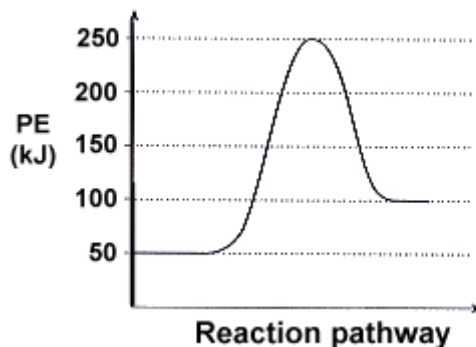
e) In another experiment, Mary carried out a reaction with 1M HCl solution which was kept under room temperature (25°C) with Magnesium. The rate of production of the gas collected was found to be 10 cm^3 per second. The experiment was then repeated using 0.5M HCl solution heated to a temperature of 35°C with same amount of Magnesium and the rate of production of the gas collected was found to be the same (10 cm^3 per second).

i) Explain as best as you can why the two experiments have similar rate of reaction

ii) What is the gas produced called _____

iii) Write down the equation for this reaction

3. Generally chemical reaction occurs due to collision of reactant particles. Effective collision which results into reaction and products only occurs when reactants possess minimum energy called activation energy. This process can be graphically represented as below



- a) Label the position of the reactants, products, and activated complex on the graph
- b) Determine the activation energy, E_a for this reaction.

- c) Explain as best as you can
- i. What is meant by activation energy of reacting particles

- ii. The relationship between activation energy and chemical rate of reactions

- d) Reacting particles do not always collide properly or effectively. Sometimes they miss or collide as shown below.
- i. Draw the missing pictures to show what might be happening to the particles in each case.

A	B	C
Particles miss each other	A glancing collision	A head on collision

- ii. Which collision results into a reaction

- iii. Explain your answer in b (ii) as best as you can in terms of proper orientation of the reacting particles

End
Luck Good

Appendix 10: Interview guide for teacher

A. Background information

Designation of the interviewee

Age

Sex

Highest qualification

B. After each lesson

1. That was well done
2. How did you find it? How was the lesson?
3. What went well? What wasn't so good?
4.specific points from you: 'what was happening when.....?'

C. At end of teaching

5. Looking back over the lessons...how do you think they went in general?
6. Did you enjoy the teaching?
7. Have you done any teaching like this before?
8. How do you think the students enjoyed the lesson?
9. What about the understanding of the students? Do you think they learned a lot?
10. Were there any new challenges here for you in teaching in this way? Using the simulation? How did you deal with these?
11. Would you use this kind of approach again? Probe why/
12. In Lesson 3.....you.....liked.....why????
13. What did YOU learn from this experience as a TEACHER?? (Alternative conceptions, simulation, talk.....dialogic.....more interactive approach....)
14. In your opinion, what are the major benefits gained from the use of C&TA as compare with NTA?
15. What are your thoughts about C&TA in teaching chemical rate of reaction?
16. How would you rate classroom participation and performance of your students in chemistry subject
 - a. before
 - b. and during C&TA?
17. (Probe for improved understanding of chemistry concept)
18. How has the use of C&TA changed the way you teach and relate to your students?
19. Any other comments or suggestions on C &TA?

Thank you for giving your time

Appendix 11: Interview guide for students

Number of students: 4-6 students
 Advice from teacher: reliable, confident, talk, range of ability

Group interviews**A. Background information**

Age
 Sex
 Class

B. After each lesson

1. How did you find it? How was the lesson?
2. What went well? What wasn't so good?
3.specific points from you: 'what was happening when.....?'
4. SUBJECT questions: For example, 'Teacher was talking about rate of reaction...can you say what that means?' UNDERSTANDING

C. At end of teaching**Group interviews**

5. Looking back over the lessons...how do you think they went in general?
6. Did you enjoy the lessons?
7. Have you had any teaching like this before?
8. Would you like this kind of approach again?
9. What else did you learn about...apart from rates of reaction??
10. In your opinion, what are the major benefits gained from the use of this NEW teaching as compared with OLD?
11. How would rate your classroom participation in chemistry subject
 - a. before
 - b. and during C&TA?
12. How has working in groups with C&TA change the way you relate with your fellow students? Probe for improved understanding of chemistry concept
13. Based on your experience with C&TA so far, do you want to continue learning using C&TA in your classroom? And Why?
14. How would you compare learning using C&TA with NTA?
15. What are your concerns or challenges when learning using C&TA?
16. Any other comments, suggestions on C &TA?
17. How do you feel about learning chemistry subject using C&TA?

Individual interviews

Go through post test

(Probe understanding of the students ideas on the written post-test?)

Thank you for giving your time

Appendix 12: Computing the CVI

The CVI of each instrument was obtained by drawing up the objectives which guided the construction of the instruments. Each instrument with its objectives was given to knowledgeable people who were asked to independently have a thorough critique of the items which specifically:

1. Linked each item with respective objective.
2. Assessed the relevance of the items to content addressed by the objectives and,
3. Judged if the items adequately represent the content in the subject under study.

They rated each item on a four-point scale as:

1. Not relevant. 2. Somewhat relevant. 3. Quite relevant. 4. Very relevant.

The following results were obtained:

Instruments	Not/ somewhat relevant	Quite/ Very relevant	Total items	CVI value
Base-line test/ Equivalence Test	4	14	18	0.75
Post-test	4	16	20	0.80

CVI - Proportion of the highly ranked items out of the number of the items in questionnaire. For an instrument to be considered valid it should have a CVI of at least 0.60 (Amin, 2005).

Appendix 13: Reliability tests for the base-line test

Base-line test Reliability Statistics	
Cronbach's Alpha	N of Items
.515	18

	Base-line test Item Statistics		
	Mean	Std. Deviation	N
what is happening to ice	2.3000	.97872	206
why temperature of water stop rising at 25 0c	1.8000	1.00525	206
How molecules move at stage A	2.1000	1.02084	206
How molecules move at stage C	1.7000	.97872	206
States of matter in the different parts	2.7000	.73270	206
States of matter in different parts	2.5000	.88852	206
Arrangements of particles	2.4500	.82558	206
Explain how cloud is form	1.3500	.48936	206
Explain why the cloud nearer to HCl end	1.0000	.00000	206
Explain how cloud is form after several minutes	1.1000	.30779	206
How long the white cloud take to form	2.3000	.97872	206
Explain how long it takes for the white cloud to form	1.7000	.97872	206
Naming the process	1.2000	.61559	206
The particles in solids have a vibrating motion	1.8000	1.00525	206
Solid particles expand when heated	1.6000	.94032	206
The particles are close together in a liquid	1.9000	1.02084	206
There is air in the spaces between the air molecules	1.3000	.73270	206
The particles in a solid attract	2.1000	1.02084	206

Appendix 14: Reliability tests for the post-test

Post-test Reliability Statistics	
Cronbach's Alpha	N of Items
.75	20

Post-test Item Statistics			
	Mean	Std. Deviation	N
Explanation for the reaction between sodium thiosulphate & hydrochloric acid- why it goes cloudy	2.2000	.69585	236
Experiment at the highest temperature	3.0000	.00000	236
Explanation of effect of temperature on the time taken for the reaction to finish	2.8000	.61559	236
Using collision theory to explain effect of temperature on reacting particles	1.9000	.44721	236
Explanation on what happens on calcium carbonate	2.0500	.60481	236
Determination of rate of chemical reaction	1.7000	.97872	236
Comparing the rate of reaction between 1M and 0.5M HCl	1.7000	.97872	236
Position the carbonate reacts fastest	2.5000	.88852	236
Position the concentration of hydrochloric acid is highest	2.8000	.61559	236
Using collision theory to explain effect of concentration on reacting particles	1.4500	.51042	236
Explanation on why two experiments have similar rate of reaction	1.4500	.75915	236
Naming the gas produced when HCl reacts with Magnesium	2.8000	.61559	236
Write down the equation of reaction between HCl and Magnesium	2.5000	.88852	236
Labelling the position of reactions, products, and activated complex on the energy graph	1.9000	.91191	236
Determination of activation energy	1.2500	.63867	236
Explaining what is meant by activation energy of reacting particles	1.7500	.44426	236
Explaining relationship between activation energy and chemical rate of reactions	1.5000	.82717	236
Drawing the missing particles showing what happens to particles	2.5000	.68825	236
Naming collision which results into a reaction	2.4000	.94032	236
Explaining reaction in terms of proper orientation of the reacting particles	1.8500	.93330	236

Appendix 15: Overall correlation statistical test

		Base-line Test Marks	Post Test Marks
Base-line Test Marks	Pearson Correlation	1	.195**
	Sig. (2-tailed)		.005
	N	212	201
Post Test Marks	Pearson Correlation	.195**	1
	Sig. (2-tailed)	.005	
	N	201	235

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

Appendix 16: Within group correlation statistical test

Group		Base-line Test Marks	Post Test Marks	
Comparison	Base-line Test Marks	Pearson Correlation	1	
		Sig. (2-tailed)	.509**	
		N	107	
	Post Test Marks	Pearson Correlation	.509**	1
		Sig. (2-tailed)	.000	
		N	99	131
Experimental	Base-line Test Marks	Pearson Correlation	1	
		Sig. (2-tailed)	.353**	
		N	105	
	Post Test Marks	Pearson Correlation	.353**	1
		Sig. (2-tailed)	.000	
		N	102	104

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

Appendix 17: Mean score and independent t- test

Group Statistics					
Group		N	Mean	Std. Deviation	Std. Error Mean
Base-line Test Scores	Experimental	105	9.42	2.882	.281
	Comparison	107	10.36	3.710	.359

Group Statistics					
Group		N	Mean	Std. Deviation	Std. Error Mean
Post Test Marks	Experimental	104	26.957	6.4812	.6355
	Comparison	131	14.447	6.8935	.6023

Appendix 18: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Base-line Test Scores	Equal variances assumed	10.731	.001	-2.070	210	.040	-.945	.457	-1.846	-.045
	Equal variances not assumed			-2.075	199.537	.039	-.945	.456	-1.844	-.047

Appendix 19: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Post Test Scores	Equal variances assumed	.740	.391	14.187	233	.000	12.5102	.8818	10.7728	14.2475
	Equal variances not assumed			14.288	226.403	.000	12.5102	.8756	10.7848	14.2355

Appendix 20: Tests of between-subjects effects (Main effect tests)

Dependent Variable: Post Test Marks

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Corrected Model	8479.914 ^a	4	2119.979	58.205	.000	.543	232.819	1.000
Intercept	2499.507	1	2499.507	68.625	.000	.259	68.625	1.000
Base-line Test Marks	1749.646	1	1749.646	48.037	.000	.197	48.037	1.000
Gender	.020	1	.020	.001	.981	.000	.001	.050
Group	7749.931	1	7749.931	212.778	.000	.521	212.778	1.000
Gender * Group	153.090	1	153.090	4.203	.042	.021	4.203	.532
Error	7138.849	196	36.423					
Total	107480.500	201						
Corrected Total	15618.764	200						

a. R Squared = .543 (Adjusted R Squared = .534)

b. Computed using alpha = .05

If there has been an interaction, it means that the effect of each variable depends on the level of the other. If an effect is different depending on something else, it must exist! So a significant interaction says that both variables predict the outcome.

Appendix 21: Ministry of Education and Sports circular (No. 19/04)

Telegram: "EDUCATION"
 General Line: 234451/8
 Fax: 234920



Ministry of Education & Sports
 Embassy House
 P.O. Box 7063
 Kampala, Uganda

In any correspondence on
 this subject please quote No. ADM/97/298/01

8th October, 2004

CIRCULAR NO.19/04

To: All Secondary Schools
 Both Government and Private

RE: ENTRY REQUIREMENTS FOR UCE

1. You are aware of Government's intention and resolve to modernize the economy of this country and one of the ways identified is through an appropriate education system.
2. The teaching of Science and all other skills related subjects is one of the means of ensuring that the education system addresses the needs of the country and therefore can be considered to be appropriate.
3. However, it has been noted that the teaching of Sciences in some Secondary Schools particularly in the Private Secondary Schools has deteriorated to the extent that many Secondary Schools presently offer only Arts Subjects contrary to the Ministry's policy regarding the implementation of a curriculum of seven core subjects and a number of optional subjects.
4. It is in view of the above therefore, that this circular intends to direct as follows:
 - (a) With effect from 2006 no Secondary School shall be allowed to present any candidate/s for Uganda Certificate of Education (UCE) unless the candidate is offering the following subjects Biology, Chemistry, and Physics in addition to the already compulsory ones (i.e. Mathematics, English, Geography and History).

- (b) Heads of schools both Private and Government working together with their Boards of Governors must ensure that their schools have at least the basic infrastructure and facilitation to offer the above subjects.
- (c) No school, Government or Private shall be allowed to operate a Uganda National Examination Centre Number without the basic infrastructure as in (b) above.
- (d) All Headteachers are required to study the circular from the Secretary Uganda National Examination Board of 15th September 2004 and begin preparing for the mentioned changes taking effect from 2006 UCE Examinations.
- (e) The Director Education Standards Agency, District Education Officers and District Inspectors of Schools should ensure that no new private school is recommended to be licensed or registered without the basic infrastructure to offer sciences.

Schools already licensed or registered should acquire the basic infrastructure before the end of the school year 2005.


F.X.K. Lubanga
PERMANENT SECRETARY

- c.c Hon. Minister of Education & Sports
- " Hon. Minister of State for Education – Higher Education
- " Hon. Minister of State for Education - Primary Education
- " Hon. Minister of State for Education - Sports
- " Members of Parliament
- " Resident District Commissioners
- " Director Education Standard Agency
- " Chief Administrative Officers
- " District Education Officers
- " District Inspectors of Schools
- " Foundation Bodies of Secondary Schools