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# Enhancing Teachers' Knowledge for Using Multiple Representations in Teaching Chemistry in Nigerian Senior Secondary Schools

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**BSc. Ed (Chemistry); M.Ed (Science Education); PGDE**

**and**

**MSc (Analytical/Environmental Chemistry)**

**Thesis submitted in fulfilment of the requirement for the award of**

**DOCTOR OF PHILOSOPHY**

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**Faculty of Education and Arts**

**at**

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**Perth, Western Australia**

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“Whatever you do, do well. For when you go to the grave, there will be no work or planning or knowledge or wisdom.

Those who live in the shelter of the Most High will find rest in the shadow of the Almighty. Taste and see that the Lord is good. Oh! the joys of those who take refuge in him.”

(The holy book of Ecclesiastes, Chapter 9 Verses 10, Psalm 34: 1 and 91:1 New Living Translation Published by Tyndale House Foundation, (2007)

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## ABSTRACT

The quality of the teaching and learning of chemistry in Nigeria is of great concern to parents, teachers, and students and has been tied to various factors such as a lack of teaching resources, learning materials and well qualified teachers, large class sizes and poor funding. This resulted in poor student performance and lack of interest in chemistry. Also, learning chemistry concepts tends to be by rote and memorising of content, and as such, students do not perceive learning chemistry as relevant to their lives. These issues motivated the Researcher to explore how teaching and learning of chemistry could be reformed in low resource Nigerian secondary schools. This study focussed on enhancing teachers' pedagogical knowledge and beliefs about using multiple representations in chemistry education through a professional learning program. Participating teachers attended a series of professional learning workshops on how to construct, interpret and use multiple representations to teach chemistry concepts in ways that more actively engage students in learning.

The study employed a mixed method approach that included descriptive and interpretive methods. Forty senior secondary chemistry teachers completed a questionnaire to gather background data about difficulties of teaching chemistry effectively and their existing teaching practice and beliefs. Fifteen of these teachers then participated in three days of professional learning workshops and three of the participating teachers at the workshop were the subjects of a case study to evaluate the impact of the professional learning on their practice and beliefs. Students also completed a questionnaire about their experiences of learning chemistry and some students in case study classes participated in focus group discussions

The research involved both qualitative and quantitative methods. The qualitative data were sourced from teacher interviews, student focus group discussions and direct classroom observation. Quantitative data, on the other hand, were collected through questionnaires administered to both participating teachers and students. The mixed data sources were triangulated to ensure confirmability of findings

The study enhanced the teaching of the rate of reactions and collision theory, and water pollution and solubility concepts by using various student constructed representations such as concept maps, particulate representations, graphs, role-plays, flowcharts, and 3D physical models. The professional development intervention impacted on the teachers' beliefs about the nature of effective teaching and learning of chemistry. The study also enriched teachers' pedagogical content knowledge for actively engaging students in constructing their own representations. As an outcome from the project, a professional

learning module has been developed that can be used to enhance the teaching and learning of chemistry in low resource Nigerian schools. In addition, new knowledge has been produced in relation to the to the use of multiple representations for effective chemistry teaching and learning in schools with limited resources.

# DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

i. incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher learning;
ii. contain any material previously published or written by another person except where due references is made in the text; or
iii. contain any defamatory material.

I also grant permission for the Library at Edith Cowan University to make duplicate copies of my thesis as required.

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Bolanle Omotoke Olaleye

# ACKNOWLEDGEMENTS

*O Lord my God! When I in awesome wonder, Consider all the works Thy hands hath made, I see the stars, I hear the rolling thunder, Thy pow'r thro'out the universe displayed*
*Then sings my soul, my Saviour God to Thee,*
*How great Thou art, how great Thou art!*
*Then sings my soul, my Saviour God to Thee,*
*How great Thou art, how great Thou art!*

*O Lord our Lord, your majestic name fills the earth! Your glory is higher than the heavens. I will praise you, Lord, with all my heart; I will tell of all the marvellous things you have done.* (The holy book of Psalms, chapter 8 verse 1 & chapter 9 verse 1 New Living Translation by Tyndale House Foundation, (2007)

I will first and foremost, give glory, honour and adoration to the Almighty God who preserved my life to this stage and has equally granted me the sufficient strength, wisdom and understanding all through my research journey

I would like to express my appreciation to the Australia Federal Government and Edith Cowan University for the financial help in the form of the Edith Cowan University International Post-graduate Research Scholarship provided for me.

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# CHAPTER 1: INTRODUCTION

**Background to the Study**

The following sections introduce the reader to the Nigerian education context.

## Nigerian education

The Federal Republic of Nigeria is located on the west coast of Africa and shares land borders with the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. The current administrative system is divided into the Federal Capital Territory (FCT) and 36 states which have an estimated population of over 160 million (Library of Congress; Okebukola, 2010) and has become the sixth most populated country in the world (Ngozi, 2011).The two dominant religions are Islam (40%) and Christianity (50%), while indigenous beliefs are held by 10% of the population (Okebukola, 2010). Recently Nigeria is listed among the “Next Eleven” economies, and is a member of the Commonwealth Nations. The country is rich in petroleum and many other natural resources. The largest and most influential ethnic groups in Nigeria are Yoruba in the southwest, Ibo in the eastern region and the Hausa/Fulani who dominate in the north. These tribes have their own languages but other widely spoken languages include Edo, Efik, Fulani Hausa, Idoma, Adamawa, Central Kanuri, Yoruba and Igbo.

English language is the official language and used as the medium of instruction throughout the educational system. English language was chosen as the official language to facilitate the cultural and linguistic unity of the country. This language is spoken by a large percentage of the population but in order to preserve the culture of the people, the government of Nigeria encourages the learning of at least one major Nigerian language: Hausa, Igbo, or Yoruba. According to Taba (1962), the school has three main purposes in any given society. It serves as a preservation of the people’s culture, transmission of accumulated knowledge and transformation of the society.

Lagos State is one of the 36 states in Nigeria and Lagos city is the largest city located in the south-western part of the country along the coast of the Atlantic Ocean with an estimated population of 15 million people. Lagos city was formerly the state capital of Nigeria before the capital was moved to Abuja, in the Federal Capital Territory (FCT) due to the swiftly rising population. There are 20 local education districts (LEDs) in Lagos state however, at the administrative level and for an effective educational development, organization and monitoring, the 20 LEDs were subdivided into six education districts (EDs) with a Tutor-General acting as the administrative head of all schools in an education district. This study was based in one of the six EDs in Lagos State, Nigeria.

## Education before independence

Formal education started through the efforts of the British missionaries in 1842 when education was considered to be of fundamental importance for the spread of Christianity at that time. Therefore, the spread of Western education in Nigeria went hand in hand with the spread of Christianity. According to Ikejiani (1964) the education brought by the missionaries was focused on religious education. In these early days of their educational activities, the missionaries themselves established and operated the initial schools in Nigeria. The subjects taught in elementary schools included: Scripture, English Grammar, Arithmetic, Geography, Music, Singing, Reading, Writing, and Dictation and for girls, Sewing (Fafunwa, 1974 ). The subjects taught to the infant classes included Reading, Writing and Arithmetic, Church catechism, Singing and Dictation. It is not certain as to when Science was introduced in Nigeria. However, according to Abdullah (1982) the foundations for science teaching were laid in Nigeria between 1861 and 1874 when rudiments of Science were introduced to the timetable of some missionary secondary schools and teacher training colleges. The school timetables showed the inclusion of Botany, Nature study, Physiology and Natural philosophy. Bajah (1982) claimed that the rudiments of Science at that time were focused on learning about the environment.

## Education after independence

Nigeria gained its independence from the British in 1960. The Federal Government of Nigeria (FGN) regards education as an instrument for effecting national development. The Governments' philosophy on education is based on the

> "development of the individual into a sound and effective citizen, the full integration of the individual into the community and the provision of equal educational opportunities for all citizens of the nation at the primary, secondary and tertiary levels both inside and outside the formal school system" (Federal Republic of Nigeria, 2004, p. 2).

Education is free but not compulsory at present in Nigeria.

While basic educational policy regarding structure, curriculum and school year is centrally determined, some powers over educational delivery are devolved to state and local governments. In effect, education is administered by three branches of government: primary education is under the control of local governments, secondary schools fall under the jurisdiction of the State governments and higher education is administered by both the Federal and State governments.

Formal education is organized into four levels: pre-primary (3-5 years of age), primary (6-11 years of age), secondary (junior: 12 – 14 years of age, and senior: 15 – 17 years of age) and tertiary (four years of University education, or four years of polytechnic education). Every child who enrols in primary education is encouraged to remain in school until the end of junior secondary education. Effectively, this means that all children should complete at least nine years of basic education. The goals of education for Nigeria as stated in section 1 of the National Policy of Education (2004) are the:

a. Inculcation of national consciousness and national unity;
b. Inculcation of the right type of values and attitudes for the survival of the individual and the Nigerian Society;
c. training of the mind in the understanding of the world around; and
d. acquisition of appropriate skills and the development of mental, physical and social abilities and competencies as equipment for the individual to live in and contribute to the development of the society. (p. 2)

The National Policy of Education (Federal Republic of Nigeria, 2004, p. 1) sets out clear objectives for science education at all levels which are related to the overall national objectives of "building a free, democratic, egalitarian, strong, just and self reliant Nigerian society, full of opportunities for all citizens". For secondary education, the important objectives in relation to science are:

a. provide all primary school leavers with the opportunity for education of a higher level, irrespective of sex, social status, religious or ethnic background;
b. offer diversified curriculum to cater for the differences in talents, opportunities and future roles;
c. provide trained manpower in the applied science, technology at sub-professional grades;
d. equip students to live effectively in our modern age of science and technology;
e. raise a generation of people who can think for themselves, respect the views and feelings of others, respect the dignity of labour, appreciate those values specified under our broad national goals and live as good citizens;
f. provide technical knowledge and vocational skills necessary for agricultural, industrial, commercial and economic development. (Federal Republic of Nigeria, 2004, pp. 13 - 14)

From the Researcher's observation, it appears that one of the most striking problems of science education in Nigeria is that of inadequate science teaching materials. The objectives of science education according to the National Policy of Education (Federal Republic of Nigeria, 2004) reflects science as an activity based subject which requires many teaching and learning materials and resources. It seems that the problem is heightened by a lack of science textbooks for the students and most of the teaching involves writing notes on the chalkboard for the students to copy.

The main interest of this research study is the improvement of chemistry teaching at the senior secondary level. Research in Nigeria has revealed that the performance of students in science and chemistry classes is very poor because of the way chemistry is being taught and that teaching strategies are dominated by didactic teacher explanations in a lecture fashion where teachers act as information givers while their students remain passive most of the time (Benjamin, Braimoh, & Ogunmade, 2002).

### Problem

The Researcher's observations in Nigeria show that there are number of factors that limit the effectiveness of the teaching of chemistry. These include: a lack of qualified science teachers (Abdullah, 1982; Keshinro, 2006; Ogunmade, 2006); a lack of laboratory equipment and instructional materials such as textbooks, models and audio visual aids to demonstrate scientific principles (Akintunde & Lawal, 2008; Olaleye, 2005; Oloyede, 2010); large class sizes and a limited range of teaching strategies resulting in the 'chalk and talk' method with few or no practical activities (Abdullah, 1982; Adenekan, Adewopo, & Ogunjobi, 2006; Akintunde & Lawal, 2008; Olaleye, 2005; Olaleye, Akinniyi, & Ogunlusi, 2008; Oloyede, 2010). In addition, students find the learning of chemical concepts difficult and boring hence, their performances in chemistry tends to be lower when compared to other subject areas (Keshinro, 2006; Olaleye, 2005; Olaleye, et al., 2008; Oloyede, 2010). The problem is further contributed to by irregular in-service teacher training to update science teachers' pedagogical and content knowledge (Adenekan, et al., 2006; Braimoh, 2008; Olaleye, Adewumi, & Akinniyi, 2009; Owolabi, 1999).

Teachers lack the laboratory facilities and models needed to make the abstract concepts of chemistry real and accessible for students and therefore need to find new ways of making classroom activities more engaging for students. Recent research on students' construction of multiple representations of science concepts (Carolan, Prain, & Waldrip, 2008; Harrison & De Jong, 2005; Harrison & Treagust 1999; Haslam, Tytler, & Hubber, 2009; Howitt, 2009; Lemke, 2004; Prain & Waldrip, 2006) offers a new approach to teaching and learning which can be implemented in the resource poor schools of Nigeria.

### Rationale

Successful learning cannot take place without effective teaching (Olaleye, 2005). From a constructivist perspective, effective teaching is not a simple one way communication but rather productive learning occurs when students are being actively engaged in the learning process rather than attempting to receive knowledge passively (Jonassen, 1999; Piaget, 1969). The constructivists argue that students construct knowledge based on their personal understanding and prior knowledge. They are not a blank slate but learn best when allowed to be active creators of their own knowledge. It then appears that when students become engaged in activities, they move from being a passive receiver of information to an active contributor in the learning process. Therefore, science teachers need to ensure that the learners understand what is being taught and are also able to put the knowledge into effective use (Adenekan, et al., 2006). Furthermore, Lemke (2004) suggests that effective communication in the science classroom involves the use of language in multiple forms that includes speech, writing, signs and gestures. Communication goes beyond mere facts or rote learning but encompasses playing roles that convey emotion, mood, health, seriousness and importance by using gesture and posture, facial expressions, drawings and vocalizations. Since chemistry has its own language and vocabulary it would be better learned when students are provided with opportunities to actively engage in constructing knowledge using multiple representational modes.

To increase the quality of science and chemistry teaching in Nigeria, teaching needs to be enhanced by using more effective pedagogies that can be implemented within the constraints of limited resources. Hackling and Prain's (2005) research report asserts that science learning is best facilitated in a representation-rich environment where students share understandings, collaborate on investigations, and clarify knowledge through constructing representations of what they have learnt. Waldrip and Prain (2006) describe multiple representations as the practice of representing the same concept in different modes, including verbal, graphic and numerical forms. Researchers such as Ainsworth (1999), Dolin (2001), and Russell and McGuigan (2001) argue that, to learn science effectively, students must understand different representations of scientific concepts and processes, be able to combine them into one another, as well as understand their co-ordinated use in representing scientific knowledge. In other words, students should be able to conceptualise the relationship between different modes so that they can develop a full understanding of the concepts taught. Teachers using multiple representations in their teaching are likely to make abstract science concepts more accessible for students. Students who represent and re-represent their understandings are likely to be more actively engaged in learning.

Chemistry was introduced into the curriculum at secondary school because of its educational value and relevance to the needs of the individual learner and to the economic development of Nigeria. Chemistry satisfies our natural curiosity about the world. Also, chemistry allows individuals to gain some experience of the scientific methods which help in everyday life and in the study of other subjects. Chemistry improves knowledge which can be applied to protect children from sub-standard drugs, unsafe food, and unclean water. Scientific discoveries of how to use natural products in the manufacture of drugs and herbal medicine, dyes, artificial fertilisers, herbicides, insecticides and pesticides for more productive agriculture, materials for home building, fuel for transportation, chemicals for road construction and the production of currencies and notes are all driven by chemistry (Majek, 2008). The poor standard of chemistry teaching and learning in Nigeria is limiting the development of individuals and the country as a whole, so there is an urgent need to address this problem (Adesoji & Olatunbosun, 2008; Keshinro, 2006; Olaleye, et al., 2008; Oloyede, 2010).

**Significance**

The most significant aspect of this study is the application of the latest research about multiple representational teaching and learning to low resource school contexts where large classes and a lack of laboratory facilities predispose teachers to traditional expository forms of instruction. This study challenged these participating teachers' beliefs about traditional teaching practices in chemistry and they developed new knowledge about using multiple representations to make abstract science concepts more accessible for students and to actively engage them in learning. This is consistent with Hackling and Prain's (2005) research finding that enhancing teachers' pedagogical content knowledge is likely to lead to greater confidence and self efficacy for teaching science. The research developed, implemented and evaluated a professional learning module in Nigeria that can be implemented more widely for improving chemistry teaching and learning in other similar African contexts. Finally, the study also extended existing theory about the role of the teacher and student in constructing multiple representations in teaching, learning and assessment.

**Purpose and Research Questions**

The purpose of the study was to describe the current beliefs, knowledge and practice of senior secondary chemistry teachers in one education district of Nigeria, involve some of those teachers in a professional learning intervention and investigate the impact of the intervention on the teachers' and students' engagement with learning. The following research questions provided a focus for the investigation:

1. What challenges do teachers face in the teaching of chemistry in Nigerian secondary schools?

2. What are the teachers' current beliefs about effective teaching and learning of chemistry, knowledge about using representation in chemistry teaching, and their current teaching practice?
3. What are the impacts of the professional learning intervention on teachers' beliefs, knowledge and practice?
4. What are the impacts of the professional learning intervention on students' beliefs about teaching and learning of chemistry and their engagement with learning?

# CHAPTER 2: LITERATURE REVIEW

This review of literature outlines concerns relating to chemistry teaching in Nigeria and develops a conceptual framework to guide the research. The chapter includes a of review current literature about sociocultural and social constructivist views of learning and also the role of representation in learning chemistry. The review then focuses on the impact of teacher's pedagogical content knowledge, beliefs and professional learning on classroom teaching. The review of the literature informs and shapes the study's conceptual framework.

**Introduction**

The primary aim of a contemporary science education should be to prepare students to use scientific knowledge for improving their lives and for managing the rapidly developing technological world. Fensham (2008) described the purpose of science education as providing opportunities for experiencing and understanding the nature of science; encouraging science learners to engage in their own theory building about natural phenomena; and to engage in decision making about scientific and technological issues in society. Harms and Yager (1981) argued that the goals of science education are categorized into four categories: personal needs, societal needs, academic preparation needs and career awareness needs. However, this study focused on science education at the senior secondary high school level in Nigeria. Specifically, there are two major purposes of science education at the secondary level as stated in Roberts (1982), which are developing students' scientific literacy for general life and preparing them for further studies in science or employment in a field of science. This view is supported by Osborne and Dillon (2008) who explained that "Most school science curricula do attempt to serve two goals – that of preparing a minority of students to be the next generation of scientists – and that of educating the majority in and about science, most of whom will follow non-scientific careers" (p. 7). However, they argued that a science education for all can only be justified, if it offers something of universal value for all rather than serving the minority who will become future scientists.

Various research papers argue that the purpose of science education is to develop scientific literacy (Bell, Blair, Crawford, & Lederman, 2003; Bybee, 1987; Duit & Treagust, 1998; Goodrum, Hackling, & Rennin, 2001; Hackling & Prain, 2005; Lemke, 2004; Millar & Osborne, 2000; Miller, 1983; Murcia, 2009). These researchers argue that, a curriculum for scientific literacy should help students make sense of their local environment, their health and well being; apply their knowledge to everyday phenomena, systems and events; and possess understanding of the scientific concepts and processes required for making crucial decisions on everyday issues and problems. In summary, developing true scientific literacy will enable students to apply what they have learnt in the classroom to real-world situations.

This view of a scientifically literate person is consistent with the definition used by the Organisation for Economic Co-operation and Development (OECD) (2006) in their programmed for International Student Assessment (PISA). It states that scientific literacy refers to an individual's:

- Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence –based conclusions about science-related issues
- Understanding of the characteristic features of science as a form of human knowledge and enquiry
- Awareness of how science and technology shape our materials, intellectual and cultural environments
- Willingness to engage in science-related issues and with the ideas of science as a reflective citizen. (p. 23)

There is an international consensus about the importance of scientific literacy however; there is some variation in how the construct is defined. For example, the American Association for the Advancement of Science (AASS, 1990) defines scientific literacy as:

> being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes. (p.4)

Likewise in Australia, Hackling and Prain (2008) refer to scientific literacy as a "multidimensional construct that requires citizens to be interested and engaged with scientific matters and have the knowledge and skills that can be applied in real-world contexts to investigate, represent and communicate findings and solve everyday problems" (p.6). With these perspectives, it appears that educating learners for scientific literacy at the senior high school should enable them to have a broad understanding of science to interpret and construct science texts, use science to meet the personal and social demands of their life and in the community (Murcia, 2007; Yore & Treagust, 2006).

In Nigeria, it was stated that science and technology shall continue to be taught in an integrated manner in the schools to promote students' appreciation of basic ideas (Federal Goverment of Nigeria, 2004). The philosophy of integration in Nigeria was designed to help students develop an appreciation of the fundamental unity of science, the commonality of approach to problems of a scientific nature and the role of science in everyday life.

To develop scientific literacy, students need to have an understanding of the nature of science which refers to the values and assumptions inherent to scientific knowledge and the development of scientific knowledge (Lederman & Lederman, 2004). Hands-on, inquiry-based activities engage students and give them the opportunity to develop an understanding of the nature of science and scientific inquiry. In other words, students develop scientific literacy more effectively from activity and experience rather than from listening to teacher explanations (Goodrum, 2004). However, with the present situation in the Nigerian schools, the reverse is the case where teaching is didactic in nature. Nigerian teachers frequent use of a chalk and talk method where they act as information givers and the learners remain passive throughout the learning processes and prioritize rote memorization. Changes to Nigerian science education are necessary to enable individuals to utilize science for improving their life, coping with an increasingly technological world, pursuing science academically and professionally, and for dealing responsibly with science related social issues (Akpan, 1992).

**Chemistry and Chemistry Teaching**

Chemistry is one of the important subjects in science, not only because of its numerous and fundamental connections with other branches of science, but also because of its wide ranging influence on the way we live. Majek (2008) views chemistry as the science of materials in the natural and built environment and that it is pivotal to the development, sustainable use and appropriate management of the built and natural world. Chemistry is one of the means by which humans describe reality. It deals with all of the substances making up the environment and with the changes these substances undergo.

Chemistry in particular comprises four components "the processes used to obtain (discover or create) chemical knowledge; the general concepts and specific ideas so produced; the applications of that knowledge in understanding and changing the world; and the implications of that understanding and change for individuals and societies" (Cheng & Gilbert, 2009, p. 3). They also argued that understanding chemistry requires understanding: the nature of chemistry, its norms and methods; the key theories, concepts and model of chemistry; how chemistry and chemistry-based technologies relate to each other; and appreciating the impact of chemistry and chemistry-related technologies on society.

Chemistry can contribute to the development of students' scientific literacy (Mumber & Hunter, 2009) and provides a concrete foundation for further studies or careers. Generally, the broad aims of the chemistry curriculum stated by the United Kingdom Curriculum Development Council (1996) are to enable students to:

- develop interest and maintain a sense of wonder and curiosity about chemistry;
- construct and apply knowledge of chemistry, and appreciate the relationship between chemistry and other disciplines;
- appreciate and understand the evolutionary nature of science
- develop skills for making scientific inquiries;
- develop the ability to think scientifically, critically and creatively and solve problem individually and collaboratively in chemistry-related contexts;
- discuss science -related issues using the language of chemistry;
- make informed decisions and judgments on chemistry related issues; develop open-mindedness, objectivity and pro-activeness;
- show appropriate awareness of working safely;
- understand and evaluate the social, ethical, economic, environmental and technological implications of chemistry; and develop an attitude of responsible citizenship. (pp. 3,4)

The revised edition of the Nigerian Senior Secondary School Chemistry Curriculum (Federal Ministry of Education, 2007) expects among other things, that chemistry will enable students to:

i. develop interest in the subject of chemistry;
ii. acquire basic theoretical and practical knowledge and skills;
iii. develop interest in science, technology and mathematics;
iv. acquire basic STM knowledge and skills;
v. develop reasonable level of competence in ICT applications that will engender entrepreneurial skills;
vi. apply skills to meet societal needs of creating employment and wealth;
vii. be positioned to take advantage of the numerous career opportunities offered in chemistry;
viii. be adequately prepared for further studies in chemistry. (p. iv).

In addition, it is expected that the revised curriculum (Federal Ministry Education, (2007) will:

- Will facilitate a smooth transition in the use of scientific concepts and techniques acquired in the new Basic Science and Technology curriculum with chemistry;
- Provide students with the basic knowledge in chemical concepts and principles through efficient selection of contents and sequencing; Show chemistry in its inter-relationship with other subjects;
- Show chemistry and its link with industry, everyday life activities and hazards;

- Provide a course which is complete for students not proceeding to higher education while at the same time provides a reasonably adequate foundation for a post-secondary chemistry course. (p. iv).

When compared to other curriculum documents, it is evident that the Nigerian chemistry curriculum does not highlight opportunities for students to develop chemical literacy and apply their knowledge for personal decisions when faced with everyday issues and problems.

Internationally, it is generally accepted by researchers and educators (Hattie, 2005; Loughran, Mulhall, & Berry, 2006) that science and chemistry in particular, needs to be taught in engaging ways. However, chemistry has been taught over the last 40 years in a traditional didactic way (McRobbie & Tobin, 1995). The focus has been on covering the curriculum which often involves well-structured problems, mechanical and algorithmic laboratory work and the rote learning of a body of knowledge (Shymansky, William, & Alport, 2003). Students have difficulty understanding the relevance of the content to their everyday lives when it is presented in this way.

Furthermore, research has revealed that students in Nigerian secondary schools have difficulties in learning chemical concepts and have found the subject boring (Benjamin, et al., 2002; Keshinro, 1998; Odubunmi, 1997; Olaleye, 2005; Olaleye, et al., 2008; Salau, 1996). A common theme emerging from these studies is that students' perceive chemistry as a subject that demands much effort for little success and they believe that the only way to pass examinations is by rote learning. Also, chemistry is not made relevant to their lives and does not encourage independent learning since the teaching has been characterized by the chalk and talk method with little or no activities. Teachers present a typically theoretical teacher-directed and extremely didactic lesson resulting in students not having a deep understanding of the concepts taught.

In making efforts to reform chemistry teaching and learning in Nigeria, various studies have been carried out with the aim of improving student's performance and attitudes towards chemistry. A research study in Nigeria indicates that teachers in Nigeria are faced with problems of large classes and they lack adequate resources to make concepts concrete and accessible to students (Aderounmu, et al., 2007). Despite various suggestions for improvement, the low standards remain (Akintunde & Lawal, 2008; Ikeobi, 1995; Keshinro, 1998; Ogunmade, 2006; Olaleye, et al., 2009; Olaleye, et al., 2008). From these perspectives, it appears that the low standards could be attributed to the following factors:

1. Teachers not having the necessary content or pedagogical knowledge needed to teach chemistry topics effectively.
2. Pressure to cover the content within a limited period of time.
3. Preparing the students just for examination purposes.
4. Attempting to attain or achieve all the objectives of course or each topic without being mindful of students gaining meaningful understanding.

Cuttance (2001) argues that capturing students' interest in chemistry at senior secondary school level is a crucial aspect to improving the uptake of chemistry at tertiary levels. For this reason, it is suggested that there is a need to improve the way chemistry is taught in schools so that students are more engaged and recognise the relevance of the science through more real-life practical activities. Minds-on as well as hands-on activities that engage students in active learning are important in any chemistry classroom. Likewise, Njoku (2004) stressed that the teacher needs to be trained how to use activities that will make learners do and experience science instead of just reading about science. Contemporary learning theory indicates that students need to be actively engaged in learning tasks if they are to develop a meaningful understanding of chemistry.

**Social Constructivist View of Science Learning**

The fundamental principles of learning theories, collectively called 'Constructivism', evolved from research into developmental, cognitive and humanistic views (Atherton, 2009; Duit & Treagust, 1998). A constructivist approach is student-centred and focuses on students' background experiences and prior learning (Duit & Confrey, 1996; Kearney & Treagust, 2001; Solomon, 2000). Learning results from experience, thinking, memory and all the other cognitive processes that build connections between new information and prior knowledge. These links then become integrated into long term memory networks. Moreover, Osborne and Wittrock (1983) recognized that learning is a generative act where learners "retrieve information from long-term memory and use their information processing strategies to generate meaning from the incoming information, to organize it, to code it, and to store it in long-term memory" (p. 5). This generative model of learning according to Osborne and Wittrock describes how students learn and how these students can be taught. Furthermore according to the model, to learn with understanding a learner must actively construct meaning because the brain is not a passive consumer of information instead it actively constructs its own interpretations of information and draws inferences from them. The stored memories and information processing strategies of the brain interact with the sensory information received from the environment to actively select and attend to the information and to actively construct meaning. It was maintained that generation is a fundamental cognitive process in comprehension.

Cognitive constructivists such as Osborne and Wittrock (1983} emphasize information processing by the individual in generating meaning from experience. However, social constructivism emphasizes how meanings and understanding grow out of social encounters. Social constructivists argue that learners construct understandings through discussion and negotiation of meaning-making with peers and teachers (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Jonassen, 1999; Vygotsky, 1978)**.** Similarly, social constructivism involves the engagement of students in a process of shared meaning-making, guided by the teacher. It also involves mastery of the discourses of science, including ways of questioning and arguing and linking ideas with evidence and linking classroom science with students' lives outside the classroom (Hubber & Tytler, 2004). Hubber and Tytler (2004) stress that there are three lessons to learn about constructivism and students' conceptual development: first, the importance of listening to students and encouraging their active engagement; secondly, involving students in authentic tasks that challenge their existing ideas and thirdly, creating the environment that encourages individual learners to construct their own meaning within a social and cultural context which helps them remember and apply what they have learned to solve new problems in new learning contexts. The emphasis is on learners as active makers of meanings who construct their own knowledge in a social context that creates a connectedness with the world around them.

Furthermore, according to self-determination theory, students have a psychological need to relate to other people. When they have positive interpersonal involvement with their peers or with the teachers; they feel better about themselves and will become more engaged in learning tasks. Likewise in science lessons and chemistry in particular, social interaction can occur when students collaborate in hands-on activities which involve group work (Palmer, 2007). In the long run, for all students to become scientifically literate, opportunities must be created to do hands-on/minds-on science; to talk about science with each other; to ask questions and get timely answers; to use what they are learning in real-world settings; to reflect on how they know what they do; and to use language appropriate to their own experiences (Blakeslee & Kahan, 1996). It is essential, therefore, that teachers develop the skills students required to help them participate activity within a constructivist classroom. Teachers should frequently assess the knowledge their students have gained to ensure that the new knowledge is what the teacher had intended. Also, learners should be constantly challenged with tasks that require skills and knowledge just beyond their current levels of mastery; this will capture their motivation and build on previous successes in order to enhance their confidence.

**Socio-cultural View of Science Learning**

Constructivist research of the late Rosalind Driver and scholars at Leeds University maintain that:

> Learning science involves being initiated into the culture of science. If learners are to be given access to the knowledge systems of science, the process of knowledge construction must go beyond personal empirical enquiry. Learners need to be given access not only to physical experiences but also to the concepts and models of conventional science. (Driver, et al., 1994, p. 6)

Sociocultural researchers such as Mortimer and Scott (2003) and Traianou (2007) would argue that this enculturation into the world of science occurs through dialogic processes using the social language of science in the context of activities. Central to Vygotsky's perspective is the notion that ideas are first constructed on the social plane, which then supports the cognitive development of the individual. Vygotsky went beyond this to argue that new thinking becomes real within social interaction before it becomes internalized in an individual's cognitive capacities.

From this sociocultural perspective, learning is therefore seen as "a process of internalization" (Mortimer & Scott, 2003, p. 10). Mortimer and Scott explained that the process of internalization always involves working on ideas and is an individual meaning making step. Learning in sociocultural perspectives is based on Vygotsky's notion of the Zone of Proximal Development which is defined as "the distance between a child's actual developmental level as determined by independent problem solving and the higher level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). The Zone of Proximal Development provides a measure of the difference between what the students can achieve working alone and what can be done with assistance.

A Vygotskian perspective on learning gives a more fundamental role to language and culture in the construction of knowledge. Knowledge is developed through participation in a discourse community and is then acquired by individuals. Alexander (2006) asserted that both students' engagement and teachers' intervention are essential components that promote the development of an individual's capacity to think and acquire knowledge. Therefore, this is seen as a process of being inducted into a culture, "learning how to talk about it, how to view it and how to approach things because, this encourages the exchange of ideas and the arriving at consensual views" (Hubber & Tytler, 2004, p. 39).

Learning as a dialogic process creates an open and fundamentally authentic learning environment and enables students to learn from each other (Bakhtin, 1981; Flecha, 2000). Meaning making according to Mortimer and Scott (2003) is a dialogic process that entails bringing together different views and working on ideas. Learning how to talk about science through the use of language in the form of signs, gestures, and facial expressions (Lemke, 2004) is a crucial aspect that brings about social interaction of classroom discourse. Through talk, scientific views are introduced to the classroom (Mortimer & Scott, 2003) and there is exploration of ideas between teacher and the students through which individual students come to their own understanding as they try to make sense from different ideas that surround them.

Sociocultural theories view the concepts and ideas expressed in language as "the product of a particular line of societal activity which take their meaning from the context of that activity" (Traianou, 2007, p. 35). Thus, learning occurs in the context of activity. In essence, for sociocultural theorists, the activity becomes the unit of analysis rather than the individual's mental structures. It is through the appropriation of such socially significant forms of activity that the individual becomes capable of the higher mental functions. Backhurst (1988) asserted that appropriation is a process in which these social activities are translated from the social plane onto the individual plane, where they emerge in a restructured form as a result of the individual's higher mental functions.

Learning the social language of science is necessary for students to effectively engage in the dialogue of the science classroom. Students' development of new understanding of abstract science concepts will depend on their understanding of the particular languages involved and diverse representations of the concept. Students need to learn the conventions that will enable them to construct and interpret representations and link everyday meaning-making to the world around them.

**Role of Representation In Learning**

Learning chemistry concepts requires an understanding of the social language of chemistry. An important aspect of developing the social language of chemistry is to acquire knowledge of the three levels of representation in which chemical ideas are expressed at the macro, submicro and the symbolic levels of representation (Cheng & Gilbert, 2009; Johnstone, 1991). The common theme among these researchers is that chemistry can be taught at these three levels for better conceptual understanding. Students' difficulties in understanding some chemistry concepts can be ascribed to their lack of meta-visualisation capability in understanding and translating different modes of representation (Cheng & Gilbert, 2009). Cheng and Gilbert suggest that, successful learning of chemistry should involve the construction of mental associations among the macroscopic, submicroscopic and symbolic levels of representation of chemical phenomena using different modes of representation. At the macro level, chemical reactions are considered as a process by which some substances disappear and new substances appear while at a submicro level, chemical reactions are considered as a process by which particles are re-ordered. The symbolic level deals with allocation of symbols to represent atoms and molecules. For example in chemistry, reaction processes are represented in symbolic form as a balanced equation (e.g., $CH_{4\,(g)} + 2O_{2\,(g)} \longrightarrow CO_{2\,(g)} + 2H_2O_{(l)}$; $NaOH_{(a\,)} + HCl_{(g)} \longrightarrow NaCl_{(s)} + H_2O_{(l)}$).

The American philosopher C.S. Pierce (1931 - 58) wrote on semiotics which is concerned with the systematic study of signs (symbols) and their meaning. The most familiar example of such a system of signs is human language. According to Peirce, humans make meanings through their creation and interpretation of signs. Anything can be a sign as long as someone interprets it as 'signifying' something. Peirce developed a triadic model comprising three basic semiotic elements, the sign, object and interpretant. A representation becomes a sign when it signifies something about the object (or referent) to someone. A theorist, Saussure (1983) says "a sign must have both a signifier (the form which the sign takes) and signified (the concept it represents)" (p. 101) which means, a sign is a recognizable combination of a signifier with a particular signified.

Figure 1 illustrates Carolan, Prain and Waldrip's (2008) representation of Peirce's triadic model.

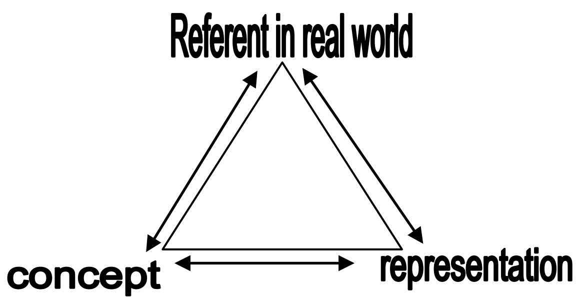


**Figure 2.1: Interpretation of Pierce's triadic model adapted from Carolan, Prain and Waldrip (2008)**

This model shows how students are supported to develop their understanding about chemistry through constructing and interpreting representations. This is because students need to draw on their experiences of the natural phenomenon to develop their mental models and whenever they are asked to create a new representation they have to think about the mental model in different ways. Also, anytime they create a representation, they go back to the concrete object and their experiences and they think about the mental model. These representational experiences engage the students in interacting with the real world examples and the mental model. It will also help them in re-develop the mental model by creating representations and re-representations. Waldrip and Prain (2006) recognised that students need to be able to link different representation modes, such as graphic, numerical and verbal modes in learning to think and act scientifically.

Some literature suggests that multiple representations are an effective way to teach a complex subject like chemistry (Carolan, et al., 2008; Haslam, et al., 2009; Prain & Waldrip, 2006)**.** Teachers who use more than one representation when explaining a concept to their students either in the form of a verbal description followed by a model, diagram, concept map, or graph is said to be teaching with multiple representations. These representations help capture a learner's interest in the learning process (Ainsworth, 1999; Harrison & Treagust 1999), engage the learner's mind in constructive and critical thinking about whatever they are learning (Carolan, et al., 2008; Jonassen, 2000) and produce more comprehensive long-term learning outcomes (Jonassen, 2003; Kiboss, Ndirangu, & Wekesa, 2004).

A diversity of modes of representation can make chemistry classrooms more stimulating for students encouraging them to think, assist them to connect prior information with new information and enable them to present their views and ideas (Harrison & Treagust 1999; Prain & Waldrip, 2006; Warden, 2006). In these classrooms, students are constructing ideas based on their imagination of the world around them and applying these ideas into the learning process which helps them in making chemistry relevant to their daily lives. Among these modes are 3D modes (e.g., models and experiments), graphic and visual modes (e.g., posters, diagrams, images, tables, charts, power-point presentations, and computer simulations), verbal modes (e.g., oral representation, guest speaker), written modes (e.g., worksheets and texts), embodied modes (e.g., role-play and gesture) and numerical modes (e.g., mathematics) (Carolan, et al., 2008; Harrison & De Jong, 2005; Prain & Waldrip, 2006)**.** These modes will be discussed in turn.

**Three dimensional concrete models are often used in teaching chemistry to make abstract concepts accessible (e.g., ball and stick models for molecules) and they can be rotated and viewed from different perspectives to help students visualize molecular shapes (Harrison & De Jong, 2005). Meanwhile, role- playing as an embodied form of representation allows students to demonstrate their understanding of processes or events without having to write about them and this is particularly effective if "students are given the opportunity to explain the way that they have acted out the process or event involved" (George, 2004; Murcia, 2009). Concept maps are two dimensional spatial or graphic displays that make use of labelled nodes to represent concepts and lines or arcs to represent relationships between pairs of concepts (Novak, 1991, 1996, 1998; Richard, 2008; White & Gunstone, 1992). Mapping involves identifying important ideas and specifying their interrelationships. In this case, concepts or ideas are identified, categorized, and related to one another. Buzan and Abbott (2005) described a 'Mind-map' as a spider web-like visual representation of knowledge. It is this visual layout that helps to make specific ideas and the relationship between them clearer and more understandable to the individual(s) who produce them. In addition, they can be used to facilitate meaningful learning, identify alternative conceptions, evaluate learning, and facilitate cooperative learning (Novak, 1996). Mind maps allow for greater creativity when recording ideas and information, as well as allowing the note-taker to associate words with visual representations. Mind maps and concept maps are different in that mind maps focus on only one word or idea, whereas concept maps show the relationships between a set of concepts.**

Graphical representation such as images, diagrams, photographs and graphs are also used as strategic classroom tools to help students conceptualize the key features of a concept and engage in the activities because as they make knowledge of chemistry fascinating and readily understandable. Student constructed graphical representations such as drawings can act as a window through which researchers can investigate learners' internal representation of concepts which are otherwise not accessible via words or textual data (Taber, 2002). Diagrams according to Brasseur (2003), are essentially drawings with text, which consist of basic lines and shapes that convey an idea. Diagrams are very good at showing actions, processes, events and ideas and also provide a visual method of thinking out ideas (Prain & Waldrip, 2006).

Carolan, Prain and Waldrip (2008) identified four stages of teaching with representations that they describe as the IF-SO framework. This is a framework where teachers Identify (I) the key concept to learn at the planning stage, followed by explicitly focussing (F) on the function and form of different representations during an activity sequence (S) of representational challenges, that elicit students' ideas and their ongoing (O) assessment through teachers evaluating the representational work of students. This framework suggests the value of focusing on the triad of the domain, teacher representing and student conceptions (D, TR, SC) which provides opportunities for negotiation of meaning making. Thus, students can engage  with the topic using their understanding, they construct their own representations of the concept and then the teacher can facilitate student conceptual growth, focusing on the triad of domain, student representations, and student conceptions (D, SR, SC). In this case, students re-represent the concepts learnt in forms that are meaningful to them. The teacher uses conceptual understandings to guide his or her representations which make the concept accessible for students to develop their understandings. The students can then develop their representations which should bear some similarities to the teacher's concept. Their triadic pedagogical model is represented below.

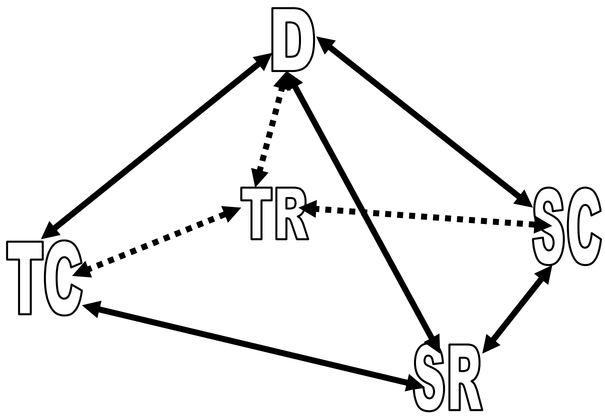



**Figure 2.2: Carolan, Prain & Waldrip's (2008) triadic pedagogical model**

Haslam, Tytler and Hubber (2009) identified four key pedagogical principles to guide effective teaching and learning with representations: first, the need for the teacher to identify key concepts and their representations at the planning stage of a topic in order to guide students to develop their concepts and representations; secondly, generation and negotiation of meaning-making between a teacher and the students to generate representational ideas that involves critical thinking; thirdly, create an activity that engages students' mind while at the same time engages their hands. This challenges students to be actively engaged in the learning process, which as a result leads to meaningful learning and lastly, an opportunity to assess students' knowledge to represent and re-represent what they have learnt.

Understanding science involves mentally engaging with representations of the phenomena to which they relate. Additionally, using multiple representations of chemistry concepts and supporting students to represent chemistry at the macroscopic, submicroscopic and symbolic levels should enhance learning. This use of multiple representations will be the main focus of the present study. There is need for chemistry teachers' pedagogical content knowledge to be enhanced to enable them to teach with multiple representation strategies. This strategy should enable teachers to better support students in making sense of chemistry concepts and will allow the students to engage consciously in dialogic processes of meaning-making as suggested in Mortimer and Scott (2003).

**Engagement in Learning**

The constructivists recommend learning through active engagement and with understanding which is more permanent than memorisation of content or learning by equation or formula. It is argued that for deep learning to occur, students' need to be placed at the centre of the learning and supported to construct meaningful understanding out of experience and prior knowledge (Atherton, 2009; Bruner, 1961; Driver, et al., 1994). Research tells us that time spent on a task can result in effective learning if the student is encouraged to be an active participant in the construction of knowledge (Buzan & Abbott, 2005; Carrini, Kuh, & Klein, 2006; Fletcher, 2005; Hake, 1997).Learners in this case see themselves as being autonomous, active creators and accountable for their own learning. Achieving students' engagement requires teachers to carefully plan lessons that actively challenge students' higher order thinking during the learning tasks. Active engagement in activities provides opportunities for the students to receive, share and record information for processing (Ausubel, 1968).

**Teacher Pedagogical Content Knowledge**

Shulman (1986) introduced the concept of pedagogical content knowledge (PCK) as a form of teachers' special practical knowledge needed to help students understand specific content. Shulman (1987) further identified the key element of PCK as "knowledge of representations of subject matter and understanding of specific learning difficulties" (p. 6). Shulman (1987) explained that PCK is the knowledge base for teaching and comprises content knowledge, curricular knowledge, general pedagogical knowledge, knowledge of learners and educational context. Likewise, William (2004) defined pedagogical content knowledge (PCK) as the knowledge base needed for teaching that includes subject matter knowledge, knowledge of students, knowledge of content and pedagogical knowledge.

Pursuing this further, several scholars elaborated on the concept of PCK. Magnusson, Krajcik, and Borko (1999) described PCK as a mixture or synthesis of five different types of knowledge: (i) orientation toward science teaching, (ii) knowledge of science curriculum, (iii) knowledge of science assessment, (iv) knowledge of students' understanding and (v) knowledge of instructional strategies. In the same way, Van Driel, Verloop and Devos (1998) identified two essential key elements of PCK about teachers' knowledge and these are "teachers' knowledge about specific conceptions and learning difficulties with respect to particular content and secondly, teachers' knowledge about representations and teaching strategies" (p. 674). From these perspectives, and for the purpose of this study, Figure 3 represents the main components of PCK for chemistry teaching.

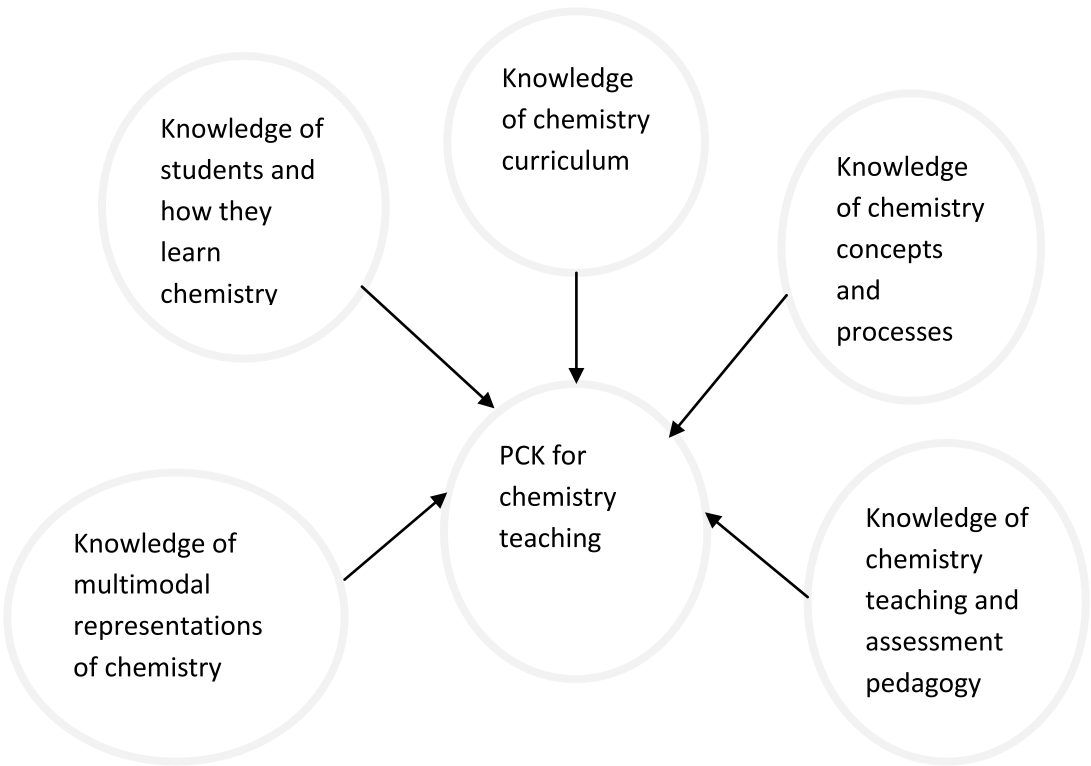



**Figure 2.3: Main components of PCK for chemistry**

Expert PCK is about knowing how to engage students with curriculum. It is also about knowing what experience the students have with those ideas and difficulties they have with the learning and how to provide opportunities for students to experience multiple representations. In the same way, it can be viewed as the ability to represent and explain difficult concepts to diverse audiences. Pedagogical content knowing, as explained by Cochran, DeRuiter and King {1993}is to know what you want to explain and have the pedagogical tools to engage students in learning the concepts. Lack of teachers' PCK in science, and chemistry concepts in particular, results in what Evans and Rennie (2009) describe as feeling uncomfortable to teach the subject or even avoiding teaching the subject. Enhancing teachers' PCK is likely to lead to greater confidence and self-efficacy for teaching science (Hackling & Prain, 2005). Teachers' PCK for chemistry teaching has a direct influence on continual development of teacher's beliefs and personal theories which consequently form a strong influence on their classroom practice (Levitt, 2001).

**Teachers' Beliefs About Science Teaching**

Beliefs influence decision-making. Beliefs are assumed to be the best indicators of why an individual makes certain decisions (Bandura, 1986; Beck & Lumpe, 1996). Tobin, Tippins, and Gallard (1994) defined belief as "a form of knowledge that is personally viable in the sense that, it enables a person to meet his or her goals" (p. 62). In the same way, teachers' perceptions and judgments influence how a teacher performs in the classroom (Schommer-Aikins, 2004). Teachers have beliefs about the characteristics of effective teaching. For example, if they believe that effective teaching is giving clear explanations and they believe science and chemistry is a body of knowledge in the textbook that is going to be transmitted to learners, then they are likely to believe that effective teaching is writing notes on the board and explaining clearly. Likewise, teachers have beliefs about the purpose of science education. For example, if they believe chemistry and science are processes of developing and refining knowledge through experimentation and inquiry they are likely to believe that effective teaching is actively engaging students in thinking and constructing meaning and they will teach by inquiry. Hashweh (1996) determined that teachers holding constructivist beliefs:

> were more likely to detect students' alternative conception; have a richer repertoire of teaching strategies; use potentially more effective strategies for inducing conceptual change; report more frequent use of effective teaching strategies; and highly evaluate these teaching strategies compared with teachers holding empiricist beliefs. (p. 331)

In the same way, teachers' beliefs about teaching and learning affect their effectiveness in enhancing students' learning and interest in all subjects areas (Levitt, 2001) and their beliefs are often translated into classroom instructional practice. It was further stressed by (Keys, 2005) that teachers' beliefs about science, science teaching and students' learning have a great influence in the implementation of science education reforms and also in the implementation of science curriculum.

Beliefs that influence actions or practice are considered to be entrenched beliefs. Keys (2005) further stressed that teachers' epistemological beliefs have an influence on how teachers implement science curriculum. It appears that there are challenges that face teachers which build their beliefs and these challenges have significant impact on their organization of classrooms activities. Among these challenges, as identified by Keys are pressures on: coverage of syllabus, lack of time, preparation of students for examinations and also a lack of adequate understanding of the concepts to be taught. To this end, teacher professional learning needs to recognise the power of entrenched beliefs and should support changes to teachers' beliefs which eventually will support change in their practice (Keys, 2005).

**Teacher Professional Learning**

Continuing professional learning is needed to keep abreast of new developments in curriculum and pedagogy arising from the changing and evolving educational, social and cultural context in which teachers work and students learn. Professional learning supports teachers to improve upon their professional knowledge and practice. A report from the American Institute for Research (1999) supports the view that professional learning activities deepening teachers' content knowledge and skills, change their teaching practice and knowledge of how their students learn particular content.

Ingvarson, Meiers and Beavis (2005) identified key factors that determine the effectiveness of professional development interventions and these findings informed the design of professional learning intervention in this study. Ingvarson et al. (2005) list the key factors that determine opportunities for teacher learning: duration of the professional learning, content focus, active learning, feedback on practice, collaborative examination of student work, follow-up and professional learning community. These principles underpinned the professional learning intervention developed and run within the current research and aspects of this are elaborated below.

- Duration of professional learning. Duration relates to the contact hours and time span over which the professional learning occurs. The teachers participated in an initial two day workshop and then a final third day.
- Content focus. The teachers learned how to identify the key concepts and their representations at the planning stage of a topic. They also constructed a concept map to guide students through the topics (Haslam, et al., 2009).
- Teachers' active engagement in learning. Teachers were engaged through activities that challenged them to develop a range of representations and approaches to teaching in meaningful ways that empowered their teaching practice. This helped them to discover that teaching chemistry for meaningful

and deeper understanding goes beyond reading textbooks, copying notes on the board and drawing diagrams on the board for students to copy but requires student's involvement in activities that engages students mind in constructive and critical thinking about whatever they are learning (Carolan, et al., 2008; Haslam, et al., 2009; Jonassen, 2003; Liu & Mathews, 2005)

- Feedback on practice. Following the initial two-day workshop, the Researcher observed the teachers teaching with representations and gave supportive and constructive feedback on how to improve their practice.
- Teachers had opportunities to learn the importance of examining and reviewing students' work that leads to deeper understanding of students' misconceptions which are common in chemistry (Garnett, Garnett, & Hackling, 1995).
- Provision for follow-up that encourages continuity in the new teaching technique. Visits to schools by the Researcher provided follow-up and encouragement to the teachers to overcome difficulties with the new practices.
- Professional learning community. Teacher professional learning is enhanced when teachers are part of a supportive and collegial community of practice (Department of Education and Training, 2004a; Hackling & Prain, 2005; Ingvarson, et al., 2005) that support them as they teach in new ways. The focus of the professional learning workshops in this study involved development of a supportive and collegial community.

Similarly, Chartres and Piage's (2005) project titled: "One pencil to share" provided a professional learning opportunity for teachers in a low resource Africa school context teaching science and mathematics subjects. The teachers were given support in researching their communities and were challenged to use everyday objects to actively engage their students with range of representations during classroom teaching. The program yielded significant professional changes which in turn helped the teachers to be creative, resourceful and apply the experiences gained in their classrooms. The teaching approach encouraged collaborative learning while students shared ideas among themselves.

Like Chartres and Piage's (2005) study, the professional learning program developed for this research aimed to develop teachers' understanding of how they can plan and teach more effectively in low resource contexts.  The focus was on the teaching of chemical concepts in an engaging manner; development of their students' skill and knowledge of constructing and interpreting multiple representations; involving students in authentic tasks that challenge them to be actively engaged in the learning process; and, exploring different ways they could use students' representations to assess their learning. Teachers were also trained on how to generate and construct effective multiple representations of a chemistry topic. The professional learning workshop focused on the teaching of rate of reactions and collision theory, and water pollution and solubility using pictures, concept maps, flowcharts, role-plays, models, particulate and graphical representation.

The research study drew on the pedagogical principles of teaching with representations based on the research of Haslam et al. (2009). The teaching and learning model provided a clear conceptual focus; representational generation and negotiation as the focus of teaching and learning; engaging students in learning that is personally meaningful and challenging;  and, it eventually helped in assessing and evaluating students' work through representation (Haslam, et al., 2009). Moreover, the professional learning intervention in this study was designed to enhance teachers' PCK for teaching with multiple representations and the study examined the impact of the intervention on teachers' practice and students' engagement in learning in a multiple representation-rich environment.

**The Conceptual Framework for the Study**

The conceptual framework guiding this study is based on social constructivist and socio-cultural theory as the research is based on assumptions about the importance of students constructing meaning through conversation with others and the need for students to understand the representational forms of chemistry if they are to understand chemistry at macroscopic, sub-microscopic and symbolic levels. The study provided professional learning workshops designed to enhance teachers' PCK for teaching chemistry with multiple representations and to challenge their beliefs about the nature of effective teaching and learning of chemistry. It is anticipated that the enhanced PCK will enable the teachers to more effectively engage students in learning through constructing multiple representations and that this will lead to enhanced learning outcomes.

Figure 4 provides a visual representation of the conceptual framework that guided this study.

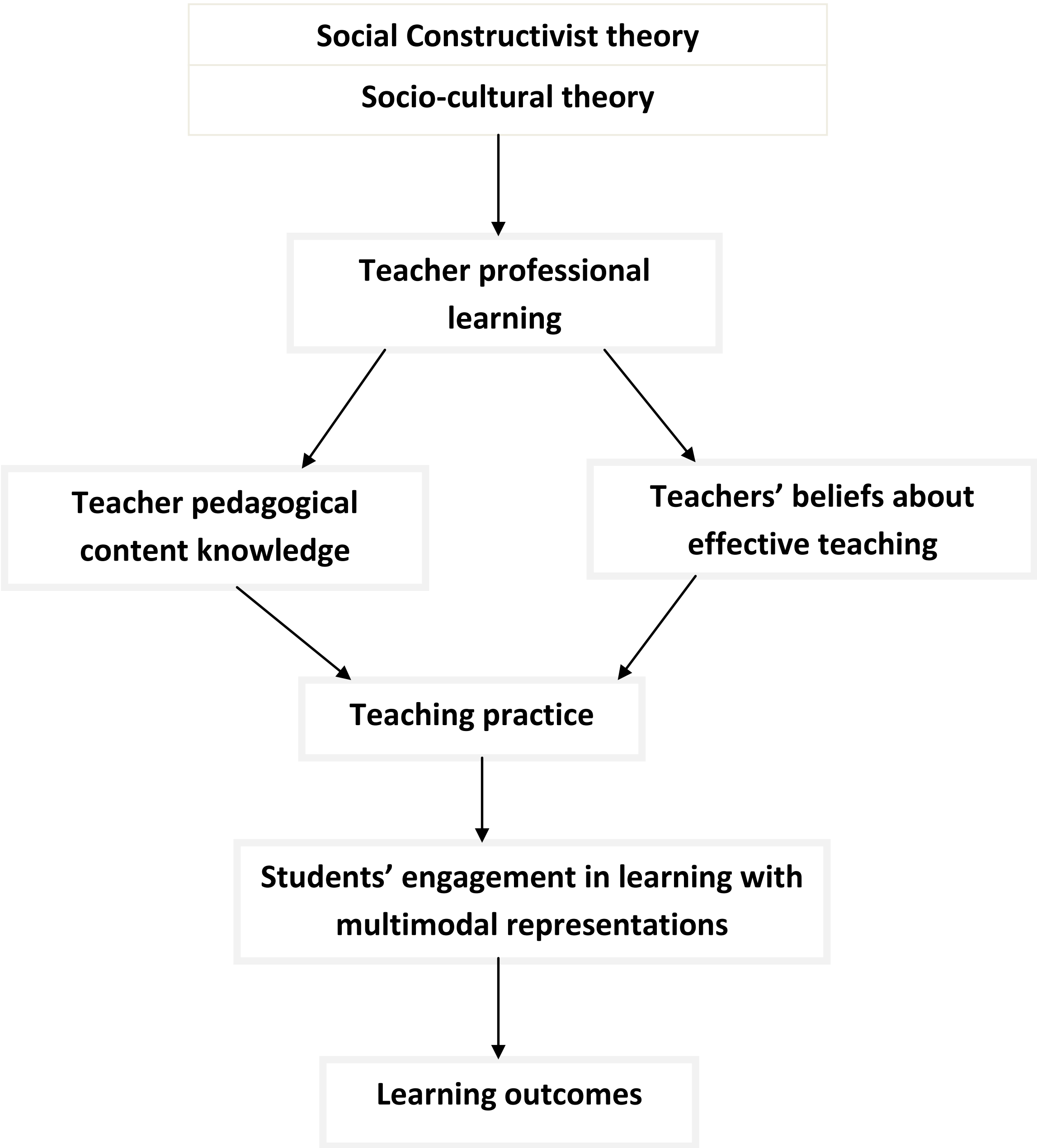



Figure 2.4: The conceptual framework

# CHAPTER 3: METHODOLOGY

## Overview

This study focussed on enhancing teachers' pedagogical knowledge and beliefs for using multiple representations in teaching chemistry. Participating teachers were engaged with professional learning activities on how to construct, interpret and use multiple representations to teach chemistry concepts in an engaging manner. The research aimed to investigate the impact of the professional learning intervention on teachers' beliefs, knowledge and practice, and on students' beliefs and engagement with learning. A mixed methods case study research design was used to investigate the impact of the professional learning intervention. The case study was compiled using descriptive and interpretive methods. This chapter describes the research approach, the research design, and the selection of research participants. The chapter also elaborates on the data sources used and the procedures for data collection and analysis. Issues with validity, reliability and ethics are also considered.

## Research Approach

The research employed mixed methods. Mixed methods can be defined as the collection or analysis of both quantitative and qualitative data in a single study in which the data are collected concurrently or sequentially (Creswell, 2009; Maione & Chenail, 1999). The multiple data types and sources were compiled into a case study.

The qualitative methods for data collection included semi-structured interviews, focus group discussions and direct classroom observations, which allowed close collaboration between the Researcher and the participants and created opportunities to explore and describe the phenomenon in context (Baxter & Jack, 2008; Yin, 2009). Qualitative aspects of the study provided a deep understanding of the professional learning program and captured participants' stories. These stories assisted in illuminating the processes and the outcomes of the program for those who make decisions about the program (Patton, 2002). Case study research is an empirical inquiry that investigates a phenomenon within its real-life context. The case study is designed to gain understanding of the situation that reveals real-life contexts and is considered to be maintained within a bounded system (Merriam, 1998; Yin, 2003) The participants in the current study were able to describe their views of reality through their shared stories and this helped the Researcher to gain a better understanding of the participants' actions.

Quantitative data on the other hand, were collected using questionnaires, administered to both participating teachers and students. The questionnaires were developed by the Researcher to suit the local context and provided background information that was used to contextualise the case studies.

The mixed data sources were converged in a triangulation process (Patton, 2002). Triangulation is a method of cross-checking data from multiple sources to search for regularities in the research data and also for combining qualitative and quantitative methods (Flick, 2009; O'Donoghue & Punch, 2003; Patton, 2002).The data from the teachers who were interviewed and observed in their classes, and students who participated in focus group discussions and filled in questionnaires were compared to each other, compiled together and referred to each other during analysis. Triangulating data sources and data types enabled the Researcher to establish a consensus across the qualitative and quantitative data collected to ensure the confirmability of findings.

**Research Design**

Descriptive and interpretive approaches were used in the mixed methods case study design. The interpretive approach attached significance to what was found; making sense of evidence, offering explanations by providing reasons for the way things occurred or the way people behaved, making inferences, considering meaning and drawing conclusions in order to generate ideas and develop theories (Kotler, Adams, Brown, & Armstrong, 2006). The approach explores data in depth, triangulates methods, and focuses on the full complexity of human sense-making as the situation emerges  (Kotler, et al., 2006; Patton, 2002)On the other hand, a descriptive approach provides an in-depth description of a particular context (i.e., it explained in details the results or things that happen within a particular social-context) thereby inspiring a new explanation within a topic area (Kotler et al., 2006). The research design included pre and post professional learning intervention data collection. The design involved the use of questionnaires to survey teachers and students; semi-structured interviews with teachers; student focus group discussions and lesson observations.

The research progressed through seven phases which are summarise in Table 3.1 below.

Table 3.1: The research design

| Research phase | Research activity |
|---|---|
| 1 | Approvals sought and instruments pilot tested |
| 2 | Forty teachers recruited and all completed a questionnaire |
| 3 | Three case study teachers identified. Lessons were observed. All students completed a questionnaire and three students from each class participated in a focus group discussion |
| 4 | Fifteen teachers participated in a two-day workshop to explore multiple representations and to plan a topic on reaction rates and collision theory |
| 5 | Case study teachers' lessons were observed, teachers interviewed and students participated in focus groups |
| 6 | The fifteen teachers participated in a one-day workshop at which participants reflected on experiences of teaching with multiple representations and planned to teach the next topic on solubility and water pollution using multiple representations |
| 7 | Case study teachers' lessons were observed, teachers were interviewed and students participated in focus groups |

The teacher questionnaire helped to identify the teachers' beliefs about effective chemistry teaching and learning, challenges of teaching chemistry, their current chemistry teaching approaches, and to their level of awareness and understanding of the use of multiple representations before the professional learning intervention. The use of questionnaires according to House (1994) gives precise and explicit information and can help identify relevant variables to observe in subsequent classroom observations. Students were also surveyed. Their questionnaire investigated their perceptions of learning chemistry in secondary schools and its relevance to their daily life.

The semi-structured interviews conducted with teachers both before and after the professional learning provided opportunities for the Researcher to probe the individuals' thinking through open-ended questions to get responses about their personal experiences, perceptions opinions, feelings and knowledge about teaching chemistry (McLawley, 2003; Patton, 2002).

The lesson observation protocol assisted in identifying and documenting teachers' classroom practices and students' learning behaviours before and after the professional learning workshops. Direct observation provides opportunities to document activities, behaviour and physical aspects without having to depend upon people's willingness and ability to respond to questions (Morgan, 1997; Patton, 2002). In addition, an interview was conducted with the teacher after the lesson to gain a deeper understanding of the actions observed.

A focus group interview was also conducted with selected students from each observed class. The students were encouraged to express their view on their learning experiences. Thomas and Nelson (1996) argue that focus group interviews can help researchers to gather information about several people's views, perceptions and opinions and also provide checks and balances as participants react to each others' views. It also assisted individuals to feel relaxed in a friendly and comfortable environment. This design allowed the Researcher to capture classroom practices used by the teachers and revealed how students responded to the challenge of engaging and representing their understanding within specific chemistry learning tasks.

**Selection of Participants**

There are 20 Local Education Districts (LEDs) in Lagos State. Each one has, on average 16 schools. However, at the Ministry administrative level these 20 LEDs have been grouped into six districts (see Figure 3.2). For the purpose of this study, one of the six administrative districts in Lagos state was selected. This administrative district, known as District 5, includes: Ojo, Agboju, Amuwo-odofin, Ifelodun and Badagry LEDs, and was chosen because of its closeness and accessibility to the Researcher

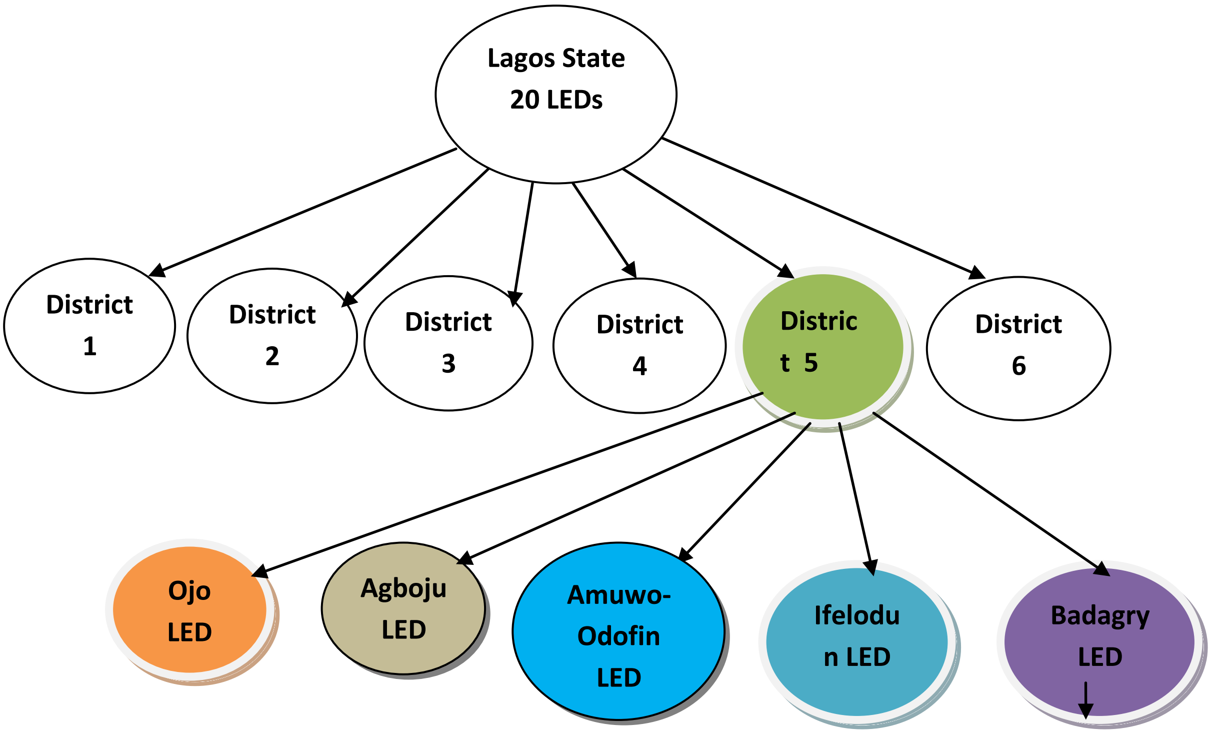



**Figure 3.1: Location of research in District 5 of Lagos state**

Senior secondary school chemistry is taken over three years. In this study, only chemistry teachers teaching senior secondary school Year 2 (SSS2) chemistry and the students in their classes participated. The reasons for choosing this year level is that it was assumed that the students would have enough experience in the chemistry classroom to enable them to describe their situation. In total, all of the 40 chemistry teachers from senior secondary schools in the selected LEDs completed a pre professional intervention questionnaire. Responses to the questionnaire were used to purposely select 15 teachers who participated in the professional learning intervention on how to construct, interpret and use multiple representations to teach selected chemistry concepts. These were teachers who had indicated on the questionnaire that they would like to participate in the professional learning workshop. Of these 15 teachers, three case study teachers were selected based on the close proximity of their schools to the Researcher. The case study teachers identified three students in their SSS2 chemistry classes willing to participate in focus group discussions. Ideally these students would be able to speak confidently when describing what happened in their classroom.

**Procedure for Data Collection**

The research procedure and data collection for this study occurred in seven phases which were outlined in Figure 3.1 and described here in more detail.

### Seeking approval, pilot testing and initial data collection.

To begin, approval was sought from the Provost of Adeniran Ogunsanya College of Education for the professional learning intervention program to be conducted in one of the college lecture rooms. Directors of LED 5, principals and vice-principals of the senior secondary schools where the data were to be collected, were contacted to give consent to release the chemistry teachers who chose to participate in the study. Also, the chemistry teachers and the parents of the students in the case study classrooms were approached to discuss the purpose of the research and to seek their consent for participation. Prior to the collection of the pre professional learning intervention data, there was a pilot testing of the questionnaire and items using a small sample of chemistry teachers and students who were not involved in the main study. A number of changes were made to the wording of items to ensure quality responses and reliability of the instruments.

Questionnaires were distributed to 40 selected chemistry teachers in the LEDs. These questionnaires were delivered and collected from each school by the Researcher to ensure a high return rate. The three case study teachers selected from the initial sample were then visited by the Researcher in order to collect teachers' lesson-notes and students' written notes. These were examined and cross-checked to enable the Researcher to gain insights into the range of representations currently used in the teaching of chemistry. In addition, students in classes of the case study teachers completed a questionnaire. Thereafter, the selected case-study teachers and their students were observed in the classroom using observation checklists. Interviews were conducted at the end of each observed lesson with the case study teachers. Focus group interviews were held with the three selected students in each class from the case study teachers. All interviews were audio recorded with an Olympus digital voice recorder for later transcription and analysis.

### Professional learning workshop (1)

Fifteen teachers participated in a two-day professional learning workshop. During the first day of the workshop (PL1), the Researcher elicited teachers' concerns about chemistry classroom practice; explored their ways of constructing and interpreting representations; and, explained a range of representations. This was followed on Day 2 with the teaching of reaction rates and collision theory using a multiple representations teaching strategy. Concept maps, flow charts, particulate and graphical representations and role-play were chosen as the multiple representational strategies for this topic. Thereafter, the Researcher and the teachers strategized the planning of classroom practice. The content of the professional workshops are described in Chapter 5.

Lessons taught by the case study teachers were observed upon their return to school after the workshop. Observations followed a consistent classroom observation protocol and classroom checklists were completed. Their purpose was to assess the impact of the learning intervention program on the teachers' practice and the students' engagement in the learning process. There was a focus group discussion with three selected students at the end of the lesson. Teacher interviews were also conducted after each observed lesson.

## Professional learning workshop (2) and post-intervention data collection

On the third day of professional learning, the teachers discussed how students in their classes responded to the challenge of engaging with and learning how to interpret multiple representations and the difficulties encountered in teaching with a multiple representations strategy. The teachers then planned for the next topic which was water pollution and solubility, using the same multiple representational strategies. A focus group discussion was held with the teachers at the end of the workshop.

Again, upon the case study teachers return to their schools they were observed to determine if there had been continuity of the teaching strategy. The teachers were interviewed and student focus groups were conducted after the lesson observations.

### Data Sources and Research Instruments

The main research instruments used for data collection in this study included: pre intervention teacher and student questionnaires; pre and post intervention teacher interview schedules; post lesson student focus group discussion schedules; and a lesson observation protocol using an observation template.

## Pre professional learning intervention questionnaires

The teacher questionnaire (Appendix A) gathered relevant information describing the current teaching approaches used by the teachers and the learning of chemistry. It also helped to identify teachers' beliefs about effective chemistry teaching and learning and their use of representations to teach chemistry concept. The question items targeting teachers' challenges and beliefs about effective teaching and learning of chemistry were open-ended, while items about teaching approaches used in the teaching and learning of chemistry were stated using scale items. The student questionnaire (Appendix B) gathered information on current teaching practices and students' attitudes to chemistry and their perceptions about chemistry as a subject. The students' perceptions and experiences of chemistry teaching were elicited using five-point Likert-type agreement and frequency scale items while an open-ended question was used to elicit their beliefs about effective teaching and learning of chemistry.

Distribution of the initial teacher questionnaire to the 40 teachers in schools commenced during week four of the second term, 1st February, 2010, and lasted for almost three weeks. The Researcher personally visited and administered the questionnaire to each teacher in the schools and ensured the completed questionnaire was returned. Throughout the distribution, the Researcher made efforts to maintain a cordial relationships that promoted a friendly and comfortable environment with the teachers. The student questionnaire was administered by the Researcher after identification of the workshop participants and case study teachers.

### Interviews

Interviews with the teachers (Appendix C i, ii & iii) were conducted on three occasions: the initial teacher interview, post-lesson observation teacher interview and the final teacher interview conducted after the final lesson observation. The purpose of the initial teacher interview was to enable the Researcher to develop an understanding of the practices used by the teachers and reasons for using those practices. It also helped the Researcher gain a better understanding of the beliefs held and knowledge of the teacher about effective chemistry teaching. The post-lesson teacher interview helped the Researcher to gather information from the teachers about their experiences of the new teaching technique and the extent of engagement shown by their students during the learning tasks. The final teacher interview provided opportunities to identify any changes in teachers' practice and beliefs about effective chemistry teaching. These interviews were digitally recorded using an Olympus voice recorder. The recordings were imported into a PC, transcribed and analysed.

#### Classroom observation protocol

A lesson observation template (Appendix D) was used to scaffold observations of key features of the lessons. The lesson observation protocol enabled the Researcher to view the effect of the learning intervention on the teacher's practice and active engagement of students in learning. Observations were recorded on the template and as field notes. Field notes were supplemented with digital photographs of representations used by the teachers and students.

### Focus groups

The focus groups involved three students from each of the classes of the case-study teachers to enable the Researcher to identify their understanding of the concept taught and the important parts in the lesson that assisted them to learn about the concept. The focus group discussions enabled the Researcher to gather the students' perspective of the teacher's practice. Interviewing students as groups created a more relaxed environment that built the individual's confidence when listening and hearing from each other. This also encouraged students to expand their ideas and from this, individuals could make sense of what was being communicated and hence assisted them to freely express their ideas and thoughts. The focus group questions are attached as Appendix C iv

### Classroom artefacts

Written documents such as the teachers' lesson plans and students' notebooks were collected from the participants and photocopied as a source of data to form a digital record. Photographs were taken of teacher's work on the board and students' activities. These documents were cross-referenced with the other data sources and to provide comprehensive data.

#### Validity and Reliability of the Instruments

Validity is concerned with the study's success at measuring what the researchers sets out to measure, while reliability is concerned with the consistency of the actual measuring instrument or procedure (O'Donoghue & Punch, 2003). In this study, the face validity of the questionnaires, the interview questions, the lesson observation template and focus group discussion questions was checked by the supervisors who are experts in the field.

In order to enhance the reliability of the instruments to ensure there is no ambiguity in the questions, the teacher and student questionnaires were pilot tested using a small sample of chemistry teachers and science students who were not involved in the study. The purpose of the pilot study was to identify any difficulties in responding to questions on the questionnaires. The Cronbach Alpha reliability statistic was calculated for the instruments using data from the main study. The Cronbach Alpha internal consistency reliability coefficient for the teacher questionnaire was found to be 0.76 while that of student questionnaire was found to be 0.79 and these were considered significantly reliable for the study. Some of the teachers and the students were used to practice interview and focus group discussion questions and also used their classes to pilot classroom observations. The interpretations of the participants' responses to each interview questions were carefully examined to ensure they were well understood.

**Data Analysis**

The research data were analysed using both quantitative and qualitative methods. An interpretive approach was taken to the analysis and interpretation of the data with triangulation of multiple data types and sources used, to ensure credibility and conformability of the research findings (Lincoln & Guba, 1985). The aim of the qualitative methods used in this study was to understand the reality of classroom practice. There was a cross-checking of ideas between the participants and Researcher to avoid any bias or mis-interpretation of data.

### Questionnaires

A coding manual was developed to guide the coding of the questionnaire data (Coding manual Appendix M). Participants' responses to closed objective items were coded into the provided response options. The frequency and percentages of responses coded into the categories were calculated and reported. Frequencies of responses on the five point Likert-type scale items were scored so that the mean ratings could be calculated. Responses to the open-ended question were coded and grouped into categories. The frequency and percentages of responses in each category were calculated using the SPSS statistical package. The categories were later grouped into themes

### Interviews and focus groups

The audio recordings from the interviews and focus groups were listened to by the Researcher, transcribed and the transcripts were read repeatedly until common patterns of responses emerged as themes. Journal entries and memo were used to describe the themes and quotations were selected to illustrate each. The data from the transcripts were reported in a narrative form and, supported with relevant quotes to enhance the credibility of the presented data.

### Classroom observations

The observations recorded on the template and as field notes, supplemented with photographs of classroom activities, were used to describe teachers' practices before and after the intervention. The data were used to determine the amount of lesson time used for different learning activities and the types of representations used and who constructed them. The descriptions were reported and supported with evidence from photographs of teachers' blackboard notes and students' written notes.

Table 3.2 summarises the data sources and analyses used to answer the research questions.

Table 3.2: Research questions, data sources and analyses

<table>
<tr><th>Research questions</th><th>Data sources</th><th>Data analysis</th></tr>
<tr><td>What challenges do teachers face in the teaching of chemistry in Nigeria secondary schools?</td><td>Teacher and student questionnaires, initial teacher interviews and lesson observations, teachers' lesson plans and students' written notebooks.</td><td rowspan="4">Scoring, coding and categorisation of questionnaire responses.<br>Thematic analysis of interviews to identify emergent themes</td></tr>
<tr><td>What are the teachers' current beliefs about effective teaching and learning of chemistry, knowledge about using representation in chemistry teaching, and their current teaching practice?</td><td>Lesson observations, post lesson teacher interviews, post lesson student focus group discussions and classroom artefacts.</td></tr>
<tr><td>What are the impacts of the professional learning intervention on teachers' beliefs, knowledge and practice?</td><td>Lesson observations, final teacher interviews and student focus group discussions and classroom artefacts.</td></tr>
<tr><td>What impact of the professional learning intervention on students beliefs about teaching and learning of chemistry and their engagement with learning</td><td>Lesson observations, student focus group discussions and classroom artefacts.</td></tr>
</table>

### Ethical Considerations

There is a need for consideration of ethical principles in any research that involves people. These ethical concerns centred on the relationship between the Researcher and the participants. This relationship is based on the issues relating to anonymity, informed consent, withdrawal rights and future use of classroom artefacts/digital photographs. There was a need for good conduct, truthfulness and desirability of the planned research (Blaxter, Hughes, & Tight, 2002). This study addressed these issues and had ethics clearance from Edith Cowan University's Human Research Ethics Committee.

## Anonymity

All research data collected in this study remained confidential and the identity of the participants was protected throughout the study. No teacher or student's names have been mentioned or will be published in any reports of this study. In order to protect the identities of the participants in this study, real names of the schools, teachers and students were not used; rather, the participants were identified using codes and then reported as codes or pseudonyms. The use of photographs to capture teachers' writing on the board, students' learning activities and active engagement were only taken from the back of the classroom so that nobody could be identified in the photographs. The teachers and students were informed of the importance of the classroom artefacts and how they would be used.

## Informed consent

Informed consent requires active communication so that participants can make an informed decision and it also, requires describing the potential benefits and risks of involvement to the participants (O'Leary, 2006). The participants were made to understand the importance of all aspects of the research study and their requested involvement. An information letter and consent forms were sent to the Local Education Districts for permission to release the teachers to participate in the research study. Permission was sought from the Provost of the College where the learning intervention took place. The participating teachers were provided with an information letter outlining the details of their time commitment and the research activity. Written consent was obtained from all participants in this study.

## Withdrawal rights

The participating teachers and students were informed of their right to withdraw at any stage if they were no longer interested in participating in the study. No participants withdraw throughout the study.

## Future use of data and classroom artefacts

The raw data, data summaries and documents collected will be stored securely for at least five years after publication of the thesis. After five years the status of the data will be reviewed and appropriately destroyed if no longer of use.

### Chapter Summary

The purpose of this study was to enhance teachers' knowledge for using multiple representations in teaching a chemistry concept in Senior Secondary Schools in Lagos State, Nigeria. A case study approach was used for this study. The study employed a mixed method approach that comprised descriptive and interpretive methods. Data generated through various sources were analysed using qualitative and quantitative procedures. The qualitative data were sourced from teacher interviews, student focus group discussions and direct classroom observations while quantitative data were collected through questionnaires. The use of multiple sources of data enabled triangulation of data which enhanced the confirmability of findings.

# CHAPTER 4: TEACHER AND STUDENT BASELINE DATA

### Introduction

The purpose of this chapter is to outline baseline data collected from teachers and students prior to the professional learning intervention. The chapter reports results from the initial teacher questionnaire (ITQ) and initial student questionnaire (ISQ). The teacher questionnaire gathered demographic data; information about challenges to effective teaching and learning of chemistry; teachers' beliefs about effective chemistry teaching and learning; and, existing teaching practice. The initial student questionnaire gathered demographic data; students' attitude towards chemistry as a subject; students' beliefs about effective teaching and learning of chemistry; and, students' experience of chemistry teaching in the classroom. Participants in this research spoke English as a second language and therefore, the direct quotations given in these chapters reflect the actual words spoken and may contain some grammatical errors.

### Teacher Baseline Data

This section reports baseline data collected prior to the professional learning intervention.

## Demographic data

This study was carried out in one education district know as (District V) which comprises five zones. Almost all of the secondary schools in the zone had only one chemistry teacher and a total of 40 chemistry teachers in the district completed and returned the questionnaire which gave a return rate of 100%. Teacher demographic data includes information about gender, age, qualifications, teaching and chemistry teaching experience. Table 4.1 reports the gender and age distribution of the teachers.

Table 4.1: Gender and age distribution of teachers as frequency (and percentage) (n=40)

| Gender | | Age (years) | | | | |
|---|---|---|---|---|---|---|
| Female | Male | 20 or less | 21 to 30 | 31 to 40 | 41 to 50 | 51 and above |
| 17 (42.5) | 23(57.5) | 0(0.0) | 9 (22.5) | 13 (32.5) | 15 (37.5) | 3 (7.5) |

Table 4.1 shows that 58% of the chemistry teachers in District V were male while 43% were female. Furthermore, a large majority of chemistry teachers (80%) were between 31 and 50 years of age, 23% of the teachers were below 31 years of age, and only 8% were 50 years and above. The qualifications of the sample of teachers are presented in Table 4.2:

Table 4.2: Number (and percentage) of teachers' with various qualifications (n=40)

| Qualifications | Number (per cent)[a] |
|---|---|
| 3 year trained including professional training in education (NCE) | 3 (7.5) |
| 4 year trained without professional training in education (BSc only) | 7 (17.5) |
| 4 year trained with professional training in education (B. Ed, BSc Ed, BSc+ PGDE) | 30 (75.0) |
| Higher qualification with M. Ed | 6 (15.0) |
| Higher qualification with MSc | 3 (7.5) |

Note. [a] Many of the teachers reported more than one qualification

The majority of the chemistry teachers (75%) had four years of science and education training and 15% had a higher degree that suggests that some of the teachers are unusually well qualified. Meanwhile, 25% of the chemistry teachers had NCE or BSc qualifications only. These teachers are under-qualified. Those teaching senior secondary science are expected to have at least four years of training that includes both science and education.

The teachers' years of general teaching experience and chemistry teaching experience are presented in Table 4.3

Table 4.3: Number (and percentage) of teachers with various years of teaching and chemistry teaching experience (n=40)

| Duration of teaching experience (years) | Number (and %) of teachers with general experience | Number (and %) of teachers with chemistry teaching experience |
|---|---|---|
| 0 – 5 | 10 (25.0) | 17 (42.5) |
| 6 – 10 | 11 (27.5) | 9 (22.5) |
| 11 – 15 | 6 (15.0) | 4 (10.0) |
| 16 – 20 | 13 (32.5) | 8 (20.0) |
| 21 and above | 0 (0) | 2 (5.0) |

Table 4.3 shows that 75% of the chemistry teachers have more than five years general teaching experience and almost 60% have more than five years of chemistry teaching experience. The sample included many teachers with more than 15 years of general teaching experience.

Teachers were asked to indicate the number of students in their senior secondary school two classes (SSS 2) and responses were grouped into categories from fewer than 30 to 100 and above. The sizes of SSS 2 chemistry classes as reported by the Chemistry teachers are presented in Figure 4.1:

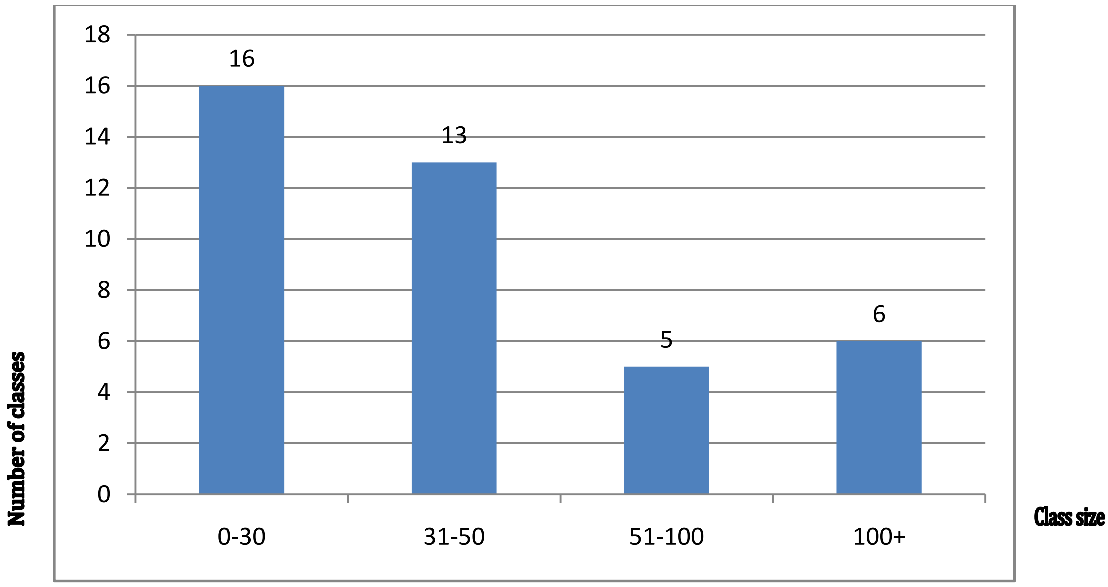



Figure 4.1: Distribution of chemistry class sizes (n = 40)

The modal group, 16 classes, shown in (Figure 4 1) had class sizes ranging from 1 to 30 students. Most of the teachers (60%) reported class sizes of greater than 30 students which is above the recommended class size of 25 ((Federal Ministry of Educaton (FME), 2007) while 40% of the teachers have 30 or fewer students per class. Of greater concern are the 28% of classes that have more than 50 students.

Key finding 4.1

A majority of teachers are male, aged between 30 and 50 years, are four- year trained and have more than five years chemistry teaching experience. Sixty per cent of the chemistry classes have more than 30 students.

## Teachers' challenges and beliefs

To identify teachers' challenges with teaching chemistry and their beliefs about effective chemistry teaching and learning, they were asked to respond to open-ended questions on the ITQ. The teachers' were asked, "What challenge(s) are you facing with teaching senior secondary chemistry effectively?" Teachers' responses were grouped into categories and a summary of these data is reported in Table 4.4:

Table 4.4: Frequency (and percentage) of challenges reported by teachers (n=40)

| Challenges | Lab facilities and equipment | Teaching aids | Students' attitude | Class size | Students' prior knowledge | Access to textbook | Overloaded curriculum | Others |
|---|---|---|---|---|---|---|---|---|
| Frequency | 27 | 12 | 10 | 7 | 5 | 4 | 3 | 10 |
| (per cent)[a] | (67.5) | (30.0) | (25.0) | (17.5) | (12.5) | (10.0) | (7.5) | (25.0) |

Note. [a] Many teachers reported more than one challenge

The teachers' responses indicated that lack of resources is their main challenge with two-thirds mentioning that they lack laboratory facilities and equipment and 40% mentioning a lack of teaching aids and textbooks. For example, Teacher 3 (T3) stated "Lack of laboratory and laboratory equipment" and this view was supported by T19 who said "Non-availability of enough teaching aids" and T13 "Lack of textbooks among the students for further studies at home" as being the main challenges.

To elicit information about the teachers' beliefs regarding the most effective ways for teaching and learning chemistry, they were asked to respond to two questions: "What do you believe are the characteristics of effective senior secondary chemistry teaching?" and What do you believe are the most effective ways of students learning chemistry?" The teachers' responses were categorised and are reported in Table 4.5

Table 4.5: Frequency and (percentage) of teachers holding various beliefs about characteristics of effective chemistry teaching and learning (n=40)

| Characteristics of effective chemistry teaching | Number (per cent)[a] | Characteristics of effective chemistry learning | Number (per cent)[a] |
|---|---|---|---|
| Laboratory facilities and equipment | 16 (40.0) | Hands-on experiment | 24 (60.0) |
| Teaching aids | 11 (27.5) | Learning from aids (charts, models, photographs, diagrams, flowcharts and audio-visual) | 12 (30.0) |
| Hands-on experiment | 9 (22.5) | Discovery learning | 12 (30.0) |
| Teacher's content knowledge | 8 (20.0) | Demonstration method | 8 (20.0) |
| Appropriate pedagogy | 7 (17.5) | Excursion method | 6 (15.0) |
| Learning environment | 4 (10.0) | Group learning | 5 (12.5) |
| Students participation | 4 (10.0) | Access to textbooks | 5 (12.5) |
| Students attitude | 3 (7.5) | Learning in well – equipped laboratory | 3 (7.5) |
| Others | 17 (42.5) | Others | 12 (30.0) |

Note. [a] Many teachers gave more than one response to the questions

Data reported in Table 4.5 indicate that teachers believe that effective chemistry teaching and learning is dependent on making chemistry real and providing hands-on laboratory experiences supported with concrete teaching aids. This view was supported by T19 who stated “adequate use of instructional materials” led to effective teaching and learning. T6 stated that “chemistry teaching must be practical oriented and must be taught in a well equipped laboratory”. Frequently mentioned characteristics of effective teaching and learning were teachers possessing mastery of the subject matter, demonstrating appropriate knowledge of teaching approaches that make concepts accessible and actively engaging students in hands-on activities. This view was supported by T13 and T4 who said, “Involving students in a discovery method” and “teachers have depth knowledge of the subject matter” respectively aid effective teaching and learning. Only a low percentage of the teachers (10%) mentioned students’ active participation and attitudes during lesson.

Key finding 4.2

More than half of the teachers (68%) mentioned lack of laboratory facilities and equipment and about 40% mentioned that lack of teaching aids and textbooks are their major challenges to effective teaching of chemistry. Many teachers believed that effective learning of chemistry is when students are engaging in hands-on activities and the teachers are competent and have comprehensive knowledge of the subject matter. Over one-quarter of the teachers also believe that effective chemistry teaching and learning depends on adequate use of teaching aids. A large minority of the teachers believe that chemistry teaching is effective when there is provision of school laboratories with adequate facilities and equipment for practical classes.

## Benefits of representation

To identify teachers’ beliefs about the benefits derived from teaching with representations, teachers were asked to respond to the open-ended question: “What benefit (s) is the use of diagrams, models, flowcharts, concept maps and photographs to the teaching and learning of chemistry?” The teachers’ responses were categorised and are reported in Table 4.6.

Table 4.6: Frequency (and Per cent) of teachers reporting the benefits derived when teaching with representations (n=40)

| Benefits in learning with the use of representations | Number (per cent)[a] |
|---|---|
| Effective teaching/learning | 14 (35.0) |
| Increases understanding | 12 (30.0) |
| Increases memory retention | 12 (30.0) |
| Learning becomes real and concrete | 11 (27.5) |
| Increases students' interest | 3 (7.5) |
| Increases students' confidence | 2 (5.0) |
| Others | 2 (5.0) |

Note. [a] Many teachers gave more than one response to the question.

The majority of the teachers' responses indicate that they believe that representations will enhance learning. For example, T15 stated that "It make the concept easy to understand, remember than when explain in abstract" and this view was supported by T 2 who said that "It make abstract concepts look real and concrete" and T33 stated "They help to make teaching easier for the teacher and students assimilate better because what they see with their eyes can hardly be forgotten".

Key finding 4.3

When asked what the benefits of a number of representations would be, the teachers reported that teaching and learning becomes effective, increases students' understanding of a concept and memory retention and learning of concepts becomes real and concrete.

### Teachers' confidence with chemistry teaching

The teacher were asked to rate their confidence for teaching SSS 2 chemistry concepts and two of the topics that were the focus of the study.

Table 4.7: Teachers' rating of their confidence for teaching chemistry (n=40)

| Aspect of chemistry teaching | Very confident | Confident | Ok | Less confident | Not confident | Mean rating of confidence [a] |
|---|---|---|---|---|---|---|
| SS2 chemistry | 23 (57.5) | 12 (30.0) | 5(12.5) | 0(0) | 0(0) | 4.45 |
| Reaction rate and collision theory | 24 (60.0) | 12 (30.0) | 4(10.0) | 0(0) | 0(0) | 4.50 |
| Water pollution and solubility | 21 (52.5) | 14 (35.0) | 5(12.5) | 0(0) | 0(0) | 4.40 |

Note: [a] Confidence was scored 5= Very confident, 4 = Confident, 3 = Ok, 2 = Less confident and 1 = Not confident for the calculation of mean confidence ratings.

The data show almost 90% of the teachers rated themselves as being very confident or confident with teaching SS2 chemistry, reaction rate and collision theory. Mean ratings of confidence were at least 4.4/5 for chemistry and the two topics.

Key finding 4.4

Most of the chemistry teachers indicated that they were very confident or confident to teach SS2 chemistry and the concepts of reaction rate and collision theory, and water pollution and solubility.

### Existing classroom practice

To identify the frequency with which various teaching approaches were used before the professional learning intervention, teachers rated their frequency of use on a five-point scale. Teachers' responses from the ITQ were scored so that mean ratings could be calculated. These data are presented in Table 4.8

Table 4.8: Frequencies with which various teaching approaches are used in SS2 chemistry before the professional learning intervention (n=40)

| Per cent of teachers reporting this frequency of use for various teaching strategies | | | | | | |
|---|---|---|---|---|---|---|
| Teaching strategies | In every lesson | In most lessons | In some lessons | In a few lessons | Never | Mean rating of frequency [a] |
| Teacher explaining | 62.5 | 30.0 | 7.5 | 0.0 | 0.0 | 4.55 |
| Teacher using equations | 0.0 | 35.0 | 45.0 | 17.5 | 2.5 | 4.13 |
| Teacher using diagrams | 22.5 | 55.0 | 20.0 | 2.5 | 0.0 | 3.97 |
| Teacher writing notes | 30.0 | 22.5 | 30.0 | 15.0 | 2.5 | 3.62 |
| Teacher drawing graphs | 20.0 | 25.0 | 47.5 | 5.0 | 2.5 | 3.55 |
| Teacher demonstrating experiment | 10.0 | 37.5 | 32.5 | 20.0 | 0.0 | 3.37 |
| Teacher leading whole class | 12.5 | 32.5 | 30.0 | 22.5 | 2.5 | 3.30 |
| Students having group discussion | 5.0 | 22.5 | 42.5 | 27.5 | 2.5 | 3.00 |
| Students doing hands-on experiments | 2.5 | 30.0 | 35.0 | 25.0 | 7.5 | 2.95 |
| Teacher using flow charts | 5.0 | 25.0 | 42.5 | 12.5 | 15.0 | 2.93 |
| Teacher using concept maps | 5.0 | 27.5 | 20.0 | 30.0 | 17.5 | 2.72 |
| Students developing diagrams | 5.0 | 12.5 | 35.0 | 30.0 | 17.5 | 2.58 |
| Students engaging in role-plays | 5.0 | 15.0 | 20.0 | 37.5 | 22.5 | 2.43 |
| Students reading textbook | 2.5 | 20.0 | 22.5 | 25.0 | 30.0 | 2.40 |
| Teacher using 3D models | 2.5 | 12.5 | 27.5 | 30.0 | 27.5 | 2.32 |

Note. [a] Frequencies were scored 5 = In every lesson, 4 = In most lessons, 3 = In some lessons, 2 = In a few lessons and 1 = never for the calculation of mean ratings of frequencies. Items were ranked by decreasing order of means.

Table 4.8 shows that the most frequently mentioned teaching approaches used in chemistry lessons are teacher-centred strategies (teacher explaining, using equation, drawing diagrams, writing notes, drawing graphs and demonstrating experiments) while students listen. Student-centred strategies were used less frequently (small group discussion, hands-on activity, students developing diagrams). Flow charts, concept maps, role-plays and 3D models were not frequently used by the teachers.

### Student assessment

To identify various methods used by teachers to assess students' understanding in chemistry, teachers were asked to respond to the open-ended question: "How do you find out what your students know about chemistry?" The teachers' responses were categorised and are reported in Table 4.9.

Table 4.9: Methods of assessing students' knowledge (n=40)

| Method of evaluation | Number (per cent)[a] |
|---|---|
| Oral question and answer during lesson | 27 (73.0) |
| Assignments | 18 (48.6) |
| Tests and examinations | 17 (45.9) |
| Projects/problem solving | 4 (10.8) |
| Practical work | 3 (8.1) |
| Others | 4 (10.8) |

Note. [a] Many teachers gave more than one response to the question.

The most frequently used method of assessing students' learning of chemistry concepts mentioned by the teachers is through oral questions and answers during lessons. Assignments, tests and exams were also frequently used. Projects/problem solving and practical modes of assessment, which could have actively engaged students in learning were not frequently used to assess students' understanding in chemistry. For example, T33 stated "Asking students' questions randomly on the previous topics" and this view was supported by T 2 who said that "Through questioning and discussion method during and after lesson".

### Students’ engagement in learning

Teachers were asked to rate levels with which students are actively engaged in learning chemistry. Teachers’ responses are reported in Table 4.10

Table 4.10: Students’ levels of active engagement in learning (n= 40)

| | Students’ levels of engagement in learning | | | | | Mean rating of engagement |
|---|---|---|---|---|---|---|
| | Very active | | | Very passive | | |
| Level of active engagement | 10 - 9 | 8 - 7 | 6 - 5 | 4 - 3 | 2 - 1 | |
| Frequency | 4 | 24 | 9 | 3 | 0 | 6.93 |
| (per cent) | (10.0) | (60.0) | (22.5) | (7.5) | (0) | |

The data reveals that 70% of the teachers reported a good level (>6/10) of student engagement in learning while 20% reported low (<6/10) levels of engagement. The mean rating was 6.93/10. Given that the teachers’ rating would be based on their experience and culture, it is likely that these Nigerian teachers would have rated the level of engagement at a higher level than teachers from other cultural contexts.

Key finding 4.5

The most frequently mentioned strategies used by teachers of chemistry were teacher explaining and teacher drawing diagrams and plotting graphs, writing notes and demonstrating experiments which support a conventional chalk and talk teacher-centred approach. Almost two-thirds of the teachers used oral questions and answers method to assessing students’ understanding of a concept and few teachers used project/problem solving and practical modes of assessment to evaluate lesson objectives. The teachers believed that there was a good level of students’ engagement in class activities.

### Student Baseline Data

Student baseline data were collected from a convenience sample of five secondary schools from three zones of District V. A total number of 268 students completed and returned questionnaires (ISQ) which gave a return rate of 100%.

### Demographic data

Demographic data are provided for students' and gender. Fifty – four per cent of the students in the sampled schools were male while 46% were female. The proportion of girls relative to boys in Nigeria schools is sometimes low which could be attributed to early marriage of girls or being needed to help at home. The age distribution of the sample of students is presented in Table 4.11

Table 4.11: Age distribution of students as frequency (and per cent) (n = 268)

| 10 to 13[a] years | 13 to 15 years | 15 to 17 years | 17 to 19 years |
|---|---|---|---|
| 3 (1.1) | 88 (32.8) | 133 (49.6) | 44 (16.4) |

Note[a]: Limitations – unfortunately, there were overlapping ages in the categories

Students are normally of 15 -17 years of age when enrolled in SS 2 in Nigerian schools but occasionally, opportunities are given to some brilliant students to be promoted by two year levels and if the performance is maintained, they may be able to complete high school at an early age. Alternatively, a child found between the category of 17 – 19 years of age in SS2 might have repeated a class level or made a late entry (i.e. not commence high school at age 12) into school. As expected, a large proportion of the students (50%) were between 15 and 17 years of age.

### Students' attitudes and beliefs about chemistry

To gather information on students' attitudes and beliefs about chemistry and chemistry teaching and learning, they were asked to respond to a set of statements using α five-point Likert-type agreement scale. Students' responses to statements about chemistry from the questionnaire are reported here as three themes in Table 4.12, 4.13 and 4.14.

**Theme 1: Enjoyment and Interest in School Chemistry**

Students' responses to the items about enjoyment and interest in school chemistry are presented in Table 4.12

Table 4.12: Students' agreement with statements about their enjoyment and interest in school chemistry (n=268)

| Statements about chemistry | Per cent of students | | | | | |
|---|---|---|---|---|---|---|
| | Strongly agree | Agree | Undecided | Disagree | Strongly disagree | Mean rating of agreement |
| I enjoy chemistry lessons | 54.9 | 36.2 | 2.6 | 2.6 | 1.1 | 4.45 |
| Chemistry is very interesting | 48.9 | 44.0 | 1.9 | 3.0 | 1.1 | 4.38 |
| I derive pleasure in chemistry | 48.5 | 48.5 | 7.1 | 8.6 | 1.9 | 4.02 |
| I would like to be a chemist | 42.9 | 31.7 | 8.6 | 7.8 | 6.0 | 4.01 |
| It makes me curious about a lot of things | 28.0 | 49.3 | 9.0 | 6.3 | 5.6 | 3.89 |
| Chemistry class is fun | 18.7 | 42.2 | 6.7 | 19.0 | 11.6 | 3.38 |
| It makes me bored | 22.8 | 23.5 | 6.3 | 27.2 | 19.8 | 3.02 |

Note. [a] Responses were scored 5 = Strongly agree, 4 = Agree, 3 = Undecided, 2 = Disagree and 1 = Strongly disagree for the calculation of mean ratings of agreement.

Table 4.12 indicates that a large majority of students agree or strongly agree that they enjoy chemistry (91%) and they find the subject very interesting (89%). A large majority of the students (77%) also agreed or strongly agreed that chemistry makes them curious and they would like to be a chemist (75%). The seven items formed a coherent scale relating to enjoyment of or an interest in school chemistry with high internal consistency (Cronbach Alpha of 0.779).

Key finding 4.6
Students enjoy learning chemistry and have an interest in the subject. They derive pleasure in learning chemistry and many students would like to be a chemist.

**Theme 2: Ease of Learning Chemistry**

Students' responses to the items about the ease of learning chemistry are presented in Table 4.13

Table 4.13: Students' agreement with statements about the ease of learning chemistry (n=268)

| | Per cent of students | | | | | |
|---|---|---|---|---|---|---|
| Statements about chemistry | Strongly agree | Agree | Undecided | Disagree | Strongly disagree | Mean rating of agreement |
| I understand my teachers' explanations because they relates them to world around me | 47.4 | 37.7 | 4.9 | 6.3 | 3.4 | 4.20 |
| Chemistry makes me think deeply | 40.3 | 42.9 | 5.6 | 7.1 | 3.0 | 4.12 |
| Chemistry is easy to learn | 20.9 | 45.9 | 7.1 | 14.9 | 6.7 | 3.62 |
| It is the subject I understand most | 15.3 | 39.9 | 11.6 | 18.7 | 11.2 | 3.31 |
| I am confused in chemistry lessons | 12.3 | 20.5 | 11.9 | 26.5 | 22.8 | 2.71 |
| Chemistry is difficult to learn | 13.1 | 15.7 | 9.3 | 30.6 | 23.1 | 2.62 |
| I don't remember what I learn | 13.8 | 14.2 | 9.3 | 32.8 | 28.4 | 2.52 |
| The language is too difficult to understand | 8.2 | 14.6 | 12.3 | 38.1 | 23.1 | 2.45 |

Note. [a] Responses were scored 5 = Strongly agree, 4 = Agree, 3 = Undecided, 2 = Disagree and 1 = Strongly disagree for the calculation of mean ratings of agreement.

The two items with the highest agreement levels indicate that students understand their teachers' explanation when they are related to real life examples (85%) and that chemistry makes them think deeply (83%).

The statement that chemistry is easy to learn was rated (3.62/5) slightly above the mid–point of the agreement scale while the statement that chemistry is difficult to learn was rated (2.62/5) slightly below the mid-point of the agreement scale. Chemistry is therefore not seen as either an easy or very difficult subject to learn. It is noteworthy that one third of students agreed or strongly agreed that they are confused in chemistry lessons. The eight items formed a coherent scale related to ease and difficulty of learning chemistry and had a reasonable level of internal consistency (Cronbach Alpha = 0.643).

> Key finding 4.7
> A large majority of the students understand chemistry when explanation relate to real life examples and agreed that chemistry makes them think deeply. They neither find chemistry very easy or very difficult to learn.

**Theme 3: Usefulness of Chemistry Knowledge**

Students' responses to the items about usefulness of chemistry knowledge are presented in Table 4.14

Table 4.14: Students' agreement with statements about the usefulness of chemistry knowledge (n=268)

| | Per cent of students | | | | | |
|---|---|---|---|---|---|---|
| Statements about chemistry | Strongly agree | Agree | Undecided | Disagree | Strongly disagree | Mean rating of agreement |
| Chemistry helps me understand the world around me | 36.9 | 44.8 | 6.0 | 7.5 | 2.2 | 4.10 |
| I can apply my knowledge of chemistry | 32.5 | 43.7 | 7.8 | 9.3 | 4.9 | 3.91 |

| | | | | | | |
|---|---|---|---|---|---|---|
| to solve everyday problems | | | | | | |
| When faced with challenges in other science subjects, knowledge of chemistry provides me with solutions | 33.2 | 40.7 | 10.1 | 9.3 | 4.5 | 3.91 |

Note. [a] Responses were scored 5 = Strongly agree, 4 = Agree, 3 = Undecided, 2 = Disagree and 1 = Strongly disagree for the calculation of mean ratings of agreement.

The data in Table 4.14 indicate that a large percentage of students agreed or strongly agreed that chemistry helps them understand the world (82%), solve everyday problems (76%) and solve problems in other science subjects (74%). This usefulness of chemistry knowledge scale had high internal consistency with a Cronbach Alpha of 0.820.

Key finding 4.7

Most students agreed that chemistry helps them understand the world and solve everyday problems and problems in other science subjects.

To elicit information about the students' beliefs regarding effective teaching and learning of chemistry, they were asked to respond to the open-ended question: "What ways would you like your teacher to teach chemistry to help you learn?" The responses were grouped into categories. The categories were grouped into four themes: learning from experiments; learning from explanation and discussion; engaging students in learning; and, teachers being lively and friendly. The students' responses to this question are reported in Table 4.15

Table 4.15: Frequency and (per cent) of students holding various beliefs about effective chemistry teaching and learning (n=268)

| Characteristics of effective chemistry teaching and learning | Number (per cent)[a] |
|---|---|
| **Learning from experiments** | |
| Doing experiments | 109 (43.1) |
| Provision of laboratory facilities and equipment | 46 (18.2) |
| **Learning from explanation, representation and discussion** | |
| Teaching chemistry with clear explanations using simple and direct language | 116 (45.8) |
| Teaching with illustrations and diagrams | 17 (6.7) |
| Not writing and explaining at the same time | 14 (5.5) |
| Copying notes on the board | 8 (3.2) |
| Discussing ideas/interactive teaching | 8 (3.2) |
| Revising previous lesson | 6 (2.4) |
| Dictating and checking notes | 2 (0.8) |
| **Engaging students in learning** | |
| Giving class work and assignments | 36 (14.2) |
| Organising extra lesson after school hours | 13 (5.1) |
| Teachers coming to classes regularly | 13 (5.1) |
| Relating chemistry teaching to the environment | 6 (2.4) |
| Developing problem solving skills | 6 (2.4) |
| **Teachers being lively and friendly** | |
| Make chemistry teaching lively and friendly | 23 (9.1) |
| Others | 14 (5.5) |

Note: [a] Many students gave more than one response to the question

Data from Table 4.15 indicate that a large proportion of students (81%) believe that effective chemistry teaching and learning is doing experiments and that laboratory facilities should be provided for this purpose (18%). For example, Student 143 stated that “I want my teacher to always perform an experiment at the end of every topic so as to give me more understanding of the topic and also learn how to use apparatus”.

The students believed that their teachers should give clear explanations of the chemistry concept using simple and direct language (46%) and not explain at same time as writing on the board (13%). For example, this view was supported by ST 47 who said “To explain very well and to speak the language in which I will understand most”. ST 58 stated that “I would advise her to reduce her grammar and make teaching clear to us” and this view was supported by ST 206 who said “Explaining a bit more than copying note and make sure all of us understand”. The students also believed in active engagement during the learning process through class exercises and homework (14%) and by using illustrations and diagrams (7%); For example, ST 107 stated that “I will like my teacher to teach by illustrations and demonstration”. This view was supported by ST 74 who said “During the chemistry lesson I would like our teacher not to do all the talking alone” and ST 64 stated “By given me a lot of assignment and class work to do”. The students also mentioned they preferred their teacher to be lively and friendly (9%). For example, ST57 stated that the teacher needs to “Make teaching more lively and often use some chemistry instruments to teach”

> Key finding 4.8
> A large proportion of the students believed that effective chemistry teaching and learning requires hands-on experiments in a well-equipped laboratory and clear explanations of the concepts. Students also believed that teachers should set class work and assignments to engage students in learning.

### Experience of chemistry teaching

To identify the frequency with which various teaching approaches were being used, students were asked to indicate how often various approaches for teaching and learning were used in their chemistry classes. Students responded on a five – point frequency scale. The items were grouped into four themes: whole class teaching; practical work; students construct representations; and, small group and individual learning activities. A summary of the students’ responses is presented in Table 4.16

Table 4.16: Frequencies with which various teaching approaches were used in SS2 chemistry before the professional learning intervention (n=268)

| Teaching strategies | Per cent of students that indicated this frequency | | | | | |
|---|---|---|---|---|---|---|
| | In every lesson | In most lessons | In some lessons | In a few lessons | Never | Mean rating of frequency |
| **Whole class teaching** | | | | | | |
| Teacher explains while students listen | 78.0 | 14.2 | 5.6 | 1.1 | 0.4 | 4.70 |
| Copying notes | 63.8 | 13.4 | 9.0 | 8.2 | 5.2 | 4.23 |
| Teacher listens to students ideas | 35.4 | 24.3 | 21.3 | 11.2 | 6.7 | 3.71 |
| Students have whole-class discussion of ideas | 25.0 | 20.1 | 25.0 | 18.7 | 8.2 | 3.36 |
| **Practical work** | | | | | | |
| Teacher demonstrates experiment | 20.1 | 20.5 | 28.0 | 21.6 | 7.8 | 3.24 |
| Students do hands-on experiment | 8.6 | 16.0 | 26.9 | 22.0 | 23.9 | 2.62 |
| **Students construct representations** | | | | | | |
| Students draw diagram to indicate understanding on chemistry taught | 23.1 | 23.5 | 28.0 | 15.7 | 9.0 | 3.36 |
| Students do role-play | 20.9 | 19.8 | 20.9 | 16.0 | 22.4 | 3.01 |
| Students draw graph of the chemistry taught | 12.3 | 17.2 | 22.8 | 26.9 | 20.1 | 2.74 |
| Students draw map to identify specific and important ideas | 10.8 | 15.7 | 21.3 | 23.9 | 26.9 | 2.59 |
| Students demonstrate understanding using flowchart | 10.1 | 11.6 | 18.7 | 25.4 | 31.7 | 2.41 |
| **Small group and individual learning activities** | | | | | | |
| Reading textbook | 23.9 | 20.5 | 29.5 | 11.9 | 13.4 | 3.30 |
| Students discuss ideas in small group | 13.4 | 20.5 | 31.3 | 19.0 | 13.1 | 3.02 |
| Students learn all alone in the class | 5.6 | 11.9 | 16.0 | 19.8 | 44.8 | 2.12 |

Note. [a] Responses were scored 5 = In every lesson,4 = In most lessons,3 = In some lessons, 2 = In a few lessons and 1 = Never for the calculation of mean ratings of frequencies.

The data reveal that most frequently used teaching strategies are related to teacher-centred methods of teaching while students remain passive (teacher explains while students listen and copy notes). Hands-on activities, drawing maps, using flowcharts and role-play which are valuable student-centred learning experiences were not frequently used. Students sharing ideas in small groups and individual learning were occasionally used in some lessons.

> Key finding 4.9
> The most frequently mentioned teaching strategies experienced by the students are teacher explains while students listen and copy notes. Approaches that actively engage students through hands-on experiments, group discussion or constructing representations were used unfrequently.

**Chapter Summary**

More than half of the teachers were male and a large percentage are between 31 to 50 years of age. A majority of the teachers have appropriate teaching qualifications in science and education while 25% are under-qualified for teaching senior secondary chemistry. A large proportion of teachers about (75%) had more than five years of general teaching experience and 53% had more than five years of chemistry teaching experience.

Lack of laboratory facilities and equipment and a lack of teaching aids were the most frequently mentioned challenge to effective teaching of chemistry while 60% of teachers reported class sizes greater than 30 students which were above the government recommended class sizes. Many teachers believed that effective chemistry teaching depends on the provision of laboratory and instructional teaching materials while effective chemistry learning occurs when students are doing hands-on experiments, learning from teaching aids and students are engaged in a discovery learning method.

The most frequently reported teaching approaches used in every lesson were the teacher explaining chemistry ideas to students, writing equations and notes, drawing graphs and demonstrating experiments without allowing students to participate. Strategies such as hands-on experiments, flowcharts, concept maps, diagrams, role-plays and 3D models were used less frequently. This indicates that the most commonly used strategies students typically do during chemistry lessons are not student-centred but rather teacher-centred and didactic. Assessment of students' knowledge is based mainly on asking oral questions.

The students possess a positive attitude to chemistry as a subject as they perceived it to be relevant to their daily lives. The teaching and learning strategies frequently experienced by the students before the professional learning intervention are teacher's explaining, writing on the board, drawing diagrams and demonstrating experiments while students passively observe. The students believed that performing laboratory experiments and teaching chemistry concepts through explanations are the characteristics of effective chemistry teaching and learning. These teacher and student baseline data indicate that students have limited opportunities to be actively engaged in learning through constructing their own representations and generating meaning for themselves.

# CHAPTER 5: PROFESSIONAL LEARNING INTERVENTION

## Introduction

In order to challenge teachers' beliefs about chemistry teaching and to develop their knowledge about the use of multiple representations to enhance learning, three days of professional learning were provided. The aims of the workshops were to improve teachers' pedagogical knowledge for using multiple representations in their teaching of chemistry and to challenge their beliefs about teacher-centred teaching practices.

## Objectives for the Workshop

The objectives of the intervention were to provide opportunity for the teachers to:

- enhance their knowledge of planning and teaching chemical concepts in an engaging and more student-centred manner using multiple representations;
- generate and construct multimodal representations of chemistry concepts; and,
- recognise different ways that students' representations can be used to assess their understanding of chemistry concepts.

The professional learning intervention comprised two workshops (Figure 5.1). Workshop 1 was implemented over two days following the initial teacher survey and classroom observations. After the first workshop, further classroom observations, teacher interviews and focus group discussions were held with students. The second workshop was implemented in one day and this was followed by further classroom observations and data collection.

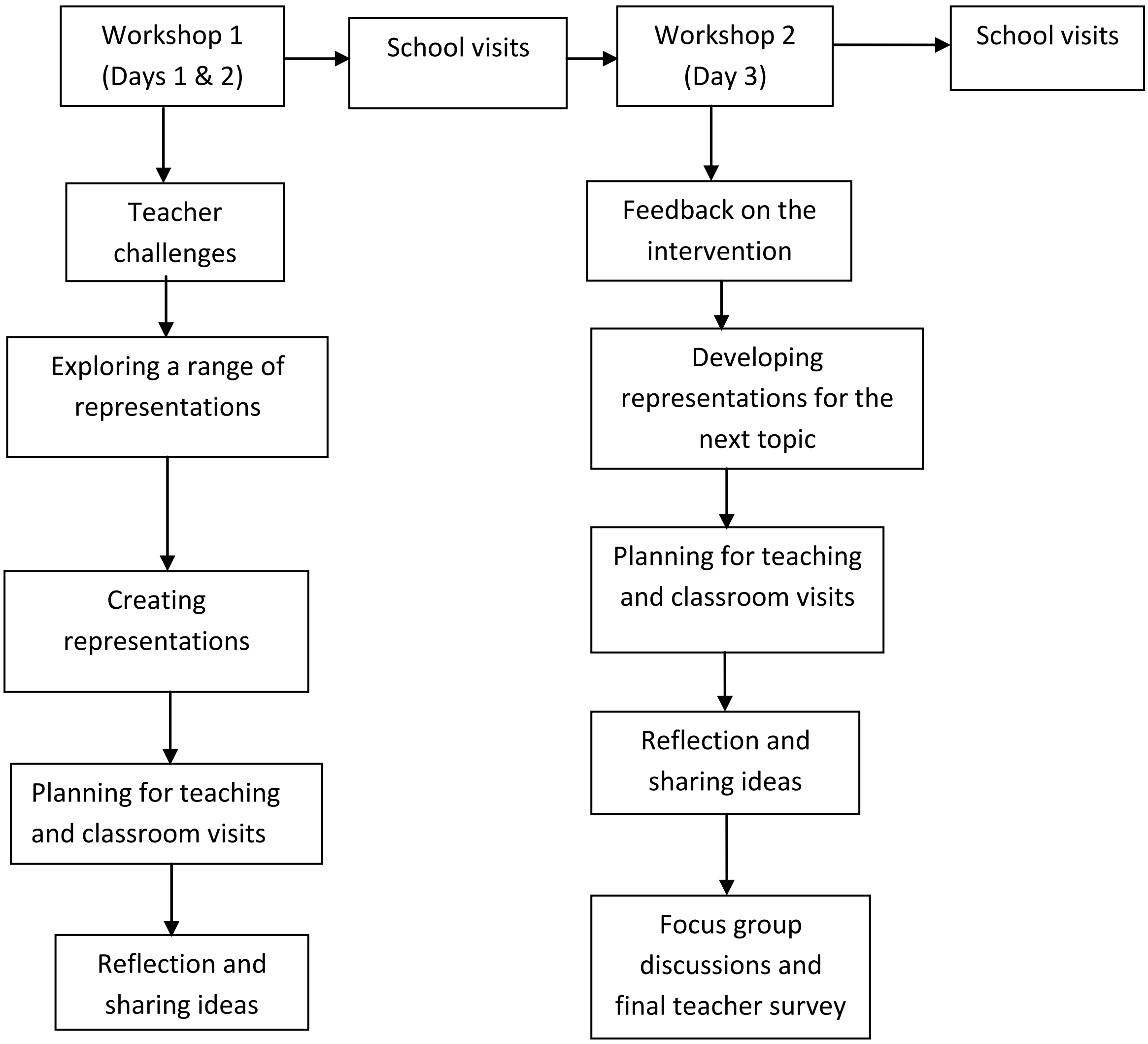



**Figure 5.1: The professional learning intervention**

**Workshop 1**

The first workshop opened with a welcome address and an introduction that discussed the workshop's objectives. Fifteen chemistry teachers participated in the workshop. These teachers were divided into five groups of three to work as teams and each team chose a representative who reported back on discussions to the whole group.

The professional learning intervention was designed to build knowledge about ways to actively engage students, promote thinking and the construction of meaning through the use of multiple representations. The strategies for enhancing learning of chemistry were realistic within the constraints of limited resources.

## Challenges of teaching chemistry and engaging students in learning

Following the opening, the teachers were given time to discuss in small groups their ideas about the difficulties they experience in teaching chemistry and engaging students in learning. The teachers then provided feedback to the whole group. The challenges shared by each group were grouped into categories. The categories were grouped into four themes as listed below.

### i. School related problems

The problems mentioned by the teachers included overcrowded classrooms and a lack of: school laboratories; laboratory apparatus and equipment; instructional materials; sufficient time allocated for chemistry lessons; career officers/counselling and guidance units in school to direct and guide students; and, proper screening of junior high school students to identify those qualified to study chemistry in senior high school.

> School lack chemistry laboratory and sufficient apparatus to perform experiment, practical classes are occasionally and mostly merge with other schools during final examination period, large population, insufficient time allocated for chemistry lesson and lack of instructional materials, no students' counsellor and proper screening before assign student to a course (Feedback from small group discussions, 29/04/10).

### ii. Government related problems

The problems mentioned by the teachers included: an overcrowded syllabus and curriculum packages that change frequently; inadequate supply of qualified chemistry teachers; and, poor funding to develop teaching materials.

> Government refuses to employ qualified chemistry teachers for more hands in schools; poor funding to improvise teaching materials where necessary; overcrowded syllabus and constant changes of curriculum (Feedback from small group discussions, 29/04/10).

### iii. Teacher related problems

The teachers mentioned: inadequate remuneration and hazard allowance; irregular in-service training opportunity for teachers to update their knowledge; ineffective planning and preparation of lessons to make teaching lively and interesting; lack of cordial teacher-student relationship; lack of teacher's knowledge for teaching abstract chemistry concepts; inadequate evaluation of students' learning; and, teachers overloaded with other responsibilities in the school.

> Poor remuneration for chemistry teacher; irregular attendance to seminars/workshop to keep teachers' current in the field; lack of teacher adequate preparation prior to the lesson, poor teacher/student

> relationship; and most at times teacher lack mastery for teaching abstract concepts; and chemistry teachers assigning for other responsibilities in schools (Feedback from small group discussions, 29/04/10).

### iv. Parent and student related problems

Problems mentioned by the teachers included: lack of support for children from parents to buy necessary textbooks; students' poor study habits and attitudes to chemistry; and, students' poor background knowledge of junior high school (JHS) science.

> Students lack parent support to buy necessary textbooks; students lack of interest to chemistry and poor study habit; students' background at JSS level is poor where some enter science class because of peer pressure (Feedback from small group discussions, 29/04/10).

The challenges of teaching senior secondary chemistry described by the teachers at the workshop corroborate the problems elicited by the teacher questionnaire reported in Chapter 4 (Key findings (KF) 4.2).

### Exploring representations

The Researcher facilitated a discussion of the range of representations that could be used to make abstract chemistry concepts real and accessible to students. Among the representations discussed were:

- concept maps to engage students' higher order thinking in identifying key features of a concept and specifying their interrelationships (Novak, 1991, 1996; Richard, 2008);
- 3D models to help students visualise molecular shapes; the models can be rotated and viewed from different perspectives (Harrison & De Jong, 2005);
- role-plays as an embodied form of representation which allow students to work on and demonstrate their understanding of processes or events (George, 2004; Murcia, 2009);
- flow charts to represent the steps in a process; flow charts usually have arrows to show a direction of flow;
- particulate representations of a sub-microscopic world that represent matter as constituent atoms and molecules; and
- graphical representations to show energy changes during a reaction.

Following this, the Researcher explained that in chemistry, chemical reactions are usually presented at three levels of representation i.e., macroscopic, particulate and symbolic (Cheng & Gilbert, 2009). It was explained that, for students to develop a conceptual understanding of chemistry, there is a need for them to be able to express their understanding of the particulate level and to be able to make connections between the three levels of representation. It was explained that utilizing multiple modes of representations helps students to demonstrate thinking at the three levels (Carolan, et al., 2008). There was also a discussion about the advantages of using students' drawings and other representations as a source of information about what students understand and their misconceptions.

### Creating representations

Following this, the teachers, in their groups, were asked to share their ideas on the key features of reaction rates and collision theory as well as list the key concepts as a way of clarifying their conceptual knowledge. The teachers developed a list of concepts using cardboard labels that were provided (Figure 5.2). Using the labels, the teachers were then shown how to construct a concept map. The teachers had little knowledge about concept mapping and were not familiar with how it could be used to teach chemistry. Each group shared their ideas about the concept maps with the whole group and discussed how to develop concept mapping with students.

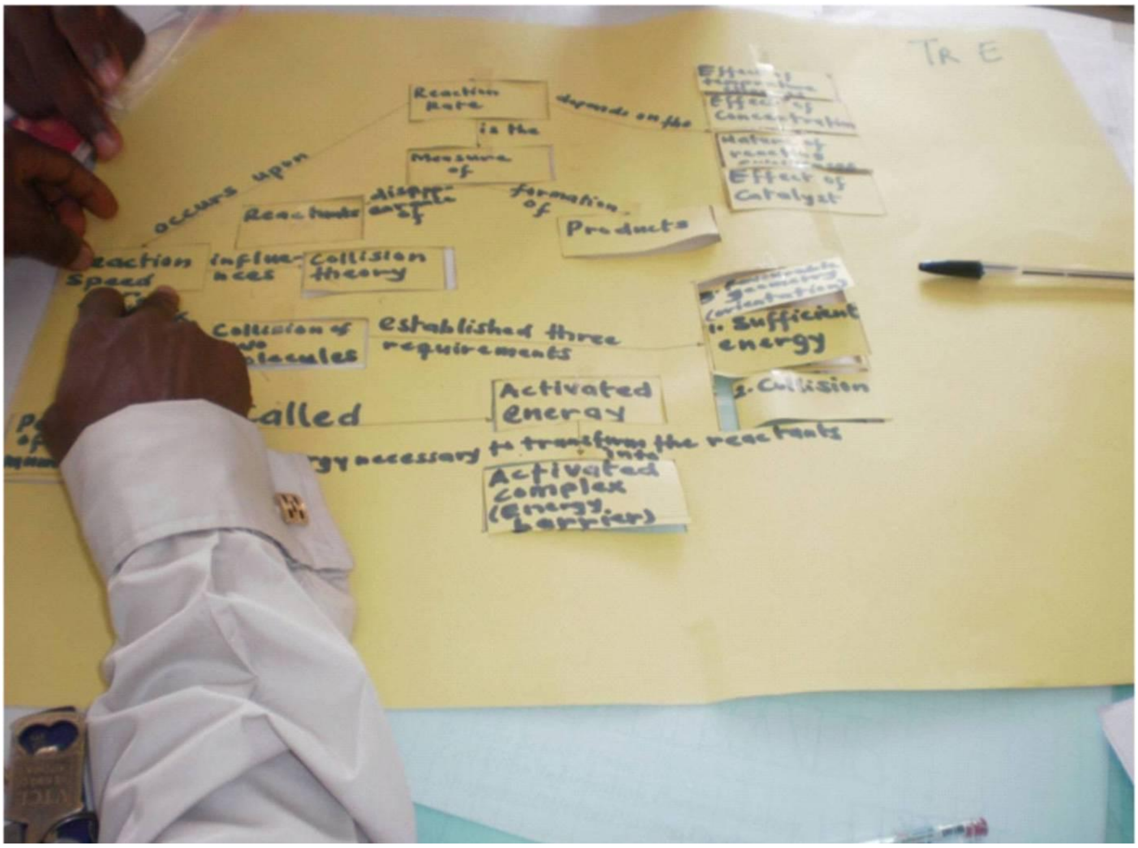



**Figure 5.2: Teachers developing concept maps of reaction rates and collision theory**

The teachers constructed and interpreted a symbolic, particulate, role-play and graphical representation of a reaction between hydrogen molecules and oxygen molecules. The teachers are usually familiar with a symbolic representation of a reaction but in order to identify their conceptual understanding, they were asked to represent their ideas using particles. The graphical representation on the other hand, introduced ideas of a progressive reaction rate using the energy profile of the reaction to show activation energy, transition state and heat formation of a reaction.

The teachers also constructed and interpreted a symbolic, particulate and graphical representation of the combustion reaction for methane gas (Figure 5.3) during the workshop. A role-play of the reaction was also demonstrated.

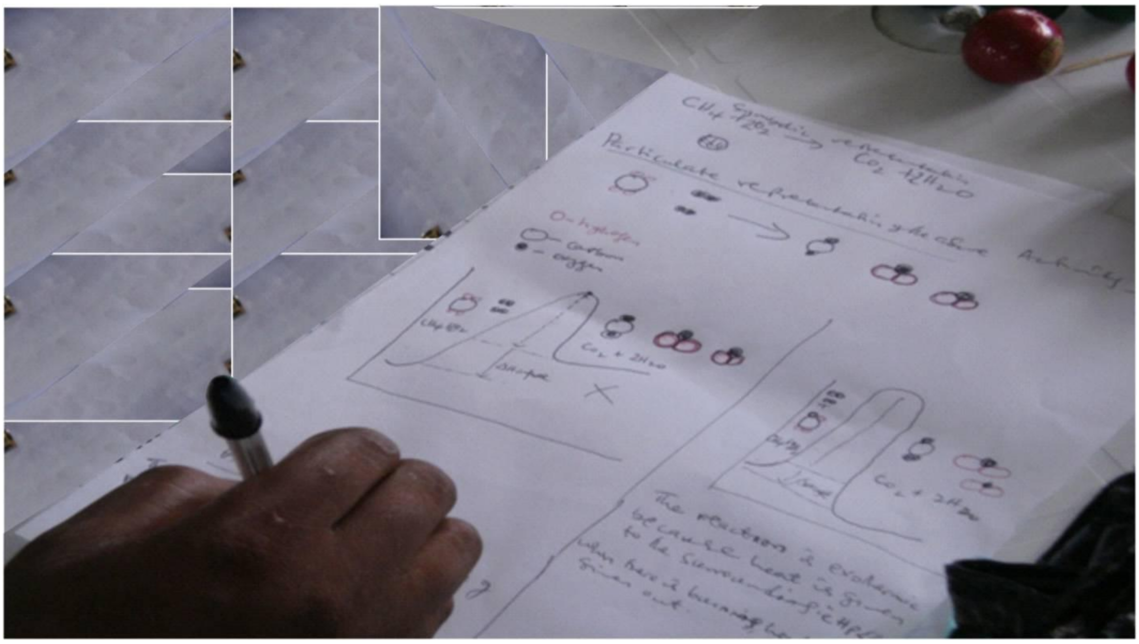


**Figure 5.3: Teacher constructing symbolic, particulate and graphical representation of methane combustion**

The teachers discussed the advantages of using multiple representations in their teaching. The most important benefit frequently mentioned by the teachers was that it helps the teacher to be in a relaxed mood while students' hands, minds and brains are actively engaged.

### Planning for teaching and classroom visits

Following discussion using multiple representations strategies to teach reaction rates and collision theory, the teachers planned a single and double lesson on the topic. The lesson plans outlined the concepts, objectives, activities and strategies to engage the learners and key discussion questions. The dates for classroom visits were also discussed with the case study teachers.

### Reflection and Sharing Ideas

Each day of Workshop 1 came to a close with reflection questions and sharing ideas from each group. The following are the key ideas contributed by the teachers during the reflections session, which were transcribed from an audio recording:

#### Day 1

**How do I make abstract ideas in chemistry accessible?**

The teachers stated: motivate students to actively participate during a learning task; use role-play representation to make concept real and accessible; use particulate representation for easy assessment of students' understanding; use concept maps to engage students' higher thinking; and, encourage active student engagement in the class activities (Teachers' reflection and sharing of ideas, 29/04/10).

**How do I actively engage students in constructing and negotiating meaning using representation?**

The teachers stated: the teacher can generate a representation and allow the students to create their own representation similar to that of teacher's representation; allow students to construct models of molecules and display them in the classroom; divide students into groups to share ideas by giving them a topic to study with specific guidelines to follow and then asking them to develop their own ideas to share with others in the classroom; involve students in a microteaching session to build up their skills and confidence in presenting; students can be given a project to develop their problem solving skills, creativeness and resourcefulness (Teachers' reflection and sharing of ideas, 29/04/10).

.

**How do I develop students' understanding of the three levels of chemical representation in my teaching?**

The teachers stated: by active student engagement through constructing particulate representations and models (Teachers' reflection and sharing of ideas, 29/04/10).

#### Day 2

**How do I plan my lesson using a multimodal representational technique learnt in this workshop?**

The teachers stated that there is a need to: possess knowledge of the students and how they learn; place students at the centre of learning; plan the lesson in a way that will actively engage students during the lesson; be accurate in the lesson delivery to avoid misconceptions and misrepresentation of ideas; be ready and willing to go extra miles for students' engagement by developing a series of activities that challenge their higher thinking and become independent learners; and, carefully select suitable representations that will capture students' imagination and interest in learning the concept within the stipulated period (Teachers' reflection and sharing of ideas, 30/04/10).

**Which of these modes will be easy to use within the available and stipulated lesson period?**

The teachers stated that concept maps, particulate representation and role-play activity will be easy to use because they require little or no efforts in searching for the materials. The teachers also noted that the type of representation chosen for a lesson depends on the concept to teach (Teachers' reflection and sharing of ideas, 30/04/10).

**What resources are needed for each concept and how do I get access to these resources?**

The teachers responded that: the choice of materials depends on how creative and resourceful a teacher is; the content of the lesson will determine the choice of materials but local materials which are available within the locality are preferred. The choice of materials in this workshop on the water filter challenge, construction of a 3D model and lists of concept maps posed a great challenge to us (Teachers' reflection and sharing of ideas, 30/04/10).

**Feedback on Workshop 1**

A short survey was distributed to collect teachers' responses about the workshop on the use of the multiple representations strategy. The survey included the following questions: What did you learn from the workshop? What did you think is difficult? Why? What did you think could have been improved in this workshop? How do you intend to apply what you gained in this workshop?

The key ideas mentioned by the teachers on what they had learned from the workshop were the use of activities that allow students active participation during the lesson; making abstract concepts real through various modes of representation; and, using students' representations for easy assessment of students' understanding of the concept:

> I learnt the need to involve students in class activities which will engage their brain and also the use of role-play, concept map, model, demonstration, particulate and graphical representations to make chemistry class challenging and interesting especially the use of role-play which is very interesting to me (Teacher's response, 30/04/10).

Responses about difficulties included getting the materials for the activities; time constraints to cover the scheme of work (a scheme of work is a breakdown detailed of instructions on specific topics and information to be covered within a particular term or period); lack of space to act role-plays because of overcrowding in the classroom; and, difficulty of representing large organic molecules using particulate representation:

> Firstly, the application of the skill require on some topics is consider difficult e.g. large molecule in organic reaction. Secondly in a large class size, using role-play could make the class noisy. Thirdly, there are difficulties getting sufficient instructional material for demonstration in a school with large number. Lastly, the period allocated for chemistry on the time-table is not sufficient for the teacher to complete the scheme of work (Teacher's response, 30/04/10).

The teachers think that the workshop could have been improved by providing more resource personnel, use of a projector, more activities and more days for the workshop.

> More activities as well as more instructional material may be introduce to make it lively and challenging, also use of projector to make the exercise easy for demonstration, more resource personnel would be needed and need to increase the number of workshop days (Teacher's response, 30/04/10).

Responses on how the teachers intended to apply what they had gained in the workshop included making the concept real using various modes of representation and actively engaging students during a learning task.

> Making students to actively participate during the lesson both in demonstration and collection of materials and also using concept map, role-play activity, particulate and graphical representation (Teacher's response, 30/04/10).

**Workshop 2**

The aim of the second workshop was to gather information on teachers' challenges of engaging students with and learning how to interpret multiple representations and to plan for teaching another topic using multiple representations.

### Feedback on the intervention and teacher's practice

A handout that asked the following questions was distributed to collect teachers' responses on the challenge of engaging students when using multiple representations: What was successful? Why? What was difficult? Why? And ways to improve ?

The key ideas mentioned by the teachers about what was successful was the use of multiple representations to engage students in learning (i.e., role-play, concept maps, models, demonstrations, particulate and graphical representations) because they allowed active student engagement during the learning process. It also makes the teaching of chemistry easier for the teacher and reduced the giving and copying of notes.

> With the use of multiple representation, students were actively engaged which in turn improve their understanding of the concept. The use of concept map really helps the students because they believes it is challenging and make learning real and meaningful. Using role-play and demonstration arouse the students' interest to learn the concept. It makes teaching easier for the teacher. The students really enjoyed the use of multiple representation compare to the conventional method of teaching and copy notes (Teacher's response, 18/05/10).

The main difficulties related to: time constraints allocated for teaching of chemistry; class size; necessary materials for the activities; teacher's preparation in planning the lesson; and, students' conceptual difficulty in expressing their understanding of re-arrangement of atoms and molecules using particulate representations:

> The difficulty aspect of using multiple representation is that material to demonstrate hands-on activity in most cases are not readily available, time and finance to improvise materials, class population, teacher's preparation that require high pedagogical content demonstration of knowledge and students sometimes in their representation were unable to differentiate a molecule from an atom (Teacher's response, 18/05/10).

The teachers thought that they needed to go back to the classroom and elaborate more on the students' conceptual understanding of the relationship between molecules and atoms and bonding. Thus, there is a need for more time to be allocated for the teaching of chemistry. A teacher needs to be creative and resourceful in order to develop improvisation skills and also to prepare adequately before teaching a concept.

> I need to plan adequately for my lesson, acquire skill of improvisation and..... to stress distinguish [ing] feature [s] between a molecule and an atom because the students are still making mistakes in this areas (Teacher's response, 18/05/10)

| Key findings 5.1 |
|---|
| Teachers reported that the use of multiple representations was successful because it encouraged students' active engagement during lessons. What was difficult was accessing the material for experiments and modelling, and students' conceptual difficulty to demonstrate understanding of chemical reaction at the molecular level. |

### Planning for the next topic

The teachers then planned for the next topic on water pollution and solubility. The teachers were asked to work in small groups to identify key ideas on water pollution and solubility and then to create a concept map on water and solutions. There was a whole group discussion linking ideas of water sources, water cycle, water pollution and its control using pictures as a way of illustration. The teachers were requested to construct ball and stick models for molecules of water, methane, methanol and ethanol (See sample of model constructed in Figure 5.4).

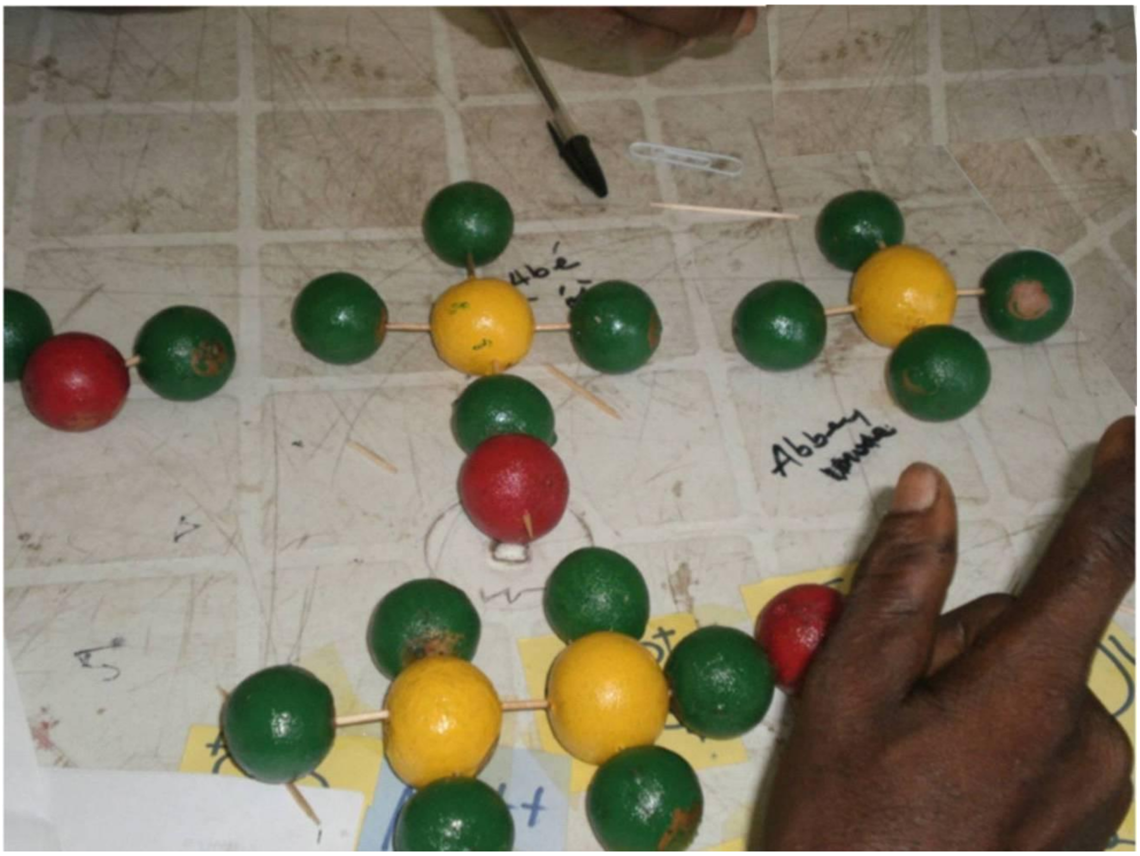


**Figure 5.4: Teacher constructing 3D physical model of molecules**

They were also asked to draw and explain, using particulate representations, the three states of water. They also constructed a water filter separating visible dirt from a plastic bottle full of muddy water. The workshop activities that teachers engaged in Day 3 were more challenging, especially the construction of a water filter (Figure 5.5). The teachers also prepared a role-play activity of the water cycle that described the movement of water within the water cycle.


Figure 5.5: Teacher constructing a water filter

### Planning for classroom teaching

The teachers discussed and planned a single and double period on the concept of water pollution and solubility. The lesson plan format outlined the concepts; objectives at the end of the lesson; activities of the lesson in the classroom; strategies to engage the learner; and, key questions. The teachers also planned the date and time to commence further lesson observations and other data collection.

#### Reflection and Sharing Ideas

The second workshop ended with reflection and sharing ideas contributed from each group on how each teacher could make available the new ideas gained during the workshop to other teachers in the field. The teachers suggested that seminars and workshops should be conducted for other chemistry teachers to update their knowledge of the multiple representations strategy. This suggestion was further stressed with a statement in the form of a metaphor, as quoted in Ogunmade (1997, p. 47), by one of the workshop personnel to encourage the teachers that they should avoid "being a Mincer that have information but keep it all alone and not willing to share the ideas with others nor a Preacher that give the words to others to create awareness but himself will not keep to the word or a Mother ends (acting a role model) that receive an information and look for subordinate, monitoring them and never leaving them to get their freedom or liberty" (Workshop personnel's response, 18/05/10).

**Focus Group Discussion with the Teachers to Share their Success Stories**

There was a focus group discussion with the teachers at the end of the second workshop to share their success stories. The following questions formed the basis of the focus group discussion and the teachers' responses:

To elicit information about the teachers' beliefs regarding the most effective ways for students to learn chemistry, they were asked: "What do you believe are the most effective ways of students learning chemistry?" The teachers explained that they should make learning student-centred through active engagement with activities; small group discussions among the students to learn ideas from each other; use of representations (role-play, models, particulate and graphical representations), regular hands-on experiments; and, the teachers should improve their own teaching skills and need a mastery of the subject matter (Focus group discussion with the teachers, 18/05/10)

> Teacher making learning the student-centred, small group discussion and allow a representative from each group to make a presentation, engage students with the use of multiple representation strategy, hands-on experiment just as water filter challenge in the workshop and teacher need to possess mastery knowledge of the concept to teach (Teachers' response, 18/05/10).

To identify teachers' beliefs regarding the most effective way for teaching chemistry, they were asked: "What can you recommend as the most effective senior secondary chemistry teaching?" The key ideas that were discussed by the teachers were: active student engagement during the lesson; having knowledge of the students learning ability; possessing knowledge of the concept; use of the multiple representation teaching strategy (i.e., demonstrations, models, role-play, flow charts, particulate and graphical representations); group learning to allow students to work together and learn from each other (Focus group discussion with the teachers, 18/05/10). The teachers explained that the particulate and role-play representations require little effort in searching for materials and are very easy for teachers to assess students' understanding of the concept.

> Use of multiple representation teaching strategy because all the representation actively engage students during learning though it all depend on the topic, having knowledge of the students in the class and their learning speed – this problem will be solve through group work, active involvement of students when demonstrating a concept (Teachers' response, 18/05/10).

To identify the teachers' beliefs on making the chemistry classroom interesting for the students, they were asked: "How do you think a chemistry classroom can be made interesting for the students?"  The key ideas that were discussed by the teachers were: Through active students' engagement during the lesson, which motivated their interest and made them eager to learn. They also mentioned that when students were involved in collecting materials to be used for a lesson, it lodges in their memory and when faced with life challenges the knowledge gained in the classroom can be used to deal with those challenges (Focus group discussion with the teachers, 18/05/10).

> It is possible by actively engaging students which captivate their interest to learn the concept and made it easier for the teacher to assess their understanding on the concept, also students could be involve to collect or look for materials to use during a particular lesson for a model construction (Teachers' response, 18/05/10).

**Distribution of Teacher Questionnaire**

The final teacher questionnaire was distributed for the workshop participants to identify changes in teachers' beliefs and practice. These data are summarised in Tables 5.1 and 5.2. The teachers completed the questionnaire and the workshop was brought to a close.

Table 5.1: Frequency and (percentage) of teachers holding various beliefs about characteristics of effective chemistry teaching and learning after the professional learning workshop (n=15)

| Characteristics of effective chemistry teaching | Number (%)[a] | Characteristics of effective chemistry learning | Number (%)[a] |
|---|---|---|---|
| Active student participation | 8 (57.1) | Active student engagement | 10 (66.7) |
| Teachers' content knowledge | 3 (21.4) | Student-centred learning | 2 (13.3) |
| Use of multiple representations | 4 (28.6) | Hands-on experiments | 4 (26.7) |
| Adequate planning | 3 (21.4) | Representation methods | 4 (26.7) |
| Others | 7 (50.0) | Others | 3 (20.0) |
| Missing | 1 (6.7) | | |

Note. [a] Many teachers gave more than one response to the questions.

Data reported in Table 5.1 indicate that teachers believed that effective chemistry teaching and learning is dependent on active student engagement through hands-on experiments and use of multiple representations. It was also mentioned that there is a need for adequate planning and a teacher having an appropriate depth of knowledge of the subject matter. For example, T9 stated that "active participation of students and use of representations such as particulate representation and modelling together with role-play method". T13 and T14 also stated, "make lesson student-centred, teacher having adequate planning" and "teacher having mastery about the subject matter" respectively. These views were supported by T1 and T3 who said "Involving students in the hands-on experiment" and "fully engaging the students in hands-on activity that involve their higher thinking" respectively.

Key finding 5.2

Many teachers believed that effective learning of chemistry is when students are actively engaging in hands-on activities and use of multiple representations, and also that the teacher is competent and has content knowledge of the subject matter and plans lessons adequately.

Table 5.2: Percentage of teachers reporting frequencies with which various teaching approaches are used in SS2 chemistry after professional learning intervention (n=15)

| Percentage of teachers reporting a particular frequency of use for various teaching strategies | | | | | | |
|---|---|---|---|---|---|---|
| Teaching strategies | In every lesson | In most lessons | In some lessons | In a few lessons | Never | Mean rating of frequency [a] |
| Teacher explains | 60.0 | 40.0 | 0 | 0 | 0 | 4.60 |
| Teacher uses equations | 40.0 | 40.0 | 20.0 | 0 | 0 | 4.20 |
| Teacher uses diagrams | 6.7 | 46.7 | 46.7 | 0 | 0 | 3.60 |
| Teacher leads whole class | 26.7 | 13.3 | 40.0 | 13.3 | 6.7 | 3.40 |
| Teacher writes notes | 26.7 | 6.7 | 46.7 | 13.3 | 6.7 | 3.33 |
| Students have group discussion | 6.7 | 40.0 | 40.0 | 6.7 | 6.7 | 3.33 |
| Teacher demonstrates experiment | 6.7 | 40.0 | 26.7 | 26.7 | 0 | 3.27 |
| Teacher uses concept maps | 0 | 53.3 | 20.0 | 20.0 | 6.7 | 3.20 |
| Teacher draws graphs | 6.7 | 26.7 | 46.7 | 13.3 | 6.7 | 3.13 |
| Students engage in role-plays | 13.3 | 20.0 | 33.3 | 20.0 | 13.3 | 3.00 |
| Teacher uses 3D | 6.7 | 20.0 | 46.7 | 13.3 | 13.3 | 2.93 |

| | | | | | | |
|---|---|---|---|---|---|---|
| models | | | | | | |
| Teacher uses flow charts | 0 | 20.0 | 46.7 | 26.7 | 6.7 | 2.80 |
| Students do hands-on experiments | 0 | 26.7 | 33.3 | 26.7 | 13.3 | 2.73 |
| Students develop diagrams | 6.7 | 13.3 | 40.0 | 26.7 | 13.3 | 2.73 |
| Students read textbook | 0 | 0 | 20.0 | 20.0 | 60.0 | 1.60 |

Note. [a] Frequencies were scored 5 = In every lesson, 4 = In most lessons, 3 = In some lessons, 2 = In a few lessons and 1 = never for the calculation of mean ratings of frequencies. Items were ranked by decreasing order of means.

Results from Table 5.2 show that the most frequently mentioned teaching approaches used in chemistry lesson after the professional learning workshop were teacher-centred strategies (teacher clearly explaining the concept using equations, drawing diagrams, and leading the whole class). Between the initial teacher questionnaire (n-40) (Table 4.8) and the final questionnaire with 15 of the teachers after the second workshop there was more frequent use of concept maps, role-play and 3D models.

> Key finding 5.3
> Following the second professional learning, teacher explanation, using equations and diagrams were the most frequently used strategies. Writing of notes became less frequent and the use of concept maps, role-play and 3D modes were more frequent than before the workshops.

To ensure continuity of the research, the teachers and their students were later observed in the classroom immediately after the second workshop.

**Chapter Summary**

The professional learning workshops provided an opportunity for the teachers to enhance their knowledge of teaching chemical using multiple representations and recognise different ways that students' representations can be used to assess their understanding of chemistry concepts. The workshop activities actively engaged teachers with activities that required higher levels of thinking and challenged their beliefs about teaching chemistry. They also provided an opportunity for the teachers to learn that they can be creative and resourceful in their teaching. The workshops also provided the benefits of group learning, which increased the learning pace of some learners, created room for sharing ideas and learning from one another, and, provided a friendly and relaxing environment.

The feedback on the intervention revealed that the teachers believed in the use of multiple representations because they encouraged students' to be actively engaged in learning. The strategy was less stressful as it required less presentation of content by the teacher and allowed teachers to assess students' understanding of a concept easily during the lesson using student constructed representations. Following the second workshop teacher reported writing notes less frequently and used concept maps, role-plays and 3D models more frequently than before the intervention.

To complement these teacher reported data about the impact of the professional learning on their practice and beliefs, the following three chapters reported case studies which include teacher and student views about the impact of the intervention plus classroom observations made by the Researcher.

# CHAPTER 6: CASE STUDY 1

**Introduction**

This chapter presents the first of three case studies, which provide a rich account of the context of chemistry teaching and how teachers responded to the professional learning intervention. Research studies indicate that teachers' knowledge, beliefs and classroom instructional practice have important greatest impacts on students' learning (Hattie, 2005; Levitt, 2001) Carefully organised professional learning interventions can impact on teachers' knowledge, influence their beliefs and bring about change in their classroom practice (Hackling & Prain, 2005; Ingvarson, et al., 2005). This research provided a professional learning intervention that challenged teachers to be actively engaged with new approaches to teaching chemistry.

The case studies were compiled from data gathered through interviews, professional learning activities, lesson observations and focus group discussions with students. This chapter reports contextual background to the case study, the nature of the usual classroom practice, challenges to effective teaching and learning, and lastly, impacts of the intervention on teachers' practice and students' engagement with learning. The case study teacher in this chapter is referred to by the pseudonym Bob and ST1, ST2 ST3 are the focus group students.

**Teacher's Profile**

Bob is a male chemistry teacher in an urban senior secondary school located in a suburb of Lagos, Nigeria. He graduated with a Bachelor degree in science education with a major in chemistry (BSc.Ed, chemistry) and has been teaching chemistry for 15 years. He was transferred to his present school one year ago and is the only teacher of chemistry in the Senior Secondary School. Bob manages laboratory facilities and equipment, teaches mathematics as an additional subject and is responsible for taking students out for a quiz competition.

**School Context**

Bob's school is co-educational and is located within the Badagry Local Education District. Bob's school was purposely chosen due to close proximity to the Researcher and more importantly, Bob indicated interest in attending the professional intervention learning workshops. Many people living within the School's community are civil servants and industry workers because of the numerous industries, companies and housing estates built for government workers. Other inhabitants are fishermen and small scale self-employed individuals. Women are mostly traders and have a positive disposition towards education.

The school chemistry laboratory was very poor as it lacked facilities and equipment with nothing displayed on the benches that could be used to demonstrate experiments. There were insufficient seats in the laboratory. Power failures are one of the most striking problems when demonstrating experiments at Bob's school. Bob's chemistry lessons and practical activities are taught and demonstrated in the classroom while students usually observe the demonstration. Four students sit at each bench with a long desk on which they can place writing materials. The classroom is well ventilated but noisy because of the crowding. The government commenced furnishing this school's laboratories with additional resources towards the later stages of this study.

**Curriculum Context**

Students spend six years at secondary school (three years each at Junior and Senior High School). Chemistry is taught at the senior high school level for the three years and is a compulsory subject for science students. Biology and physics are also compulsory subjects for science students. Chemistry teaching in Bob's school is based on the core content of the National Chemistry Curriculum for SSS 1-3 (Federal Ministry of Educaton (FME), 2007) which specifies the content to be covered each week across the three terms of the academic year. Senior secondary schooling is of three years duration after three years of junior high school before three to four of tertiary stage. Bob makes use of the following documents in his teaching: a laboratory manual that contains lists of the student's activities for practical lessons; a record of students' continuous assessments; the teacher's weekly timetable; students' attendance register; teacher's diary; and, lesson notes. These are important documents that every teacher needs to prepare for their teaching in Lagos State. The documents are mandatory for every teacher to complete and require signatures from the school's principal and district school inspectors to ensure thorough supervision of teaching materials.

Bob was the only chemistry and mathematics teacher in the senior high school which had 554 students in SSS 1-3. The five streams of SSS 2 students were combined into two classes due to the lack of classrooms. Of the 209 students in SS2, 49 chose to study chemistry. These 30 male and 19 female students formed one class for chemistry lessons.

### Research Data Collected Prior to the Intervention

Before the professional learning intervention, teachers completed a questionnaire and the Researcher made classroom observations and interviewed the teacher. The sResearcher also conducted a focus group interview with students from the chemistry class. The data collected prior to the intervention are presented below describing the challenges of teaching and learning chemistry; beliefs about effective chemistry teaching and learning; students' assessment; students' learning and engagement; and, Bob's classroom practice.

## Teaching and learning challenges

Bob's main difficulties with teaching chemistry were that students lacked interest in the subject; there was a lack of laboratory space and equipment for practical classes and teaching aids; and, parental problems (Initial Teacher Interview, 2/3/10). Students' poor attitude towards chemistry was attributed to inability of some students to easily understand topics taught in chemistry as a result of a poor foundation in science from Junior Secondary School (JSS).The JSS is of three years duration after six years spent in primary school. Explaining the main difficulties Bob has with teaching SSS chemistry, he stated:

> Students have a negative attitude towards the subject and when it's time for chemistry class, the turn-out is very poor/low this can be attributed to student home background. In some cases, most of these students are coming from background that knows little about education/science (illiterate background) which can motivate a student found in science area to appreciate science subjects. There is also problem on student poor foundation of science experience at JSS (ISC) level, for instance little or no enough encouragement and motivation from Integrated Science teacher at JSS level the agitation there is just to know more about science. Students don't buy textbooks thereby very difficult to do assignment when given to them (Interview with Bob, 2/3/10).

Bob also explained the difficulties he had trying to teach chemistry without a well equipped laboratory:

> School lack laboratory facilities that requires making the concepts real through practical activities. For example, teaching a concept on law of conservation of matter requires showing the students a reaction process, it will be more registered if students can visualise the practical aspect of this concept than theoretical aspect but necessary chemicals and reagents are not available to demonstrate the concepts. Though government are supplying the materials but the laboratory is not conducive to carry-out the necessary experiments. For example, setting-up Bunsen burner to set-up a reaction involving heat, no electricity (there is always power failure) and lack of water supply. Government are just supplying test-tube, beakers, we don't have gases in the laboratory to carry-out reaction involving heat except using stove which does not give blue flame but red flame which gives soot (Interview with Bob, 2/3/10).

He also mentioned that parents assumed that whatever their children needed in schools would be provided by the government and hence they would not be required to make a financial contribution. Explaining this, he stated:

> In some cases, parent do not help by having wrong perception that government is doing everything and not ready to come to aid assisting in one area or the other. Actually, it is the issue of politics that really paralyses education in Lagos State. When free education is been professed which gives these parents an impression at the back of their mind that government will and should provide everything- Parents are not really to contribute anything again (Interview with Bob, 2/3/10).

As a consequence of this, many parents would not buy their children necessary textbooks to further their studies of chemistry at home.

| |
|---|
| Key findings 6.1<br>Bob's main difficulties with teaching chemistry were a lack of laboratory facilities and equipment for practical classes, inadequate instructional materials, poor students' attitudes towards the subject and parents not assisting in buying textbooks for their children. |

**Beliefs about effective chemistry teaching, learning and assessment**

Bob believed that the use of demonstrations was the most effective method for teaching chemistry because it was visual and helped students understand and remember:

> If the atmosphere is conducive enough, demo is the best, because seeing believes and this is mostly registered so well in the students' brain and remains permanent. Students remember easily what they see rather than abstract teaching. Demo [demonstration is better and we will try to work towards this (Interview with Bob, 2/3/10).

When Bob mentioned the conducive atmosphere, he meant that if the school provided teaching resources and laboratory equipment, he would use the demonstration method. When asked about usual learning activities the students do in his chemistry lessons, Bob explained:

> Jotting down some points (summarising the lesson in their notes) from this they bring out their questions (Interview with Bob, 2/3 /10).

Bob believed that the most important things to consider when planning lessons were to start with an introduction that reviews the previous lesson and to relate it to the incoming knowledge.

> I introduce the lesson in a way that the lesson will not look bored to the students- looking at some previous knowledge that relate to the new concept to learn (Interview with Bob, 2/3 10).

Bob used oral questions and answers during lessons based on behavioural objectives stated in his lesson plans for the first six weeks of the term to assess students' achievement. He also mentioned that he usually set two class tests each term to assess students' understanding of the chemistry concepts. Bob also assessed students' chemistry learning through their notes; and, through group and individual research projects *(*Interview with Bob, 2/3/10).

Bob explained that his students learn best through practical work and research projects and these provided useful opportunities for assessment. Bob did not use homework assignments to assess students' understanding of chemistry because they do not clearly reflect students' understanding of a concept (Initial teacher interview, 2/3/10). Bob believed that students' assignments are an unreliable form of assessment because the students copy one another, which does not reflect their understanding of the concepts. Explaining the indicators Bob considered as evidence of effective learning of chemistry, he stated:

> The practical research project that students are able to carry out and oral-test. I will not use assignment because it is porous and deceptive (Interview with Bob, 2/3/10).

| Key findings 6.2 |
|---|
| Bob explained that his mode of teaching is typically a conventional chalk and talk method although he believed that the demonstration method is the best, however, a lack of resources limits the number of demonstrations he can perform. He also believed that students learn best when involved in practical work and research projects and these are used to assess students' knowledge and understanding of chemistry concepts. Oral questioning is also an important method of assessment. |

**Classroom Practice**

Five of Bob's lessons were observed commencing on the 2$^{nd}$ March 2010. Bob usually has single and double chemistry lessons in a week. Prior to the intervention, a single and a double period were observed. These lessons were observed to indentify Bob's current practice, his use of representations and the extent of students' engagement in the lessons. Classroom observations were also made after the first professional learning workshop. These observations focussed on impacts of the learning intervention on Bob's practice, the generation and negotiation of representations and students' active engagement. There were also further observations after the second workshop. Observations of Bob's teaching prior to the first workshop, an interview and focus group with students generated data regarding Bob's teaching practice; and students' perceptions about learning chemistry; These data are reported in the following section.

## Teaching style

Before the first workshop, Bob explained that his teaching was based on lecturing, which involved the teacher acting as an information giver, and demonstrating the experiment while students observed and wrote a few notes. Bob's reasons for using these methods (lecture and sometimes demonstration method) were that class sizes were large, the laboratory was not appropriately equipped and that laboratory materials were unavailable (Initial teacher interview, 2/3/10). He stated:

> For SSS 1, I usually carrying out experiment in the classroom while for SSS 2 the classes are too large and most of the materials needed are not available. For example, preparation of oxygen – laboratory is not conducive to carry out such experiments. Mostly, I use lecturing method- this is well pronounced in my teaching. Demo [demonstration] method is not much because of lack of materials (Interview with Bob, 2/3 10).

To develop an understanding of teachers' classroom practices and students' learning behaviour for a specific chemistry concept before the professional learning intervention, an observational checklist was used to document teaching and learning activities. The next section reports activities observed during an 80 minute double lesson.

## Lesson observations

The topic of the lesson was oxidation and reduction reactions. Bob's lesson was highly teacher-centred as the teacher dominated the classroom talk (explaining ideas and a short period of interacting with students). Out of 80 minutes of the lesson, 50 minutes were used for teacher explanation and teacher-student interaction occupied only 25 minutes. Bob started the lesson with a review of the previous topic using a question and answer technique in order to assess the students' understanding. Following the introduction, he provided definitions of oxidation, reduction, oxidising agents and reducing agents in terms of electron transfer. He explained the electron transfer in redox reactions and that redox reactions can be recognised with the aid of oxidation numbers which are determined by set of rules. The rules for determining oxidation numbers were stated by Bob. A redox equation was written on the board by the teacher, the oxidation half and reduction half of the equation was stated to balance the redox reaction (See Figures 6.1a & b). Bob wrote approximately four equations for reactions on the board and the students were asked to copy the reactions and write the redox equation for each reaction as an assignment. The word ‘equation’ and the symbolic representation of the reaction were used frequently during the lesson. However, there was little emphasis on what happens at the macro and sub-micro level of the chemical reaction which involves making and breaking of bonds and this is the area where students normally have conceptual difficulties relating their ideas (at the macro, sub-micro and symbolic representation levels). During the lesson therefore, the students copied the reaction as written on the board by the teacher (Figure 6.1b) but mostly, students lacked an understanding of the re-arrangement of atoms and molecules at the macro and sub-micro levels because these aspects were not made real and accessible to students.

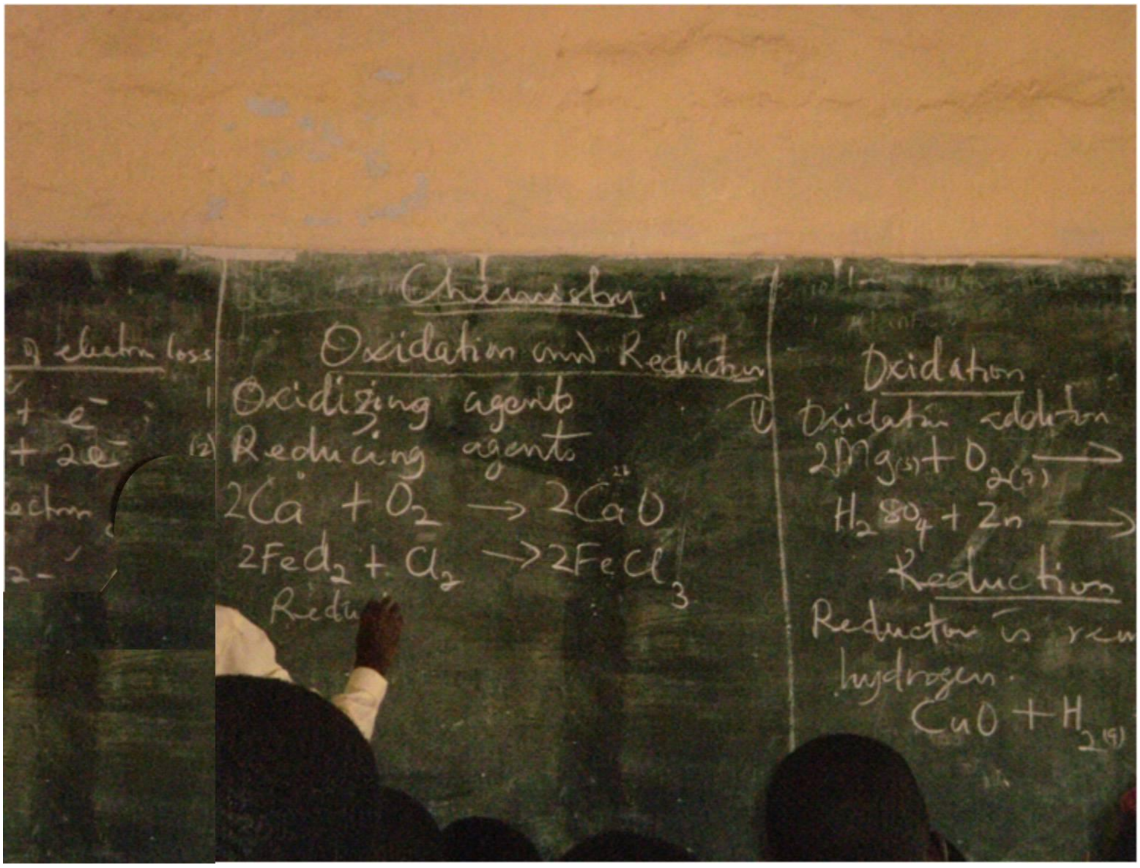



**Figure 6.1a: Bob’s blackboard notes**

Bob dominated the teaching activities and provided no room for students to respond to the presented content. Some of the students struggled to write down a few notes in their notebooks because there was not enough time to copy all the information.

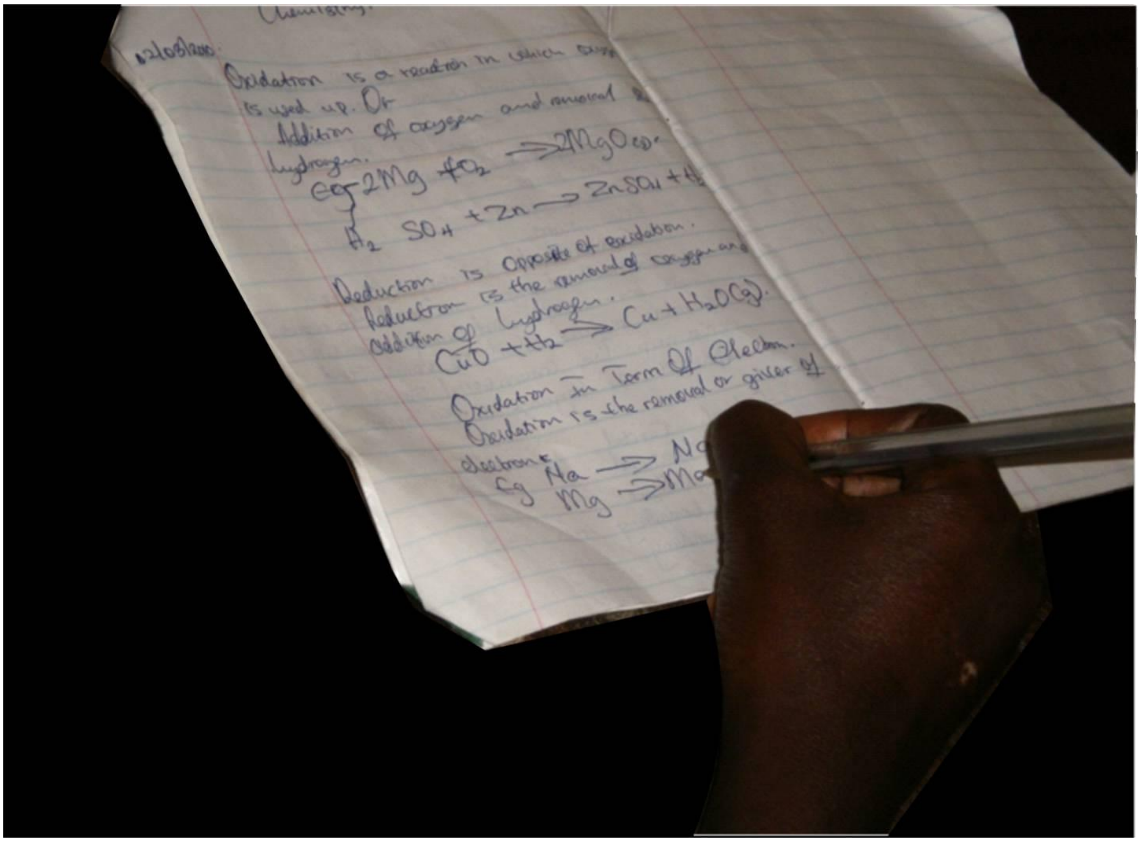


Figure 6.1b: Notes written by a student in Bob's lesson

The teacher played an active role of explaining and calculating problems on the chalkboard throughout the lesson, while students mainly played a passive role of listening. Table 6.1 summarises Bob's pre-intervention classroom teaching practice as observed in this double lesson.

Table 6.1: Pre-intervention lesson observation for Bob

Lesson topic: Oxidation-reduction

Date: 03/03/10

Lesson duration: 80 minutes/double period

| Teaching and learning strategies | Time |
|---|---|
| Teacher talking and writing on the board while students are jotting down a few notes | 50 mins |
| Teacher and students interacting (Q & A) during the lesson | 25 mins |
| Students in small group discussing during lesson | 0 mins |
| Teacher challenging and engaging students in class activities constructing representations (e.g. concept maps, role-plays, models, flow-charts, particulates, graphical) | 0 mins |
| Students copying an assignment written on the board by the teacher | 5 mins |

In the lesson observed, the teacher spent 63% of the lesson talking and writing while only 31% was used for classroom interaction when students asked some questions. Students were given no time to engage in class activities to develop their understanding of the concepts.

> Key findings 6.3
>
> Bob's teaching style was largely based on lecturing which provided no room for students to be actively engaged during the lessons 'so' students remained passive except for a period of teacher student interaction .

A focus group discussion was conducted with three students from the class to elicit information about the students' understanding of the concepts taught and learning chemistry as a subject.

**Students' Perceptions about Learning Chemistry**

The students explained that chemistry provides knowledge about healthy living, the environment, food in-take and its processes in the body, the air we breathe, the water we drink, its pollution and treatment. When asked "What is it like learning chemistry?"

and “Give example(s) of things around you that you do at home that shows you are learning chemistry” they stated:

> ST1: Chemistry is one of the science subjects that help us to learn more about our environments, ourselves and daily lives for example, polluted water, air and land.
>
> ST2: Chemistry helps us to learn things that are around us and about our health for example, water treatment by boiling to remove/kill germs and bacteria present.
>
> ST3: Chemistry involves things about our daily lives because chemistry deals with chemicals and whatever we see around us or do in the school knowingly or unknowingly are more or less about chemistry. It also helps to study about our environments for example, there is no food we eat that... [does] not contain salt... [which we refer] to as sodium chloride ($NaCl$) in chemistry (Focus group meeting with students in Bob’s class, 2/3 10).

When asked to explain the concept taught in the observed lesson, the students were not confident enough in their ability to share what they had learned. ST1 explained a few things about the lesson but lacked confidence to discuss key features of the concept taught while ST2 could not share any knowledge gained at all and ST3 rated himself to be 80% if tested on the concept taught. The students were asked: “What actually has been helping you to learn chemistry?” and “Did your teacher teach differently today?”

> ST1: My teacher who happens to be well qualified in explaining the concepts to the best of my understanding. There is no difference in the way my teacher taught today.
>
> ST2: My teacher helps me to be independent. The way he taught today has been his usual way of teaching.
>
> ST3: The textbooks I read after the class teaching. Not really, that has been his usual way of teaching (Focus group meeting with students in Bob’s class, 2/3 10).

The students confirmed that the lesson observed was typical of Bob’s normal practice and was therefore a fair representation of his teaching prior to the intervention.

To identify students’ opinions about the benefits of learning using representations, the students were asked: “Do you think the use of models, charts, and pictures can help you to learn chemistry better?” The students responded that chemistry becomes easy to understand and remember when visual representations and models are used.

> ST1: This will help me to learn chemistry better because I can easily remember the concepts at the recall.
>
> ST2: It will help to retain the concept permanently and not easily forgotten.

> ST3: Seeing is believing and concept learnt could easily be recall, the way model is being illustrated can easily flash back to my memory (Focus group meeting with students in Bob's class, 2/3/10).

The students were also asked: "What would you like your chemistry teacher to do differently"? The students believed engaging in hands-on activities that actively involved them during a learning task would help them:

> Involving in hands-on experiment especially the topics that involve practical demonstration (Focus group meeting with students in Bob's class, 2/3 10).

| Key findings 6.4 |
| --- |
| Students believed that knowledge of chemistry helps them understand things happening in the world around them and that the teacher's explanations with further reading of textbooks has helped them to learn chemistry. They thought that the use of representations would make chemistry easier to learn and remember and that active participation in hands-on experiment would make chemistry real for them. |

**Bob's Participation in the First Workshop**

The active engagement and level of participation shown by Bob during the workshop is reported in this section. During the first workshop, Bob engaged in various activities that challenged his classroom practice. The aim of the workshop activities was to develop his knowledge of using multiple representations to teach a chemistry concept. Bob was familiar with teaching using symbolic representation of chemical reactions prior to the workshop but the workshop activities developed Bob's understanding of active student engagement in the learning process through the use of concept maps, role-plays, models, flow charts, particulate, and graphical representations.

Bob participated actively during the workshop. He was selected in his group as a representative to share the ideas discussed during the small group discussions with the whole group. Table 6.2 presented below summarises the challenges and solutions to the problems mentioned by Bob's group.

Table 6.2: Solutions to the challenges of teaching and engaging students in learning chemistry proposed by Bob's group

| Challenges of teaching and engaging students in learning | Recommended solutions |
|---|---|
| Large class size | Group discussion, adopting applied scholastics method and assistance from private organisation |
| Inadequate laboratory equipment | Improvisation |
| Students lack of interest towards the subject | Teacher possessing mastery of subject matter, applying a concept to students' daily life experiences and use of role-play method of teaching |
| Inadequately qualified chemistry teachers | Employing professionally trained teachers |
| Students' poor background knowledge | Building a strong foundation at JSS level |
| Curriculum packages that change constantly | Teachers attending seminars/workshops |
| Inadequate remuneration | Provide a hazard allowance to teachers and review salaries |
| Techniques for teaching abstract concepts | Use of concept maps and flow-charts |

Bob was particularly interested in the particulate, 3D physical model and role-play representations when asked about what interested him most during the learning intervention. He stated that the particulate and role-play representations require less effort in preparing materials while 3D model representations can easily be constructed using locally available materials such as those presented during the workshop. He explained that the particulate representations would engage students' higher thinking and reveal what they know and do not yet understand. The representations would also engage students' hands, minds and brain. Bob stated that the benefits of the representations were to reduce teacher's stress of writing notes on the board and that students would be actively engaged with activities related to the concept; learning would become real and it would be easier for the teacher to assess students' understanding of the concept:

> The particulate, role-play and 3D physical model are the most interesting to me as this requires less effort in getting the materials and reduce teacher's burden of writing notes. The representations engaging students' higher thinking, hence learning were made real and students are able to demonstrate their understanding on the concept (Bob's response during Workshop 1, 29/04/10).

**Teaching and Learning Following Workshop 1**

Bob was observed teaching another 80 minute double lesson after the first workshop to identify any impacts of the professional learning program on his practice and his students' engagement. After the lesson observation, Bob was interviewed and a focus group discussion was again conducted with students from his class. This time, Bob's lesson focussed on reaction rates and collision theory. Classroom settings included the teacher having discussions with the whole class, small group and individual student work respectively.

## Lesson observation

After attending the workshop, Bob's lesson was more student-centred and he used multiple representation strategies, which actively engaged the students throughout the period. Bob used a number of representational modes to develop an understanding of the thermal decomposition of hydrogen peroxide. He wrote an equation for the reaction on the board and then asked the students to construct a particulate representation of the reaction. The teacher and students conducted an experiment to demonstrate the speed of the reaction when catalysed and uncatalysed. The students also engaged in a role-play activity of the reaction to demonstrate the breaking of the bonds during the decomposition of hydrogen peroxide to produce water and oxygen molecules. Bob introduced ideas of progressive reaction rates using energy profile diagrams (energy diagrams explaining activation energy, transition state, endothermic and exothermic reactions). The students were asked to construct a graphical representation of the catalysed and uncatalysed thermal decomposition of hydrogen peroxide to predict the shape of the activation energy. They also added particulate representations of the molecules to the graph and explained what they had learnt to the whole class. During the lesson, the teacher and students had many interactions about the concept; students shared ideas in groups and individually responded to the challenge of constructing representations of the concepts. The students' representations would have provided useful work samples for the teacher to assess students' understanding and misconceptions of the concept (See Figures 6.2 & 6.3).

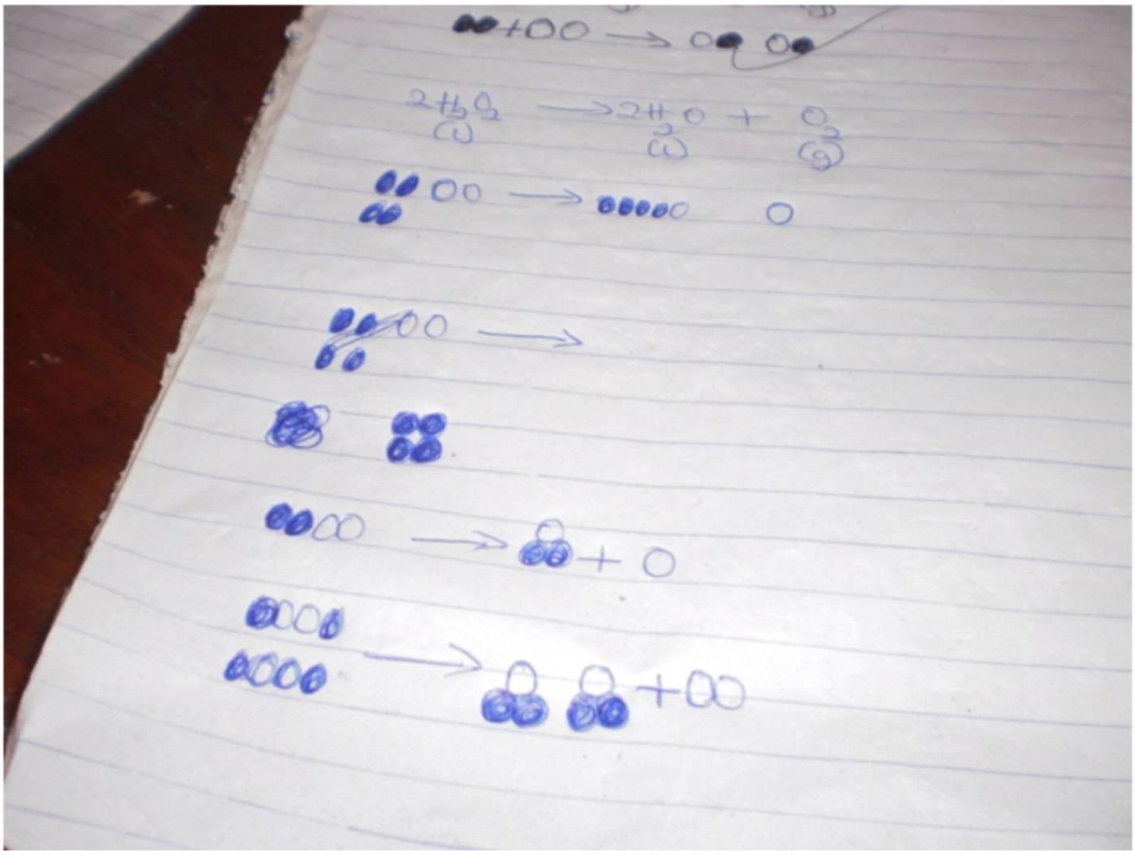


**Figure 6.2: Particulate representation of thermal decomposition of hydrogen peroxide constructed by a student**

Figure 6.2 reveals a student's misconception about $H_2O_2$ molecules in the representation shown above. The first representation in the figure above reveals that the student misrepresented $H_2O_2$ molecule as two separate hydrogen and oxygen atoms but not as an entire molecule. The student was probed to explain the representation, realised his mistake, was corrected and then presented the second attempt, as shown at the base of the paper.

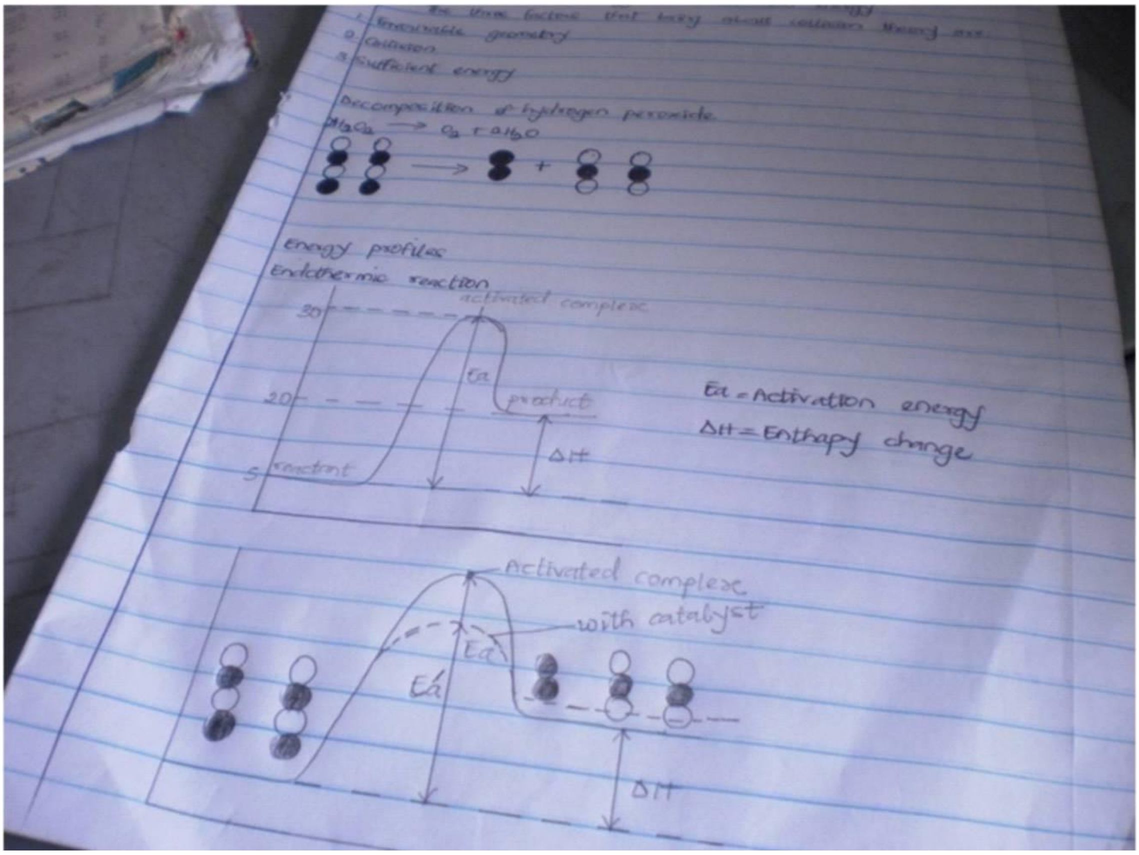



**Figure 6.3: Particulate and graphical representations of thermal decomposition of hydrogen peroxide constructed by a student**

Figure 6.3 shows a student's representation of the activation energy graph, catalysed and uncatalysed with molecules shown as particles. The representations were generally accurate even though the atoms were not placed in the correct geometry for effective collision to occur.

The whole 80 minutes were used for the teacher and students to interact with learning materials while the students constructed meaning during the learning process. The lesson was interesting and students were actively engaged with and enjoyed the activities. Table 6.2 summarises the teaching strategies that Bob used in this double lesson, after the first professional learning workshop.

Table 6.3: Bob's teaching strategies after the first workshop

| Lesson topic: Reaction rate and collision theory<br>Date: 07/05/10<br>Lesson duration: 80 minutes/double period | |
|---|---|
| Teaching and learning strategies | Time |
| Teacher talking and writing a summary on the board while students write notes | 0 mins |
| Teacher and students interacting as a whole class during the lesson | 10 mins |
| Students in small group discussion during the lesson | 10 mins |
| Teacher challenging and engaging students in class activities constructing representations (i.e., demonstration, role-play, particulate, graphical) | 60 mins |
| Students copying an assignment | 0 mins |

One quarter of the lesson time was used for interactive learning in whole class and small group discussions. Three-quarters of the lesson was spent challenging and engaging students in class activities and in which students' actively participated in role-play activities, demonstrated an experiment, and constructed particulate and graphical representations of the molecules.

**Bob's Experiences of using Multiple Representations**

To elicit information about Bob's experience and challenges with using the new teaching technique and the extent to which students were actively engaged during the lesson, a post lesson interview was conducted. Bob believed that the students learn chemistry better when engaging actively in class activities. He mentioned that materials, for example chemical reagents, to demonstrate some reactions were not readily available at all or sometimes were not sufficient for individual students to perform their own experiments. Bob was asked "Can you explain the process used to actively engage your students' higher thinking during lesson"? "During the processes, what challenges did you face"? Bob explained that:

> Students need to be involved in series of activities to develop their conceptual understanding of the concepts and active engagement during

> the lesson. The challenges are materials to use- for example; hands-on-experiment to demonstrate decomposition of hydrogen peroxide are not readily available in laboratory. Some students believed that the activities carried out in group is not sufficient enough but prefer to carry it out individually. Though not difficult but in a large class size, it is somehow clumsy. It will be best applicable in a normal class size between 25-30 students (Interview with Bob, 7/5/10).

In order to assess Bob's understanding of the use of multiple representations for teaching chemistry and its advantages in a large class, he was asked "What do you understand by the use of the multiple representations strategy in Chemistry"? and "What do you think about the advantages of the use of multiple representations in a large class size"? Bob responded that a teacher re-representing a concept or an idea using different modes is said to be using multiple representation strategy. The strategy quickly awakened students' interest and attention, which in turn provided a better understanding of the concept. Bob explained:

> Teacher re-representing a concept with students in different modes for better understanding is said to be using multiple representation. Students are usually more effective in one area than the other for example, students may prefer a particular representation than the other which is even to the teacher's advantage because if a teacher wants to put a principle of concept across and a student believes he/she has a way to best explain the concept- I think it is best than just only one route he/she doesn't understand. The advantage of multiple representations is that it gives freedom and opportunity to understand a concept using different approaches, gain interests and attention of many students (Interview with Bob, 7/5/10).

Bob was also asked "Were the students actively engaged and did they feel supported during the learning process"? and "What factors do you think motivated students to learn in the chemistry lesson"?

> The students were willing to participate actively because chemistry class look so fun with activities introduced during the lesson and simple words of encouragement that learning chemistry is not difficult and they are actively engaged with class activities (Interview with Bob, 7/5/10).

Bob was asked to explain the impact of the professional learning intervention on his teaching practice and his confidence in teaching chemistry. He stated:

> Personally, it has great impact because it broadens my thinking and throws me into a great challenge. MR strategy has increased my confidence in teaching chemistry concept because my teaching methodology is broadening for knowing how to use different modes to illustrating a concept (Interview with Bob, 7/5/10).

Key findings 6.5

The students were actively engaged in class activities and willingly participated as they perceived that learning chemistry is easy and not difficult. Bob also indicated that the multiple representations strategy learned during the workshop has impacted positively on his confidence to teach chemistry topics and has broadened his thinking about teaching strategies.

**Students' Response to the Multiple Representation Learning Strategy**

To identify how students responded to the new strategies of constructing and interpreting multiple representations of a chemistry concept, a focus group discussion was conducted with some of Bob's students.

The students were actively engaged in class activities that challenged their higher order thinking, observing a demonstration and constructing particulate and graphical representations of thermal decomposition of hydrogen peroxide. When students were asked to explain what they enjoyed most in the lesson, they responded:

> ST 1: Seeing the reaction taking place through demonstration of the experiment.
>
> ST 2: Making the concepts real and accessible.
>
> ST 3: Active involvements in the demonstration.
> (Students' focus group discussions, 7/5/10).

The students explained that this was an unusual lesson because they were actively involved during the learning process "He brought a uniqueness to today's lesson because we were actively involved" (Students' focus group discussions, 7/5/10).

To elicit information on students' beliefs about teaching and learning of chemistry, they were asked "What do you believe are the most effective ways to learn Chemistry"?

> ST 1: Performing practicals and constructing the graphical representation to demonstrate the reaction progress.
>
> ST 2: Hands-on experiment and role-play activity.
>
> ST 3: Active engagement using particles to construct the reaction, acting role-play activity. (Students' focus group discussions, 7/5/10).

The students were asked to respond to the question "What would you like your teacher to continue doing to facilitate learning of Chemistry"? They stated that they would like hands-on experiments, role-plays, particulate representations and graphs for all the concepts they learn in chemistry (Students' focus group discussions, 7/5/10).

**Bob's Level of Participation in the Second Workshop**

Bob reported success in engaging students with and learning how to interpret multiple representations of the same concept. He explained that the use of a concept map made learning real and meaningful because it challenged students' higher thinking. The role-play activity and the demonstration engaged and stimulated students' interest for learning. He stated further that students who did not usually show interest during chemistry lessons were motivated to be in class and participated actively. On his teaching methodology, Bob reported that the technique improved his creativity to improvise and overcome the non-availability of materials and identify the most important thing needed to consider when planning a lesson. It reduced his stress about giving explanations and writing notes on the board. Therefore, his confidence to teach chemistry concepts increased.

Bob mentioned the constraint of having insufficient chemicals for students to perform individual hands-on experiments, though this was not a major problem as students were easily divided into groups. Bob overcame this problem using particulate and role play representations where necessary and where applicable to engage individual students. Time management was another constraint as some students were slower learners and there was not enough time to give attention to these students, but, he managed to organise after-school lessons to focus on those students.

The construction of a water filter to illustrate a water treatment plant was a great challenge to Bob and his group members. The activity was to extract clean water from a plastic bottle full of muddy water. Bob initially thought the activity was easy and did not carefully arrange materials provided before he poured the muddy water; not surprisingly, he got the muddy water in return instead of clean water. This activity posed a great challenge which required higher order thinking to learn how the filtering materials could be arranged correctly. Bob later extracted the expected clean water, having re-arranged the materials. He reported that "water cannot be tamed because it passes through every available space". A role-play representation was used to improve the teachers' understanding of the water cycle and Bob was chosen to rehearse the play with his group members.

**Teaching and Learning Following Workshop 2**

Following the second workshop, an 80 minute double period lesson that focussed on water and solutions was observed. Classroom settings included whole class, small group and individual student work. The observations were recorded on the observation template. The lesson was more student-centred as opposed to the traditional method of only the teacher talking, because students were actively engaged in various activities and used representational modes to develop an understanding of the solution concept. The students acted out a role-play of the water cycle, constructed a model of water molecules, created concept maps related to water and solution, and performed a hands-on experiment of a reaction between silver nitrate and sodium chloride solutions. Bob had enough interaction with the students to easily assess their understanding of the concepts. Bob moved from group to group assessing students' understanding as they responded to the challenge of engaging and learning with multiple representations (see Figure 6.4).

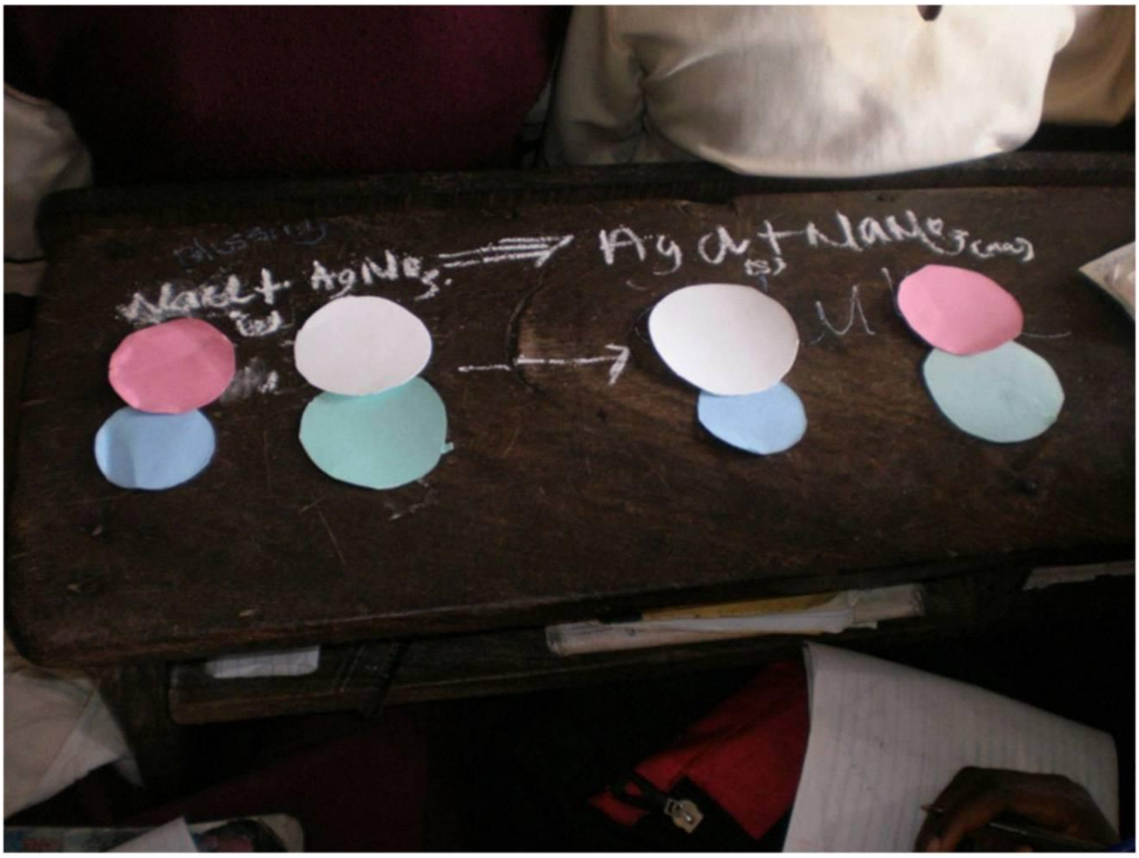


**Figure 6.4: Particulate representations of reaction between sodium chloride and silver nitrate constructed by students**

The teaching challenged students' higher thinking about using particles to represent the reacting molecules and it made the reaction real and accessible. The students were actively engaged during the lesson and this made them lively and eager to learn. Table 6.3 presented below summarises the observed lesson.

Table 6.4: Teaching strategies used by Bob in a double lesson after the second workshop.

Lesson topic: Water solution

Date: 01/06/10

Lesson duration: 80 minutes/double period

| Teaching and learning strategies | Time |
|---|---|
| Teacher talking and writing notes on the board while students are writing notes | 0 mins |
| Teacher and students interacting as a whole class during the lesson | 10 mins |
| Students individually and in small group discussion during lesson | 15 mins |
| Teacher challenging and engaging students in class activities constructing representations (i.e. concept maps, role-plays, models, particulates, hands-on experiment) | 55 mins |
| Students copying assignment | 0 mins |

After the second workshop, Bob spent 69% of the lesson challenging and engaging students in class activities using role-play, constructing models, developing concept maps, and fully participating in a hands-on experiment. The students worked together and discussed ideas in small groups, and then individually recorded their ideas in their notebooks. This provided Bob with work samples to identify students' misconceptions and assess their understanding of the concepts. Enough time was created in the lesson to allow the teacher and students to generate and negotiate representations of the concepts. Learning was facilitated as the concepts taught were made real and accessible. Bob appreciated and enjoyed being released from only talking and writing notes on the board.

Key findings 6.6

Following the intervention, teaching and learning activities were based on generation and negotiation of representations in the classroom. Bob's practice became more student-centred as students were more actively engaged in role-play activities, developed concept maps, performed hands-on experiments and constructed models. Students collaborated and shared ideas in small groups and individually also constructed knowledge on their own. The teacher had more time to identify individuals' student needs and misconceptions.

To identify teachers' and students' beliefs about effective chemistry teaching and learning after the intervention, and their responses to the new teaching and learning practices, a post lesson interview with the teacher and a focus group discussion with the students were conducted.

### Bob's beliefs about effective chemistry teaching and learning after intervention

To identify Bob's beliefs about effective chemistry teaching and learning, he was asked to respond to two questions "What do you believe are the most effective ways of students learning chemistry"? And "What can you recommend as the most effective way of teaching senior secondary chemistry"? ( Final Teacher Interview, 01/06/10). Bob believed that the multiple representations strategy actively engaged students in the learning process. He stated:

> Multiple representation [MR] teaching strategy is most effective because it involve students' active participation during learning process. I will recommend MR approach for teaching senior secondary chemistry (Interview with Bob, 01/06/10).

In the Final Teacher Questionnaire (FTQ) he was asked "What do you believe are the characteristics of effective senior secondary chemistry teaching"? and "What do you believe are the most effective ways of students learning chemistry"? He wrote:

> It involves effective students' participation during the lesson, demonstration of the concept to learn, introduction of multiple representations strategy and teacher's ability to explain the concept clearly. Students should be at the centre of the learning for active participation in the teaching activities (Bob's responses from FTQ, 18/05/10).

To further identify changes to his beliefs, knowledge and practice, Bob was asked "Do you think it is possible to make chemistry classrooms interesting for students"? and "As a result of your participation in the professional development workshop, explain what benefited you most in the program"? (Final Teacher Interview, 01/06/10). He responded that:

> Chemistry classroom can be made interesting for student through the use of multiple representations strategy among such as practical oriented teaching activity, role-play demonstration arousing student's interest and creating concept maps that challenge student's higher thinking towards meaningful learning. The workshop has opened my eyes to a new method of teaching chemistry which now make teaching of chemistry concepts easier for a student to understand and less stressful for teacher (Interview with Bob, 01/06/10).

| |
|---|
| Key findings 6.7<br>Following the intervention, Bob believed that demonstration, active student engagement with multiple representations and clear explanations are important characteristics of effective chemistry teaching. These approaches will motivate students to fully participate and learn the concept effectively. |

### Students' beliefs about effective teaching and learning of chemistry following the intervention

To identify students' beliefs about effective learning of chemistry, they were asked "What can you recommend as the most effective way of learning chemistry"? and "What will actually help you to learn chemistry"? The students explained that they needed to be actively engaged in activities through hands-on experiments, concept maps, flow charts, role-plays and particulate representations of the concept:

> To engaging us actively in activities through hands-on experiment, concept maps, flow chart, role play and particulate representation of the concept to learn. To learn chemistry is doing hands-on experiment and active engagement in the class activities (Students' focus group discussions, 01/06/10).

The students believed that they learnt effectively when they did experiments and were actively involved with class activities and representations:

> Performing hands-on experiment with active participation and engaging in the class activities (Students' focus group discussions, 01/06/10).

Key findings 6.8

Students believed that active participation in role-play activities, developing a concept map, flow chart and constructing a particulate representation of a concept during the lesson are important characteristics of effective chemistry learning. They also believed that their active involvement when performing experiments helped them to learn.

**Chapter Summary**

Data from the teachers' questionnaire, interviews with Bob, focus group discussions with students in Bob's class, and lesson observations were used to generate the key findings that emerged from the data. Data analyses identified the main challenges of teaching chemistry, Bob's beliefs about effective teaching and learning, and his practice before and after the professional learning workshops.

**Challenges**

Bob mentioned that a lack of laboratory facilities and equipment, inadequate instructional materials, students' poor attitudes to the subject arising from a poor science preparation in JSS, and lack of co-operation from the parents in buying their children necessary textbooks were the main challenges to effective teaching and learning of chemistry (KF 6.1).

**Beliefs and Practice Prior to the Professional Learning Workshops**

Prior to the workshop, Bob believed that the demonstration method is the best way of teaching chemistry, however, Bob believed that the lack of resources and laboratory equipment limited the number of demonstrations he could perform (KF 6.2). Bob assessed his students' understanding of a chemistry concept through tests, oral questions and answers, group work or individual projects the students carried out.

Bob's classroom practice prior to the intervention was typically a conventional chalk and talk method, characterised by the teacher doing all the talking, demonstrating the experiments, drawing diagrams, writing notes on the board and that students played a role of passive recipients of information. Bob rarely engaged his students in constructing knowledge during a learning task as emphasised by the constructivists

(KF 6.3). The didactic method of teaching initially observed in Bob's classroom disengages students from the learning process.

### Changes to Beliefs and Practice Following the Workshops

Following the workshops, Bob believed that effective learning of chemistry involved active student participation during the lesson which places students at the centre of learning. Bob's responses to the final teacher questionnaire revealed: a more student-centred approach through the use of multiple representations (i.e. concept maps, models, flow charts, role-plays, graphs, hands-on experiments) in most lessons; students were divided into groups to discuss chemistry ideas among themselves; more time was given for classroom interaction among the students; students were actively engaged in the class activities to develop understanding of the concept that challenged their higher thinking; and, students were then challenged to re-represent their ideas based on the understanding and knowledge of the concept learnt (KF 6.6). Bob believed that the multiple representation teaching strategy and active student engagement during a learning task resulted in more effective chemistry teaching and learning (KF 6.7).

### Impacts on Students' Engagement in Learning

Prior to the intervention, Bob only engaged his students with copying notes and diagrams drawn on the board, answering oral questions during the lesson, sometimes carrying out project work and sometimes answering a test. Following the intervention it was found that students were more engaged in role-play activity; developed concept maps; performed hands-on experiments; constructed models, particulates and graphical representations of the chemical reaction and that the students felt supported and were willing to participate actively with the use of multiple representation strategy. Students perceived that learning chemistry concepts was easier, both to understand and to remember (KF 6.4 & 6.8).

The next chapter will discuss data analysed on the second of the three case study teachers. This includes discussion of the lesson observations, interviews and focus group discussions with students in the class of the teacher.

# CHAPTER 7: CASE STUDY 2

**Introduction**

This chapter presents the second of three case studies which provides a rich account of the context of chemistry teaching and how the teacher responded to the professional learning intervention. The case study was compiled from data gathered through interviews, professional learning activities, lesson observations and focus group discussions with students. This chapter reports contextual background to the case study, the nature of the usual classroom practice, challenges to effective teaching and learning, and lastly, impacts of the intervention on the teacher's practice and students' engagement with learning. The case study teacher in this chapter is referred to by the pseudonym Guy, and ST1, ST2 and ST3 are the focus group students.

**Teacher's Profile**

Guy is a male chemistry teacher in an urban senior secondary school located in a suburb of Lagos, Nigeria. Guy holds a Nigerian National Certificate of Education (NCE) and also graduated with a Bachelor's degree in science education with a major in chemistry (BSc. Ed, chemistry) and has been teaching for 13 years. He has been the only teacher of chemistry in the senior secondary school (SSS 1-3) for about 7 years. Guy's major responsibility is to teach chemistry at the senior secondary school, however, he was also assigned the responsibility of acting head of department for chemistry to ensure appropriate record keeping, consistent with Local Education District guidelines. He also manages laboratory facilities and equipment that are kept in the store. Guy has the most populated class of about 139 students in a single class offering chemistry at SSS 2 level and this makes it difficult for him to give attention to individual students.

**School Context**

Guy's school is co-educational and is located within the Badagry Local Education District. Guy's school was purposely chosen due to close proximity to the Researcher and more importantly, Guy's was very interested in attending the professional learning intervention workshops. People living within the community are predominantly civil servants and traders. Other inhabitants are fishermen and small scale, self-employed individuals. Women are mostly traders and have a positive disposition towards education.

The school has a chemistry laboratory that lacked facilities and equipment that could be used to demonstrate experiments. Guy's chemistry lessons and practical activities were taught and demonstrated in the classroom while students usually observe the demonstration. Power failures are common at Guy's school. There were not sufficient seats in the classroom for all students to sit. Four students sit at each bench with a long desk on which they can place writing materials. The classroom though is well ventilated but very noisy because of the crowding.

## Curriculum Context

Chemistry teaching in Guy's school is based on the core content of the National Chemistry Curriculum for Senior Secondary Schools (SSS 1-3) (Federal Ministry of Educaton (FME), 2007) which specifies the content to be covered each week across the three terms of the academic year. Guy makes used of the following documents in his teaching: a laboratory manual that contains lists of the student's activities for practical lessons; a record of students' continuous assessments; the teacher's weekly timetable; students' attendance register; teacher's diary; and, lesson notes. The total number of students in SSS 2 was 299. Of the 299 students is SSS 2, 139 chose to study chemistry. These 96 male and 43 female students formed one class for chemistry lessons due to the lack of classrooms.

### Research Data Collected Prior to the Intervention

Before the professional learning intervention, teachers completed a questionnaire and the Researcher made classroom observations and interviewed the teacher. The Researcher also conducted a focus group interview with students from the chemistry class. The data collected prior to the intervention are presented below, which describe the challenges of teaching and learning chemistry, beliefs about effective chemistry teaching and learning, Guy's classroom practice, and, students' engagement with learning.

## Teaching and learning challenges

Guy's main difficulties with teaching chemistry were handling practical classes as a single teacher with a very large class; poor laboratory structure and facilities; lack of teacher-student communication; and, students' poor foundation in science from JSS (Initial Teacher Interview, 9/3/10). The laboratory facilities are very poor and materials to demonstrate experiments are not sufficient. There are neither laboratory technologists nor attendants to provide assistance during practical classes. No megaphone is provided to ease the teacher's voice. The teacher finds it difficult to move round the class to assess individual student's work. Guy also mentioned the difficulty of assessing students' understanding of concepts due to the limited interactions with students. Among other problems mentioned is the students' poor foundation of science experience at junior secondary school level. At JSS level, students have a limited science preparation due to teachers' level of qualification or background. Explaining the main difficulties Guy has with teaching Senior Secondary School (SSS) chemistry, he stated:

> Introduction of practical as a single teacher because no laboratory personnel to demonstrate practicals; class population is large to teacher ratio (1:139 teacher-students ratio) and no megaphone provided. No functioning laboratory structure and facilities, lack of teacher-students communication where students nodding their heads when being asked whether they understand the topic taught or not, and student poor foundation of science experience at JSS level when taught integrated science subject (Interview with Guy, 9/3/10).

> Key findings 7.1
>
> Guy's main difficulties to effective teaching and learning of chemistry are poor laboratory facilities; large class size; poor teacher-student communication; and, students' poor foundation of science experience from junior school level.

**Teacher's beliefs about effective chemistry teaching, learning and assessment**

Guy believed that demonstration is the most effective method to explain chemistry concepts, however, in most lessons, he uses a diagram, chart or model for illustration (Initial Teacher Interview, 9/3/10). Guy used a ready-made diagram, chart or model to allow students enough time for copying notes while explaining the lesson rather than spending time drawing diagrams during the lesson for student to copy.

When asked about usual learning activities the students do in his chemistry lessons, Guy explained that "Asking questions from students on the concept to identify their conceptual understanding and students copying notes" (Interview with Guy, 9/3/10) Guy believed that the most important things to consider when planning lessons were to get students ready and maintain orderliness in the classroom, which normally takes time because of the class population. He would start with an introduction emphasising the key features of the concept to learn (Interview with Guy, 9/3/10). He assessed his students understanding through oral and written class tests with homework assignments. He also believed that students individual project or group work reveals a great deal about what they know and what they don't know of a concept (Initial

Teacher Interview, 9/3/10). Guy also engaged his students through oral questions and answers and work activities at the end of his lesson to evaluate students' understanding of the concepts taught

Key findings 7.2
Guy believed that effective teaching and learning of chemistry is demonstration method with the use of ready-made charts, diagrams and models for illustration. Asking questions and writing notes on the board for students to copy are the learning activities students usually do in his chemistry lessons. Guy believed that students' knowledge and understanding are assessed through oral questioning and written evidence from individuals' work. Settling students and introducing key features of the concept to be learned were important aspects of Guy's lesson planning.

**Classroom Practice**

Five of Guy's lessons were observed commencing on the 9th March, 2010. Guy usually has two single and a double chemistry lessons in a week. Prior to the intervention, a single and a double period were observed to identify Guy's current practice. Classroom observations were also made after the first professional learning workshop. These observations focussed on impacts of the learning intervention on Guy's practice. There were also further observations after the second workshop.

## Teaching style

Before the first workshop, Guy stated that his teaching was focussing on the science content of the lesson and he would write notes on the board for students to copy down in their notebooks. Guy's reason for using this mode of teaching was to cover the scheme of work on time. He explained that he introduced his lessons with questions to identify students' prior knowledge on the target concept and then gave explanations while writing notes on the board concurrently (Initial Teacher Interview, 9/3/10).

In addition, data about Guy's teaching methods were collected through classroom observation and the next section reports activities observed during an 80 minute double lesson.

## Lesson observations

The topic of the lesson was chemical equilibrium. Guy's lesson was highly teacher-centred as the teacher dominated the classroom talk. Out of 80 minutes of the lesson, 70 minutes were used for teacher explanation and copying notes and teacher-student interaction occupied for only 10 minutes. Guy started the lesson with a review of the previous topic using a question and answer technique in order to assess the students' understanding.

Following the introduction, he provided definitions of equilibrium that it is a state of a system where there is no observable change in the properties of the system with respect to time. He illustrated the definition with two examples: a balanced see-saw (as an example of static equilibrium) and a saturated sodium chloride solution (as an example of dynamic equilibrium since the salt particles are dissolving and crystallising at the same rate i.e. constant motion in the system). Thereafter, Guy provided a symbolic representation of two opposing processes, dissolution and crystallisation of sodium chloride. However, the chemical symbolic forms of representation were not made clear for students. Furthermore, the re-arrangement of particles in the reaction were not made real and accessible for students. Guy also provided a diagram on the board that illustrated a volatile liquid in an air tight container as an example of a system that can exist in a state of dynamic equilibrium. He then continued by telling the students that equilibrium in reversible reactions is easily identified by the sign $\rightleftarrows$ written between the reactants and products. Guy dominated the teaching activities and provided no room for students to respond to the presented content (see (Figures 7.1a & b).

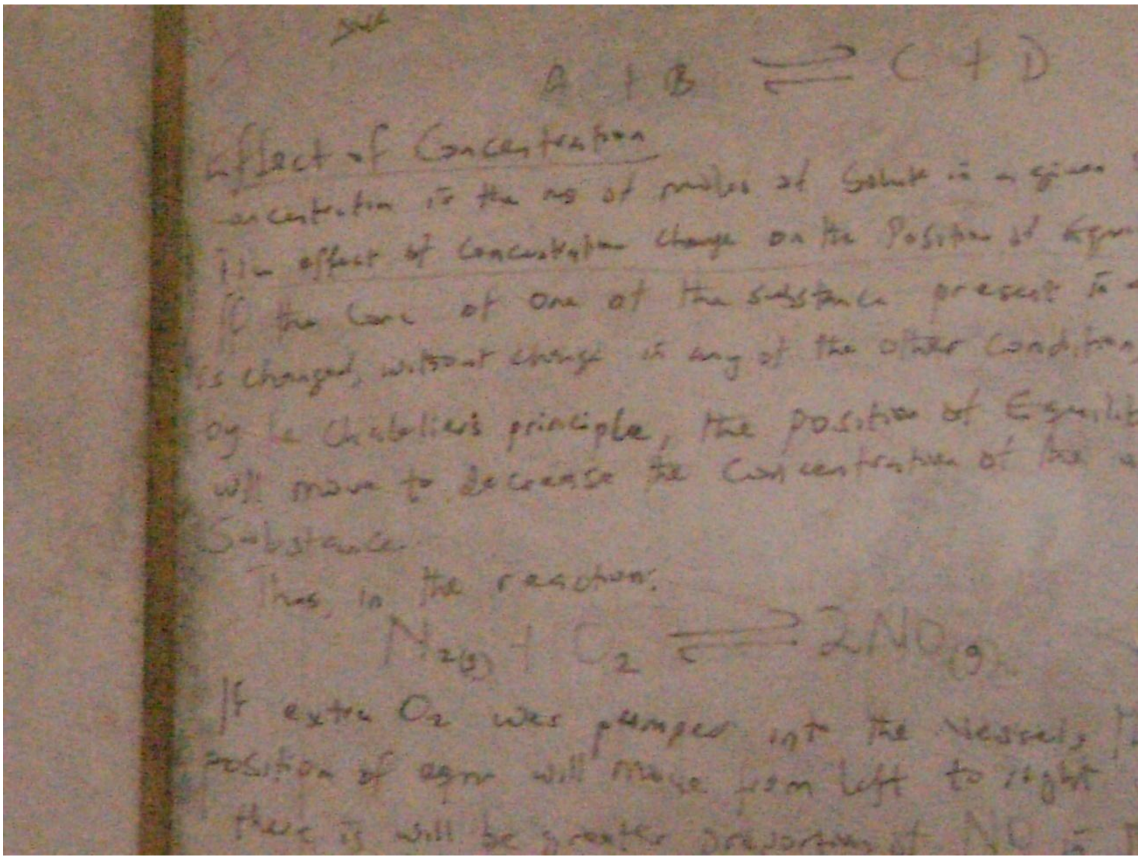



Figure 7.1a: Guy’s whiteboard notes

The students were busy copying notes written on the board by the teacher. The teacher played an active role of explaining and writing notes on the whiteboard throughout the lesson, while students mainly played a passive role of copying the notes.

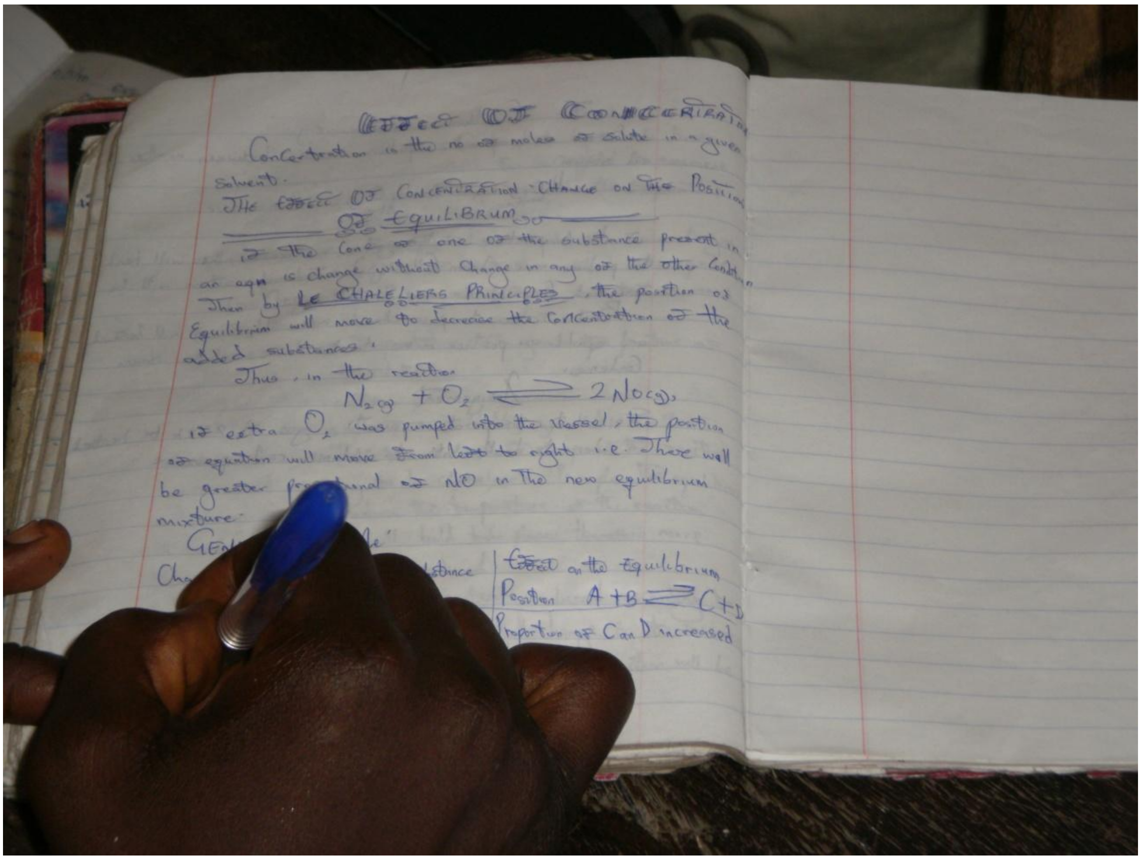



**Figure 7.1b: Notes written by a student in Guy's lesson**

Table 7.1 summarises Guy's pre-intervention classroom teaching practice as observed in this double lesson.

Table 7.1: Pre-intervention lesson observation for Guy

| | |
|---|---|
| Lesson topic: Chemical Equilibrium<br>Date: 09/03/10<br>Lesson duration: 80 minutes/double period | |
| Teaching and learning strategies | Time |
| Teacher talking and writing on the board while students are copying notes | 70 mins |
| Teacher and students interacting (Q & A) during lesson | 10 mins |
| Students in small group discussing during lesson | 0 mins |
| Teacher challenging and engaging students in class activities constructing representations (e.g. concept maps, role-plays, games, models, flow-charts, graphs) | 0 mins |
| Students copying an assignment written on the board by the teacher | 0 mins |

In the lesson observed, the teacher spent 88% of the lesson talking and writing notes on the board while only 12% was used for classroom interaction when students asked some questions. Students were given no time to engage in class activities to develop their understanding of the concept.

> Key findings 7.3
> Guy's teaching style was largely based on chalk and talk, he was observed talking and writing on the board while students copied notes. No room was provided for students to interact with each other or to be active participants in the lessons.

Subsequently, a focus group was conducted with three students from the class to elicit information about the students' understanding of the concepts taught and learning of chemistry as a subject.

**Students' Perceptions About Learning Chemistry**

Students were asked two open questions, which were "What is it like learning chemistry?" and "What does the learning of chemistry mean to the environment, other subjects and individual life? Given example(s) of things around you that you do at home that shows you are learning chemistry". In response, they stated that chemistry interrelates with all other subjects. It was mentioned that through learning chemistry, good health and safety are promoted. They further stated that learning chemistry provides useful knowledge about things that happen in day-to-day activities. It was also mentioned that knowledge of chemistry is needed for the production of agricultural products and refining of hydrocarbons.

> ST1: Chemistry helps individual to be careful in order to prevent accidents and different reactions occurring. It also helps to promote good health; chemistry helps in the area of agriculture to provide certain chemicals like germicides, insecticides, fertilizers etc which aids the production of agricultural products.
>
> ST2: It is a practical oriented subject because it helps us to observe things in our day-to-day activities. For example, human activities sometimes destroy the ozone layer which allows radioactivity from the Sun to penetrate into the earth. Chemistry is a qualitative science that helps us to know the actual thing used to give an actual answer or production as a standard condition. Knowledge of Chemistry helps in the refinery of hydrocarbons which we use its products for kerosene, fuel, road construction and medicine.
>
> ST3: Chemistry helps us to develop our education career and to know what is happening around us and some of the effects of materials in our areas. Chemistry is an inter-related subject which combines all subjects we are studying. An advantage of chemistry in agriculture is that chemical is used in producing more fertilizers that helps in the production of more crops. Some negative effects are petrochemical industries that cause more drainage to the environment which uses crude oil to make some

> substances. Some of these waste products are been discharge into the environment (oil spillage) and when this erode through the soil into any water bodies to eat up the oxygen in the water, it destroys the aquatic habitats- they become inconvenient. Bush burning is corrosive to the environment because it emits some poisonous gases into the environment (CO) which attacks haemoglobin in the blood (Students' focus group discussions in Guy's class, 9/3/10).

ST1 revealed that his teacher's method of teaching and encouraging words had motivated him to learn chemistry. ST2 explained that personal research and project work completed after school had helped him learn chemistry. ST3 added that relating what is been taught in the classroom to things happening in the environment assists understanding more and motivates him to learn chemistry.

> ST1: My teacher method of teaching and his encouraging words.
>
> ST2: Personal research and project work
>
> ST3: Observing things happening in my environment and relating it to what has been taught in the classroom (Students' focus group discussions in Guy's class, 9/3/10).

When asked to explain the concepts taught in the observed lesson, the students were not confident enough in their ability to share what they had learned. ST1 provided definition of chemical equilibrium but lacked confidence to discuss further any of the key features of the concept taught while ST2 named factors affecting the rate of chemical equilibrium but could not explain those factors he mentioned. ST3 on the other hand, was able to mention the factors but missed out the important key feature of the concept that was stressed by the teachers during the lesson. The students were asked "Did your teacher teach differently today?"

> ST 1, 2 & 3: No, our teacher has been teaching just the way he taught today due to class population and no good laboratory (Students' focus group discussions in Guy's class, 9/3 10).

The students confirmed that the lesson observed was typical of Bob's normal practice and was therefore a fair representation of his teaching prior to the intervention.

To identify students' opinions about the benefits of learning using representations, the students were asked: "Do you think the use of models, charts, and pictures can help you to learn chemistry better?" The students' responded generally that chemistry becomes easy to understand and remember while memory is retained when representations visuals and models are used.

> It can really help us to learn because it retains what we've learnt and makes it permanent (Students' focus group discussions in Guy's class, 9/3 10).

The students were also asked: "What would you like your chemistry teacher to do differently"? The students believed learning in a well and equipped chemistry laboratory, teacher having a comprehensive knowledge of the concepts and doing hands-on activities.

> ST 1 Asking government to construct good laboratory and provide enough laboratory facilities
>
> ST2: Teacher giving us more details by researching more on the concepts to be learnt- so as to broaden our knowledge
>
> ST3: Involvement in practicals (Students' focus group discussions in Guy's class, 9/3 10).

| Key findings 7.4<br>Students believed that knowledge of chemistry contributes to avoiding pollution in the environment, promotes healthy living and is important for agriculture and industry. They stated that the teacher's explanation and encouragement helped them to learn chemistry. Also that the use of visual aids and models would make learning easier and hands-on experiments would make the chemistry real and accessible. |
|---|

**Guy's Participation in the First Workshop**

Guy was in a group of three during the Workshop 1. Although, he was not appointed as the group representative, he contributed significantly during small and whole group discussions. The significant ideas contributed by his group on the challenges of teaching chemistry and engaging students in learning are summarised in Table 7.2 together with suggested solutions to the challenges:

Table 7.2: Solution to the challenges of teaching and engaging students in learning proposed by Guy's group

| Challenges of teaching and engaging students in learning | Recommended solutions |
|---|---|
| Large class size | Collaborative learning in small group discussion |
| Inadequate laboratory equipment and personnel | Improvisation and also the recruitment of laboratory technologist and attendant |
| Lack of instructional materials | Produce charts, pictures and models |
| Students' poor study habits and lack of interest in chemistry | Use of mnemonics, drama and story-telling, play-away method and relating concept to students' daily life experiences.<br>Microteaching approach |

| | |
|---|---|
| Time constraints for chemistry periods to cover scheme of work | After school hour lessons |
| Students' poor experience of science at junior school level | Building a strong foundation at JSS level |
| Irregular training workshop and seminar for teachers | Regular training of teachers through seminars, workshops and conferences. |

When Guy was asked which of the workshop activities were most challenging, he responded that the particulate, role-play, and 3D physical model representations engage his higher thinking because it involved hands and minds. The multiple representations strategies were also challenging in accessing the required resources. For example, teachers could make use of coloured chalk to draw circles to representing atoms, students can also conduct the role-play activity and construct models of a molecule using local materials such as the ones used at the workshop for the ball and sticks model.

> Representing molecules using particles which I can easily make use of colour chalk, constructing models with local materials such as displayed in this Workshop and the role-play activity are the most challenging and interesting because there is no need to struggle before getting the materials. It does not cost anything but only requires students' initiative and higher thinking to demonstrate their understanding about the concept and reduce the burden of talking. (Guy's response during Workshop 1, 29/04/10).

**Teaching and Learning Following Workshop 1**

Guy was observed teaching another 80 minute double lesson after the first workshop to identify any impacts of the professional learning program on his practice and his students' engagement. After the lesson observation, Guy was interviewed and a focus group discussion was again conducted with students from his class.

## Lesson observations

This time, Guy's lesson focussed on reaction rates and collision theory. Classroom strategies included the teacher discussing with the whole class and students working individually. The lesson observed after attending the workshop was more student-centred and included the use of multiple representation strategies which actively engaged the students throughout the lesson. Guy used a number of representational modes to develop an understanding of the reaction between hydrogen and oxygen molecules and also the thermal decomposition of hydrogen peroxide.

The teacher and students generated symbolic and particulate representations of the reaction between hydrogen and oxygen molecules to produce liquid water. The students were then asked to draw symbolic, particulate and graphical representations of the thermal decomposition of hydrogen peroxide in their note books (see Figure 7.2a). The role-play of the reaction was conducted within the limited spaces at the front of the class by the students demonstrating effect of collision geometry in the reaction and also, what happens when bonds were broken in the reaction. The decomposition of hydrogen peroxide was demonstrated in order to observe the speed of the reaction when catalysed and uncatalysed. Selected students participated by measuring the volume of the reagents during the demonstration. Students were involved in measuring the volume of $H_2O_2$ and powdered $MnO_2$ used as catalyst into a cylinder and also handled the stopwatch for timing how long it took the foam to rise to the top of the cylinder. Students also assisted in placing a glowing splint into the gas produced confirming that it was oxygen.

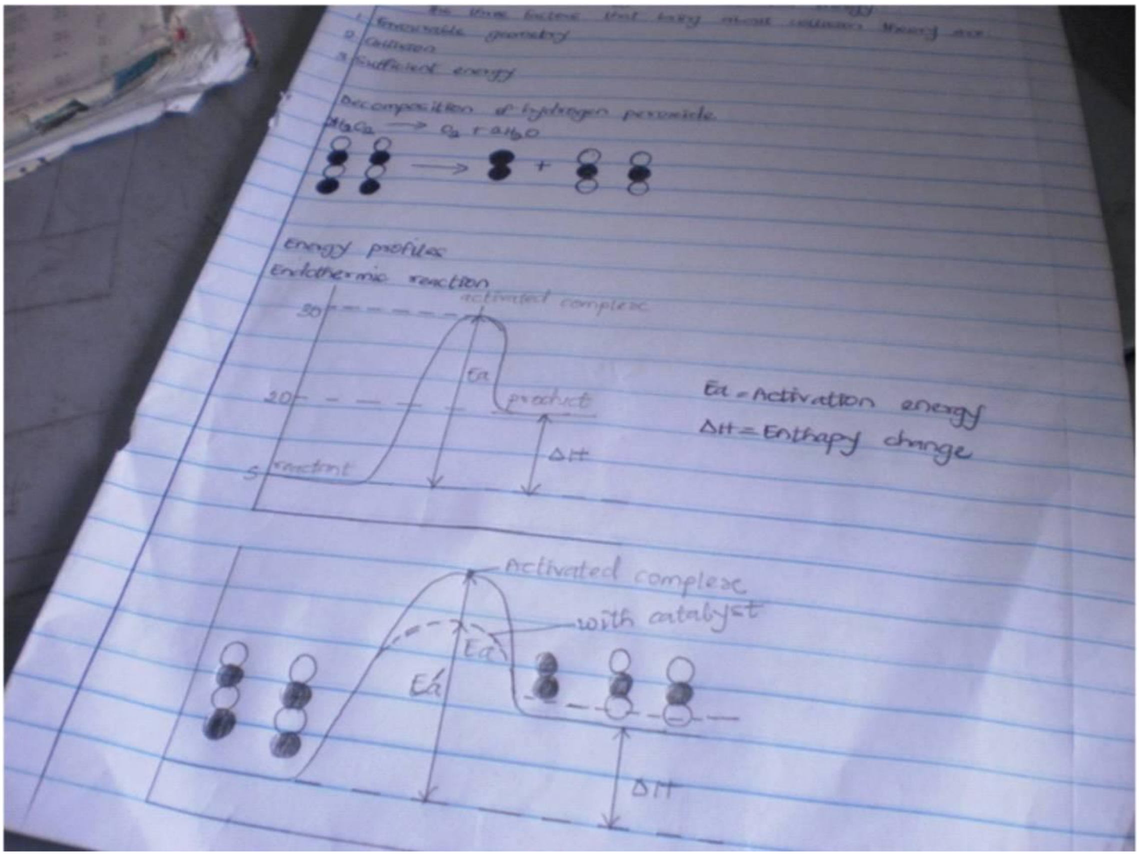



**Figure 7.2a: Symbolic, particulate and graphical representation of thermal decomposition of hydrogen peroxide constructed by a student**

About 70 minutes of the lesson involved the teacher and students conducting the demonstration and generating and negotiating representations using symbolic, particulate, graphical and role-play representations. The demonstration of the reaction when a catalyst was added to the reaction captured the students’ interest seeing the rate of the reaction speed up (Figure 7.2b).

Figure 7.2b: Teacher and students demonstrating experiment on thermal decomposition of hydrogen peroxide

During the lesson, the teacher and students spend more time interacted on the concept and individual students responded to challenges of constructing representations. Students were actively engaged and interacted with learning materials while constructing meaning during the lesson. The lesson seemed to be interesting and students were lively, seeing the activities as fun. The students constructed representations helped the teacher to easily assess their understandings. Table 7.3 summarises Guy's post Workshop 2 lesson strategies.

Table 7.3: Guy's teaching strategies after the first workshop

Lesson topic: Reaction rate and collision theory

Date: 05/05/10

Lesson duration: 80 minutes/double period

| Teaching and learning strategies | Time |
|---|---|
| Teacher talking and writing a summary on the board while students write notes | 0 mins |
| Teacher and students interacting as a whole class during the lesson | 5 mins |
| Students in small group discussion during the lesson | 0 mins |
| Teacher challenging and engaging students in class activities constructing representations (e.g. symbolic, particulate, graphical, role-plays and hands-on experiment) | 70 mins |
| Students copying an assignment | 5 mins |

Eighty-eight per cent of the lesson was spent challenging and engaging students in class activities in which students' actively participated in the role-play activity, demonstrated experiment and constructed particulate and graphical representations of the molecules. This contrasted sharply with the lesson observed prior to the first workshop in which most of the lesson involved the teacher writing notes on the board for the students to copy.

**Guy's experiences of using multiple representations**

To elicit information about Guy's experience and challenges with using the new teaching technique and the extent to which students were actively engaged during the lesson, a post lesson interview was conducted. Guy believed that the students learn chemistry better when engaging actively in class activities. He mentioned that the demonstration of the thermal decomposition of hydrogen peroxide made the concept real as students could actually see and observe the gas being produced. He also mentioned as an example, though not used it during his lesson, the use of concept mapping to engage students' higher thinking during the lesson which helps students in identifying the key features of a concept to learn. Guy was asked "Can you explain the process used to actively engage your students' higher thinking during the lesson"? "During the processes, what challenges did you face"? Guy explained that:

> The use of concept maps to identify key features of the concept to learn (by the teacher) and also use of particulate representation to assess their understanding on the concept. The challenge is time constraint. Using a

> multiple representation (MR) teaching strategy is not difficult because it makes learning easier and removes abstract nature of the concept as it allows students to demonstrate their conceptual ability. A teacher is able to assess students' understanding during the learning period. (Interview with Guy, 5/5/10).

Guy was also asked "Were the students actively engaged and did they feel supported during the learning process"? and "What factors do you think motivated students to learn in the chemistry lesson"?

> There was enthusiasm in them to actively participate because the technique makes the concept real and practicable. Teacher's illustration of the concepts and active students' engagement during the learning process motivated them to learn effectively. (Interview with Guy, 5/5/10)

Guy was asked to explain the impact of the professional learning intervention on his teaching practice and his confidence for teaching chemistry. He stated:

> It has improved my teaching methodology and also makes teaching easy, less stressful and lively. My confidence to teach chemistry concepts has been greatly increased because MR has been an eye-opener to see various modes to use and transmit messages in the class to make lesson easier, challenging and independent. (Interview with Guy, 5/5/10).

> Key findings 7.5
>
> Guy was challenged by lesson time constraints when using the multiple representational strategies. Students actively participated in representational challenges and their motivation to learn the concept increased. Guy's confidence and pedagogical knowledge has increased in terms of using the multiple representations teaching strategy. This lesson was far more student-centred than the observed prior to the first workshop.

**Students' response to the multiple representation learning strategy**

To identify how students responded to the new strategies of constructing and interpreting multiple representations of a chemistry concept, a focus group discussion was conducted with some of Guy's students. When students were asked to explain what they enjoyed most in the lesson, they responded:

> Our teacher's explanation that involved us to construct the particulate representation of the concept and also acted the role-play activity during the lesson because the representation made the concept real and understandable (Students' focus group discussions, 5/5/10).

The students explained that their active involvement in the lesson was quite different to their usual passive role (Students' focus group discussions, 5/5/10).

To elicit information on students' beliefs about teaching and learning of chemistry, they were asked "What do you believe are the most effective ways to learn Chemistry"?

> ST 1: Participating in experiment during practical class.
>
> ST 2: Hands-on activities in every lesson.
>
> ST 3: Going for an excursion to industries to see how chemicals are produced and having practicals regularly (Students' focus group discussions, 7/5/10).

The students were asked to respond to the question "What would you like your teacher to continue doing to facilitate learning of Chemistry"? They stated:

> ST 1: Involving us more in hands-on activities
>
> ST 2: Actively engaging in class activities with particulate, role-play and hands-on experiment during the lesson
>
> ST 3: Government should extend their efforts to provide good laboratory and our teachers taking us out to industries where all the chemicals are been produced (Students' focus group discussions, 5/5/10).

### The Professional Learning Workshop 2

Activities in Workshop 2 elicited information on the teachers' experiences and challenges with the use of the multiple representation strategy and the extent to which students were actively engaged in lessons. The Workshop also developed new representations that could be used to teach the next topic.

## Guy's level of participation in the second workshop

Guy reported success in engaging students with learning through interpreting multiple representations of the same concept. This he stated that using different approaches, illustrations and demonstrations, generated excitement amongst students during the learning process. On his teaching methodology, the technique has reduced the stress of explaining and note copying. Hence his confidence to the teaching of chemistry concepts has greatly increased.

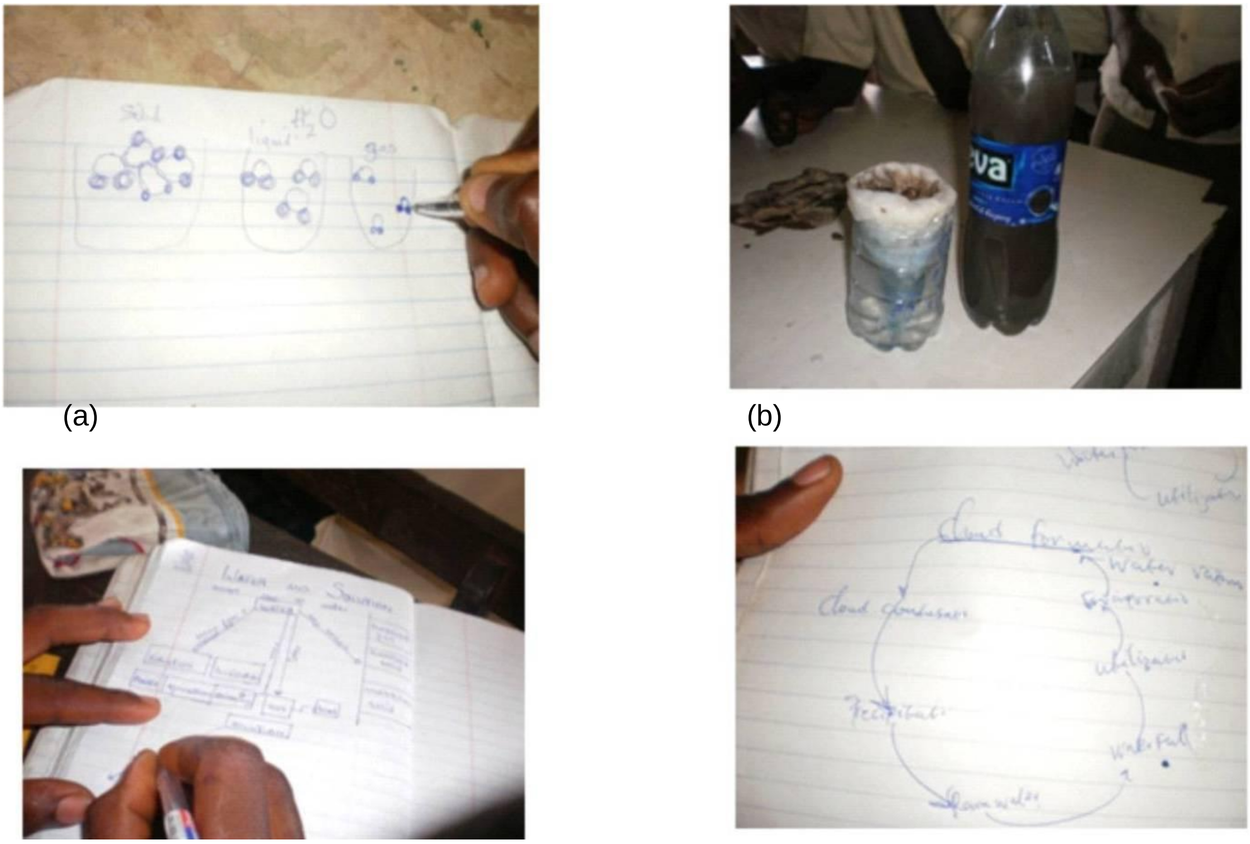
Guy mentioned time constraint and access to material for illustration (e.g. insufficient chemicals) for students to perform hands-on experiments individually though not a major problem because the students worked in groups. The time required for the teacher to prepare the lesson was thought to be another challenge. Guy stated that the highlighted problems would be improved by giving an assignment on a topic to be taught prior to the lesson so students had prior knowledge about the concept.

Reducing note copying on the board but set more time to the use of multiple representations strategy that actively engage student's high thinking.

In Workshop 2, the teachers constructed a water filter model to illustrate how a water treatment plant works. Guy and the members in his group took up the challenge of constructing a water filter and they were the first group to get a clean water sample. This challenged other groups to prove that it is possible to produce clean water from the muddy water. The teachers also participated in a role-play to improve the teachers' understanding of the water cycle concept.

**Teaching and Learning Following Workshop 2**

Following the second workshop, an 80 minute double period lesson that focussed on water and solutions was observed. Classroom settings included whole class, small group and individual student work. The observations were recorded on the observation template. The lesson was student-centred as students were actively engaged in various activities and representational modes to develop an understanding of the concept. The students developed a concept map about water and solutions, acted out a role-play of the water cycle, and drew particulate representations of the three states of water (Figure 7.3). The students were also given an opportunity to engage in the water filter challenge. With difficulty, Guy moved from one group to another because of the overcrowding and the seating arrangement, to assess students' understanding. Table 7.4 presented below summarises the observed lesson.



(a) (b)

(c) (d)

**Figure 7.3: Classroom activities during Guy's lesson:**

(a) Student constructing particulate representation of three states of water
(b) Student conducting water filter challenge
(c) Student developing concept map of water and solution
(d) Student constructing flow chart of water cycle

Table 7.4: Teaching strategies used by Guy in a double lesson after the second workshop

Lesson topic: Water solution

Date: 01/06/10

Lesson duration: 80 minutes/double period

| Teaching and learning strategies | Time |
|---|---|
| Teacher talking and writing notes on the board while students are copying the notes | 5 mins |
| Teacher and students interacting as a whole class during the lesson | 5 mins |
| Students in small group discussion during lesson | 20 mins |

| | |
|---|---|
| Teacher challenging and engaging students in class activities constructing representations (e.g. concept maps, particulate, role-plays, flow-charts and the water filter) | 50 mins |
| Students copying an assignment | 0 mins |

After the second workshop, Guy spent about 63% of the lesson challenging and engaging students in the class activities that included role-play, drawings of particulate, models and the water filter challenge, and also developed concept maps. In about 25% of the lesson, students worked in groups, discussing knowledge and ideas together.

Key findings 7.6
Following the intervention, teaching and learning activities were provided that required students to generate and negotiate multiple representations in the classroom. Guy's practice was more student-centred as students were actively engaged in role-play, concept mapping, performed hands-on experiments, constructed particulate and flow chart diagrams. Students collaborated and shared ideas in groups and the teachers were able to identify students' misconceptions from their representations.

To identify teachers' and students' post intervention beliefs about effective chemistry teaching and learning, an interview was conducted with the teacher and a focus group discussion was held with the students.

### Teacher beliefs about effective chemistry teaching and learning after the intervention

To identify Guy's post intervention beliefs about effective chemistry teaching and learning, he was asked to respond to two questions "What do you believe are the most effective ways for students to learn chemistry"? and "What can you recommend as the most effective way of teaching senior secondary chemistry"? (Final teacher interview, 01/06/10). Guy believed in the use of the multiple representations strategy, which promoted active student engagement during the learning process. He stated:

> Multiple representation teaching strategy is the most effective and encouraging small group discussion that allows students to sharing ideas in the classroom. The most effective learning chemistry is the particulate representation strategy because it reveals students' conceptual understanding of a concept. Consequently, engaging students' in hands on activities during learning process. (Interview with Guy, 01/06/10).

On the Final Teacher Questionnaire (FTQ) he was asked "What do you believe are the characteristics of effective senior secondary chemistry"? and "What do you believe are the most effective ways for students to learn chemistry"? (Final Teacher Questionnaire 1 & 2) He wrote:

> Use multiple representations strategies. Most importantly, particulate representation and students involving in role-play activities. This fully engages students' higher thinking as this involves use of hands and brain. (Guy's response from FTQ, 18/05/10)

To further identify changes to the teacher's beliefs, knowledge and practice, Guy was asked two questions "Do you think it is possible to make chemistry classrooms interesting for students"? and "As a result of your participation in the professional development workshop, explain what benefited you most in the program"? (Final Teacher Interview 01/06/10). He responded that:

> Use particles to represent the molecules and create structure through its representation on the magic board. Chemistry classroom can be made interesting for student by active students' engagement during the lesson (Interview with Guy, 01/06/10).

A magic board as explained by Guy could also be referred to as a flannel pin-up board or sign board used to display information. Cardboard of different colours representing various atoms in a reaction or a molecule could be cut to round shapes and pinned on the flannel board, then re-arranged to demonstrate the chemical change

| |
|---|
| Key findings 7.7<br><br>Following the intervention, Guy believed that the multiple representation strategy actively engages students during the lesson and this was an important characteristic of effective chemistry teaching and learning. |

### Students' beliefs about effective teaching and learning of chemistry following the intervention

To identify students' beliefs about effective learning of chemistry, they were asked "What can you recommend as the most effective way of learning chemistry"? and "What will actually help you to learn chemistry"? The students responded that:

> ST 1: Use of concept map is the most effective way to learn chemistry because it's ascribed to the summary of the concept to learn and allows effective learning.
>
> ST 2: Role-play and models.
>
> ST 3: Particulate representation.
> (Students' focus group discussions, 01/06/10).

| Key findings 7.8 |
|---|
| Students believed that role-play activities, developing concept maps, constructing models and particulate representations are the characteristics of effective chemistry learning. |

**Chapter Summary**

Data from the teachers' questionnaire, interviews with Guy, focus group discussions with students, and, lesson observations were used to generate the key findings that emerged from the data. Data analyses identified the main challenges of teaching chemistry, Guy's beliefs about effective teaching and learning, and his practice before and after the professional learning workshops.

### Challenges

Guy mentioned that poor laboratory facilities, large class sizes, poor teacher-student communication and students' poor foundation of science experiences at the JSS level were the main challenges to effective teaching and learning of chemistry (KF 7.1).

### Beliefs and Practice Prior to the Professional Learning Workshops

Prior to the intervention, Guy believed that effective teaching and learning of chemistry is demonstration method with the use of ready-made charts, diagrams and models for illustration. Asking questions and writing notes on the board for students to copy are the learning activities students usually do in his chemistry lessons. Guy believed that students' knowledge and understanding are assessed through oral questioning and written evidence from individuals' work. Settling students and introducing key features of the concept to be learned were important aspects of Guy's lesson planning (KF 7.2).

Guy's classroom practice as observed prior to the intervention was typically a conventional chalk and talk method characterised by the teacher doing all the talking while writing on the board with the students passively copying notes (KF 7.3). This method of teaching observed provided no room for students to discuss, ask questions or be active participants in the learning process.

### Changes to Beliefs and Practice Following the Workshops

Following the workshops Guy believed that effective learning of chemistry involved active student engagement during the lesson, which placed students at the centre of the learning experiences. He used role-play activities, concept mapping, hands-on experiments and students constructing particulate and flow chart representations. Students collaborated and shared ideas in group and worked on individual tasks (KF 7.6). After the Workshops, Guy believed that the multiple representation teaching strategy and active students' engagement during a learning task resulted in the most effective approach to chemistry teaching and learning (KF 7.7).

### Impacts on Students' Engagement in Learning

Prior to the intervention, Guy only required his students to copy notes, copy diagrams drawn on the board, answer oral questions during the lesson, carry out project work and sometimes complete written class tests. The students were not required to produce representations of concepts themselves. Learning chemistry was mostly done by memorisation of content presented by the teacher. Following the intervention, the students were more engaged in the role-play activity, developed concept maps, performed hands-on experiments, drew models and also particulate and graphical representations of the chemical reactions (KF 7.4 & 7.7).

The next chapter reports the third of the three case studies. This includes lesson observation, interviews and a student focus group discussion data.

# CHAPTER 8: CASE STUDY 3

## Introduction

This chapter presents the third of the three case studies which provides a rich account of the context of chemistry teaching and how the teacher responded to the professional learning intervention that challenged her to be engaged with ideas that could be used to improve her teaching of chemistry. The case study was compiled from data gathered through interviews, professional learning activities, lesson observations and focus group discussions with students. The case study teacher in this chapter is referred to by the pseudonym Sally, and ST1, ST2 ST3 are the focus group students.

## Teacher's Profile

Sally is a female chemistry teacher in an urban senior secondary school located in a suburb close to the Local Education District's Office. Sally has a Nigerian National Certificate of Education (NCE) and also graduated with a bachelor degree in science education with a major in chemistry (BSc.Ed, chemistry) and has been in the teaching profession for 19 years. Sally was transferred to her present school three years ago and she is the only teacher of chemistry in the SSS 1 – 3. She has been teaching chemistry in the SSS for about 17 years. Sally teaches mathematics as an additional subject in her present school and is also, responsible for taking students out for a quiz competition.

## School Context

Sally's school is co-educational and is located centrally close to the Local Education District's office. Sally's school was purposely chosen due to close proximity to the Researcher and more importantly, Sally's was very interested in attending the professional learning workshops. Many people living within the community are civil servants, retired soldiers; small scale, self-employed individuals and women which, are mostly traders and have a positive disposition towards education. Sally's goal is to teach chemistry effectively and adequately prepare her students for excellent performances in the West African Examination Council (WAEC) and for life challenges.

The school lacked a chemistry laboratory and has limited laboratory facilities and equipment is kept in a corner of the staff common room which, is not secured. Sally's chemistry lessons and practical activities are taught and demonstrated in the classroom while students usually observe the demonstrations. The apparatus are usually brought to the classroom to demonstrate experiments and then returned to the staff-room after use. There were insufficient seats in the classroom. Three to four students sit at each bench with a long desk on which they can place writing materials. Most of the students lack access to textbooks and the school lacked adequate instructional teaching materials.

### Curriculum Context

Chemistry teaching in Sally’s school is based on the core content of the National Chemistry Curriculum for Senior Secondary Schools (SSS 1-3) (Federal Ministry of Educaton (FME), 2007) which specifies the content to be covered each week across the three terms of the academic year. Sally makes use of the following documents in her teaching: teacher’s diary and lesson notes; a laboratory manual; stock book; students’ attendance register; record of students’ continuous assessments; and, teacher’s weekly timetable. There is an enrolment of 96 students in the SSS 2. The three streams of SSS 2 students were combined into two classes due to the lack of classrooms. Of the 96 students in SSS 2, 44 chose to study chemistry which formed one class for chemistry lessons and are comprised of 20 female and 24 male students.

### Research Data Collected Prior to the Intervention

Before the professional learning intervention, teachers completed a questionnaire and the Researcher made classroom observations and interviewed the teacher. The Researcher also conducted a focus group interview with students from the chemistry class. The data collected prior to the intervention are presented below describing the challenges of teaching and learning chemistry; beliefs about effective chemistry teaching, learning and students’ assessment; students’ learning and engagement; and, Sally’s classroom practice.

## Teaching and learning challenges

Sally’s main difficulties with teaching chemistry were lack of a laboratory and equipment for practical classes hence, the need to carry the laboratory equipment for observation from the staffroom to the classroom; and, students typically have a poor foundation in science from JSS (Initial Teacher Interview, 26/04/10). The high student population and limited seating prevents the teacher giving attention to individual students. When explaining the main difficulties Sally has with teaching SSS chemistry, she stated:

> Insufficient laboratory apparatus and students' poor background knowledge from JSS (Interview with Sally, 26/04/10).

| |
|---|
| Key findings 8.1<br>Sally's main difficulties with chemistry teaching and learning related to lack of a chemistry laboratory, limited equipment and students' poor foundation of science experience from junior school level. The classroom was also crowded. |

### Beliefs about effective chemistry teaching, learning and assessment

Sally believed that demonstrating experiments is the most effective method to explain chemistry concepts. She explained further that due to the nature of chemistry, as a subject that is central to everyday activity, she also relates concepts to students' life experiences and daily activities because it helps students understand and remember the concept:

> Chemistry is central to life and it is an everyday activity. It deals with matter, its component and properties. I make use of illustration i.e. relating the concept to things that goes on around them with demonstration. Making the laboratory apparatus available for demonstration is the most effective method (Interview with Sally, 26/04/10).

When asked about the usual learning activities the students do in her chemistry lessons, Sally explained:

> Copying notes and students responding to questions in the class (Interview with Sally, 26/04/10).

Sally believed that the most important things to consider when planning lessons to facilitate students learning was to focus on the stated behavioural objectives and to evaluated whether they have been achieved:

> Evaluating the stated behavioural objectives of the lesson (Interview with Sally, 26/04/10):

Sally used oral questions and answers and also explained that she usually asked students to solve problems on the board to provide evidence that students understand the concepts being taught (Interview with Sally, 26/04/10). Sally's response to the question "How do you find out what your students know about chemistry?" she stated:

> Students' responses to questions and also being able to solve problems on the board based on the concepts learnt (Interview with Sally, 26/04/10).

| |
|---|
| Key findings 8.2<br>Sally believed that effective teaching and learning of chemistry involves demonstration and relating concepts to students' daily life experiences. Focusing on the objectives of the lesson is the most important thing Sally considered when planning her lesson.  Sally believed that students' knowledge and understanding should be accessed through oral questions and answers in an interactive way. |

**Classroom Practice**

Five of Sally's lessons were observed commencing on the 26th April, 2010. Sally usually has a single and double chemistry lesson in a week. Prior to the intervention, a single and a double period were observed. Both the lessons observed before the intervention focused on Sally's current practice. Classroom observations were also made after the first professional learning workshop and again after the second workshop. Observations of Sally's teaching prior to the first workshop helped describe her teaching practice and a focus group discussion with three students provided information about their perceptions of chemistry teaching and learning

## Teaching style

Before the first workshop, Sally explained that her mode of teaching was interactive and involved teacher-students discussion. This technique as Sally mentioned was to identify students' misconceptions about the concept through sharing of ideas. Sally explained that she usually starts her lesson through review of the previous concept taught using oral questioning (Initial Teacher Interview, 26/04/10).

To develop an understanding of Sally's classroom practices and students' learning behaviour for a specific chemistry concept before the professional learning intervention, a lesson observational checklist was used to document teaching and learning activities observed during an 80 minute double lesson.

## Lesson observations

The topic of the lesson was standard solution. Sally's lesson was interactive with the teacher and students sharing ideas about the concept. Sally introduced the lesson by asking the students questions based on their previous knowledge about the concept of solution and then linked that to the new topic of standard solution. She defined a standard solution and its uses and further explained the procedure involve in the preparation of a standard base and an acid solution. She explained that the density of the acid is usually found written on the bottle and the molar mass can be calculated from its formula weight. Sally asked the students to calculate the molar mass of HCl, $HNO_3$, and $H_2SO_4$ on the board (See Fig 8.1). There was insufficient apparatus (test-tubes) for the individual students to carry out the practical preparation of a standard acid solution but she involved the students during the demonstration to operate weighing equipment and the students were also asked to dissolve the measured acid in water.


**Figure 8.1: Work sample on the blackboard by a student in Sally's lesson**

Out of 80 minutes of the lesson scheduled, 15 minutes were used for teacher-students interaction in asking and answering questions based on the lesson while 45 minutes were used to engage the students with activities during the lesson. Table 8.1 summarises Sally's pre-intervention classroom teaching practice as observed in this double lesson.

Table 8.1: Pre – intervention lesson observation for Sally

Lesson topic: Standard Solution

Date: 26/04/10

Lesson duration: 80 minutes/double period

| Teaching and learning strategies | Time |
|---|---|
| Teacher talking and writing on the board while students are jolting down a few notes | 20 mins |
| Teacher and students interacting on questions and answers (Q & A) during the lesson | 15mins |
| Students in small group discussion during lesson | 0 mins |
| Teacher challenging and engaging students in class activities constructing representations (e.g. doing an experiment, working calculations) | 45 mins |
| Students copying an assignment | 0 mins |

In the lesson observed, the teacher and students spent 25% of the lesson giving and writing notes while 20% was used for classroom interaction and 55% was devoted to students participating in a demonstrated experiment. She was far more student-centred in her teaching than Bob and Guy.

Key findings 8.3

Sally's teaching style was student-centred and interactive, which allowed students to participate during the lesson and to demonstrate their understanding on the concept.

A focus group was conducted with three students from the class to elicit information about the students' understanding of the concepts taught and their learning of chemistry.

**Students' perceptions about learning chemistry**

The students explained that chemistry constitutes knowledge of matter and its composition; and, the constituents of things in the environment. In essence, learning chemistry provides knowledge about things that happen around and help us understand the environment. For example, the students stated that knowledge of chemistry satisfies human's natural curiosity about the present world and the production of agricultural products, and that the refining of hydrocarbons is all based on a knowledge of chemistry. When asked "What is it like learning chemistry?" and "What does the learning of chemistry means to the environment, other subjects and to individual life? "Give example (s) of things around you that you do at home that shows you are learning chemistry" they stated:

> Learning Chemistry constitutes knowledge of matter with its composition and the constituents of things around us. Through the knowledge gained in chemistry as a subject, we understand activities in the environment and relate its happening to knowledge gained in the classroom. For example, experience of the scientific method facilitates the understanding both in everyday lives and in our studies of other subjects. For individual life, basis knowledge gained in chemistry that are used in the manufacture of artificial fertilizers for increasing supply of food, and synthesis of vitamins to keep us healthy are good examples of things motivating our learning of chemistry (Focus group meeting with students in Sally's class, 26/04/10).

The students were asked: "What actually has been helping you to learn chemistry?" (Initial student focus group, 26/04/10). They stated:

> ST 1: My teacher method of teaching and her encouraging words.
>
> ST 2: Reading chemistry textbooks,
>
> ST 3: Laying my hands on experiments improves my ability in Chemistry. (Focus group meeting with students in Sally's class, 26/04/10).

When asked to explain the concept taught in the observed lesson, the students remembered the steps for preparing a standard solution. They were able to explain a few things about what they had learned and that their active involvement during the lesson was helpful. When students were asked "Did your teacher teach differently today?" They all responded:

> No- but occasionally, if the concepts to be taught deals with practicals, she usually brings the materials/apparatus to the class to demonstrate the experiment (Focus group meeting with students in Sally's class, 26/04/10).

To identify students' opinions about the benefits of learning using representations, the students were asked: "Do you think the use of models, charts, and pictures can help you to learn chemistry better?" The students responded that chemistry becomes easy to understand, remember and memory of the concepts is retained when visual representations are used. They responded:

> Seeing is believing and it makes learning to be retained in our memory. It will also help us to remember the context of the concepts (Focus group meeting with students in Sally's class, 26/04/10).

The students were also asked: “What would you like your chemistry teacher to do differently”? The students believed in a well and equipped chemistry laboratory that provides access to chemicals. This will engage them in hands-on activities and improve on their problem solving skills.

> ST1: Enabling and having access to the chemicals in the laboratory to personally experiment on some of the concepts.
>
> ST2: Engaging us actively in the demonstration during the learning.
>
> ST3: Giving project works to develop my problem solving skill. (Focus group meeting with students in Sally’s class, 26/04/10).

Key findings 8.4
Students believed that learning chemistry provides good knowledge about the environment, agriculture and the manufacture of fertilizer, and vitamins. The students explained that doing experiments, reading the textbooks and doing project work had helped them to learn chemistry.

**Sally’s Participation in the First Workshop**

Sally was among a group of three that worked together during the first workshop. Although, she was not appointed as the group representative, she contributed significantly during small and whole group discussions. Table 5.4 summarises the significant ideas Sally’s group contributed to the discussion of challenges of teaching chemistry and possible solutions to the problems.

Table 8.2: Solutions to the challenges of teaching and engaging students in learning chemistry proposed by Sally’s group.

| Challenges of teaching and engaging students in learning | Recommended solutions |
|---|---|
| Large class size | Government raising funds to put up enough classrooms<br>Collaborative learning to share ideas |
| Inadequate laboratory equipment, instructional materials and personnel | Improvisation and recruitment of a laboratory technologist and attendant |
| Students’ poor study habits and lack of interests in chemistry | Practical/project work<br>Relating concept to students’ daily life |

| | |
|---|---|
| | experiences. |
| | Microteaching approach |
| Students’ poor science background from junior high school level | Teacher possessing good content knowledge of the subject matter |
| | Teaching based on course specialisation |
| | Building a strong foundation at JSS level |
| Irregular training workshop and seminar for teachers | Regular training of teachers through seminars, workshops and conferences. |

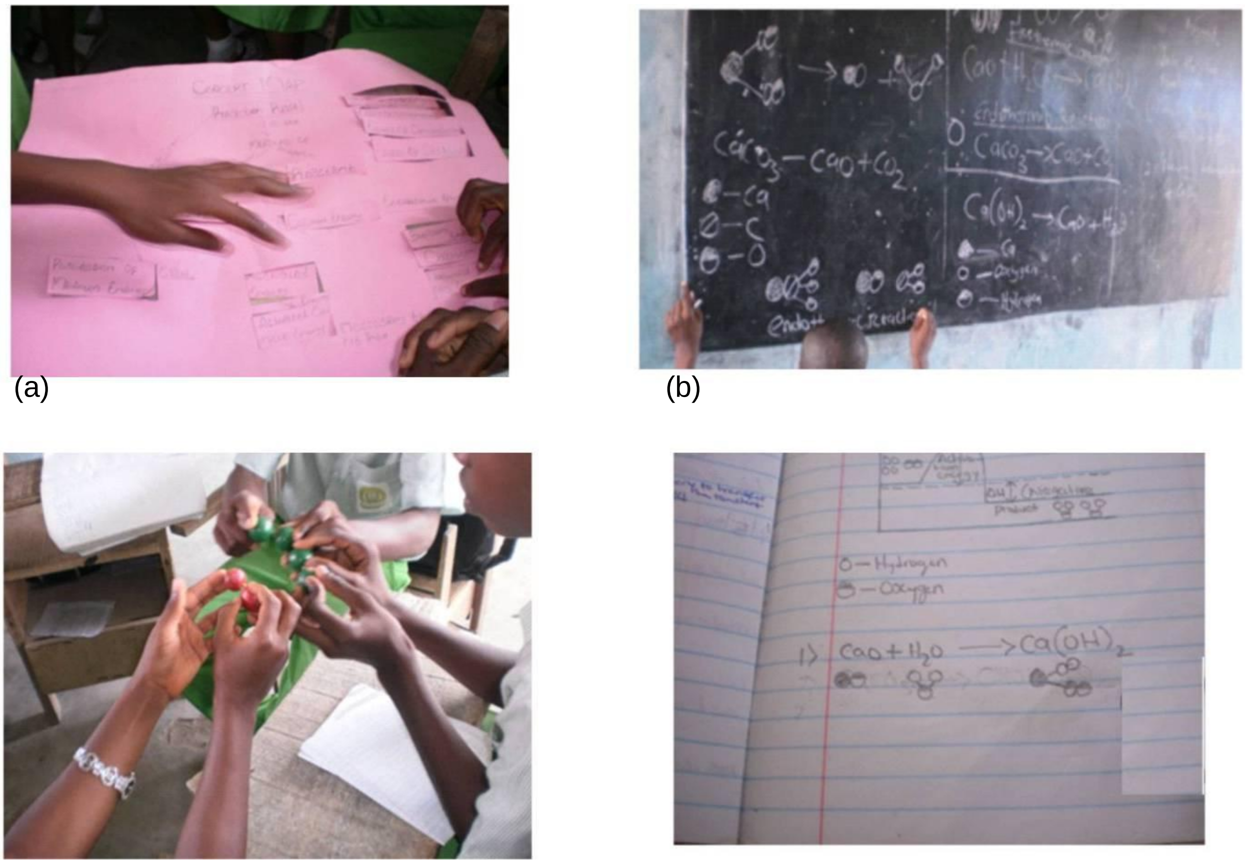
When asked about what interested her most during the workshop, she stated that the particulate, 3D physical model and role-play representations require less effort in preparing materials. She stated that the particulate and 3D model representations in particular engage students’ higher order thinking and could reveal what a student knew about the topic and would also engage students’ hands, and minds. Sally stated further that the role-play representation was the most interesting part of the representation strategy because it helped students learn by impacting on their memory. She explained students’ minds will always flash back to a memory how the play was acted and “who” represent “what”. Sally related various benefits in using the representation strategies. These were to reduce teacher stress of talking, students would be actively engaged with activities related to the concept, makes learning real and concrete. It would also become easier for the teacher to assess students’ understanding of the concept.

**Teaching and Learning Following Workshop 1**

Sally was observed teaching another 80 minute double lesson after the first workshop to identify any impacts of the professional learning program on her practice and her students’ engagement. After the lesson observation, Sally was interviewed and a focus group discussion was again conducted with students from her class. This time, Sally’s lesson focussed on reaction rates and collision theory.

## Lesson observations

After attending the workshop, Sally’s lesson was more student-centred and she used the multiple representations strategies which actively engaged the students throughout the period. Less time was spent giving notes and more time was allocated to whole-class discussion. Sally used a number of representational modes to develop her students’ understanding of the bond-breaking rules. The representations used demonstrated that a new bond formed between a chemical reaction of hydrogen and oxygen molecules to produce a molecule of water. Students constructed a 3D model of the water molecule and also acted out a role-play of the reaction. Sally also developed students' understanding of the bond breaking and new bond formed on thermal decomposition of calcium carbonate (see Figure 8.2). Sally wrote an equation for the reaction on the board and then asked the students to construct a particulate representation of the reaction. During the lesson, there was good teacher-students interaction and students responded to the challenge of constructing representations of the reactions. Students were actively engaged and interacted with learning materials as they constructed meaning during the learning process.




(a) (b)

(c) (d)

## Figure 8.2: Classroom activities during Sally's lesson

(a) Students developing a concept map of water and solution
(b) Student constructing particulate representation of thermal decomposition of calcium carbonate
(c) Student constructing a model of a water molecule
(d) Student constructing a particulate representation of calcium hydroxide

Table 8.2 summarises the teaching strategies that Sally used in this double lesson.

Table 8.3: Sally's teaching strategies after the first workshop

| | |
|---|---|
| Lesson topic: Reaction rate and collision theory | |
| Date: 11/05/10 | |
| Lesson duration: 80 minutes/double period | |
| Teaching and learning strategies | Time |
| Teacher talking and writing a summary on the board while students write note | 5 mins |
| Teacher and students interacting as a whole class during the lesson | 20mins |
| Students in small group discussion during the lesson | 0 mins |
| Teacher challenging  and engaging students in class activities constructing representations (e.g. concept maps, role-plays, models, graphs) | 55 mins |
| Students copying an assignment | 0 mins |

Sally provided more time for the students to demonstrate meaning and construct knowledge of the subject matter following the workshop. About 70% of the lesson was spent challenging students in class activities which required students to develop concept maps, role-play activities, construct particulate, graphical and 3D model representations of the molecules.

## Sally's experiences of using multiple representations

To elicit information about Sally's experience and challenges with using the new teaching technique and the extent to which students were actively engaged during the lesson, a post lesson interview was conducted. Sally believed that the students learned chemistry better when engaging actively in class activities. She mentioned that representations, for example, the particulate and role-play representations used to demonstrate the decomposition of calcium carbonate reaction challenged students' higher order thinking and revealed students' understanding of the concept. Sally mentioned time constraints and that this was easily overcome through a take-home assignment for students to complete after school hours. Sally considered the use of representation easy because it reduced the stress of too much explanation and writing notes on the board. It allows students to ask a question which reveals their understanding of the concept. It also engaged students actively during the lesson and makes the teaching a student-centred approach. Sally was asked "Can you explain the process used to actively engage your students' higher thinking during the lesson"? "During the processes, what challenges did you face"? Sally explained that:

> Before now, students have not being engaged during lesson but the workshop on multiple representations strategy has been an eye-opener. Since exposed to the new ideas of teaching methodology, it has been very interesting. Students are actively engages in class activities using role-play, constructing 3D model of a reacting molecules and the use of particulate representation which made it easier to assess their understanding on the concept. The challenge is time constraint but I overcame by giving assignment to cover the system at the stipulated period. (Interview with Sally, 11/05/10).

In order to assess Sally's understanding of the use of multiple representations for teaching chemistry and its advantages in large classes, she was asked "What do you understand by the use of the multiple representations strategy in Chemistry"? And "What do you think about the advantages of the use of multiple representations in a large class size"? Sally responded that a teacher re-representing a concept or an idea using different modes is said to be using multiple representation strategy. The strategy quickly awakened students' interest and attention, which in turn provide a better understanding of the concept. Sally explained:

> Teacher in developing students' understanding of a chemistry concept with different modes of representation is said to be using multiple representation strategy. The method reduces teacher's stress of too much talking and notes written on the board. It also lessen the burden of overcrowding in the classroom and encourage group work which results in sharing of ideas among the students during the lesson (Interview with Sally, 11/05/10).

To identify whether Sally find the use of multiple representation easy or difficult, she was asked "Do you consider the use of multiple representations teaching strategy difficult or easy"? " Explain" She explained that:

> The multiple representation strategy is not difficult because it makes learning easier and understandable. It allows students to be inquisitive because they want to learn more. The strategy reduces teacher stress and makes the work easier, therefore lesson becomes lively and helps teacher to assess students understanding on the concept (Interview with Sally, 11/05/10).

To elicit whether the students were actively engaged and feel supported during the learning process and identify those factors that motivated them, Sally was asked "Were the students actively engaged and did they feel supported during the learning process"? and "What factors do you think motivated students to learn in the chemistry lesson"?

> The students were very happy and felt challenged since they were actively involved during the lesson. The following factors can motivate students to learn in chemistry lesson: relating the teaching of a concept relevant to students' daily life experiences; using multiple representations strategy to make concept real and practicable; making the lesson lively

> through students' active engagement in learning (Interview with Sally, 11/05/10).

Sally was asked to explain the impact of the professional learning intervention on her teaching practice and her confidence in teaching chemistry. She stated:

> It has much impact because it has exposed me to various methods to make teaching easy, less stressful and lively. My confidence to teach chemistry concepts has been greatly increased because there are a lot of techniques on representation learnt in the workshop that I will be using on different topics in chemistry for effective teaching even for SSS1 syllabus (Interview with Sally, 11/05/10).

| |
|---|
| Key findings 8.5<br>Following the first workshop Sally used a wider range of representations and most of them were constructed by the students. The strategy impacted positively on her confidence for teaching different topics in chemistry with different modes of representations. Using the multiple representation strategy reduced the stress of writing notes on the board for students to copy. |

**Students' Response to the Multiple Representation Learning Strategy**

To identify how students responded to the new strategy of constructing and interpreting multiple representations of a chemistry concept, a focus group discussion was conducted with some of Sally's students.

The students were actively engaged in constructing a particulate and graphical representation of thermal decomposition of calcium carbonate. The students were also asked to construct a 3D physical model of the reaction in the classroom. When students were asked to explain what they enjoyed most in the lesson, they responded:

> ST 1: The concept map constructed and the particulate representation.
>
> ST 2: The particulate representation, construction of 3D models and mostly, the role-play activities because I can imagine and remember how the play was acted.
>
> ST 3: The role-play activities, these methods really posed challenges to us and the concept mapping (Students' focus group discussions, 11/05/10).

Students explained this lesson was different to their usual lessons because they were actively involved with role-play activities and constructing a model, particulate and graphical representations of the reactions (Students' focus group discussions, 11/05/10).

To elicit information on students' beliefs about teaching and learning of chemistry, they were asked "What do you believe are the most effective ways to learn Chemistry"?

> ST 1: Making the teaching practicable and involving us during the lesson-by drawing our attention towards the teaching.
>
> ST 2: Actively engaging us during the lesson most especially developing lists of concept maps in identifying key features of a concept.
>
> ST 3: Developing our understanding on the concept through questioning technique and also actively engaging us in the lesson through the use of particulate, role-play, and concept map.
> (Students' focus group discussions, 11/05/10).

The students were asked to respond to the question "What would you like your teacher to continue doing to facilitate learning of Chemistry"? They stated that:

> ST 1: Make the concept real and practicable.
>
> ST 2: Making the students acting role-play.
>
> ST 3: Actively engaging us during the lesson. (Students' focus group discussions, 11/05/10)

**The Professional Learning Workshop 2**

The second workshop elicited information about the teachers' experience and challenges with the use of the multiple representations strategy and introduced new representations that could be used to teach the next topic.

### Sally's level of participation during Workshop 2

Sally reported success in engaging students with and learning how to interpret multiple representations of the same concept. She explained that using multiple representations to engage students created room for individual students to fully participate during the lesson which help teaching and learning.

Sally mentioned the constraint of lack of access to materials to illustrate different concepts in chemistry and to allow students to perform hands-on experiments individually though this was not a major problem as students were easily divided into groups. Sally stated that the highlighted problems can be addressed if teachers develop skills of improvisation to illustrate a concept effectively.

Making a model to illustrate a water treatment plant was a great challenge to Sally and her group members in Workshop 2. Sally and her group members struggled to extract clean water from the muddy water after many trials.

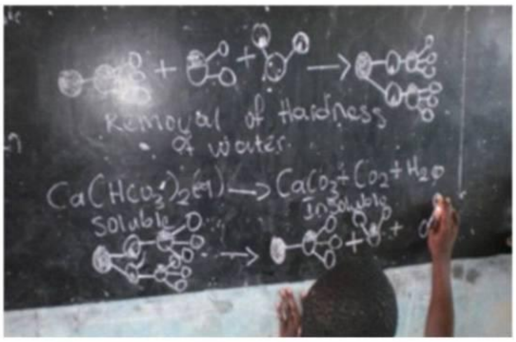
**Teaching and Learning Following Workshop 2**

Following the second workshop, an 80 minute double period lesson that focussed on water and hardness of water was observed. Classroom settings included whole class, small group and individual student work. The observations were recorded on the observation template. The students were actively engaged in various activities and Sally used a number of representational modes to develop an understanding of the concept. Sally introduced the lesson with social stories of the chemistry of water and stated that water is one of the most common substances known which rarely occurs in its pure form. She asked the students to construct symbolic and particulate representations of the reaction between hydrogen and oxygen molecules to form water. She asked students to name various types of naturally occurring water and they mentioned rainwater, spring water, well water, river water, lake water and sea water. Sally explained how the various types of natural water mentioned could be treated to make it fit for human use.

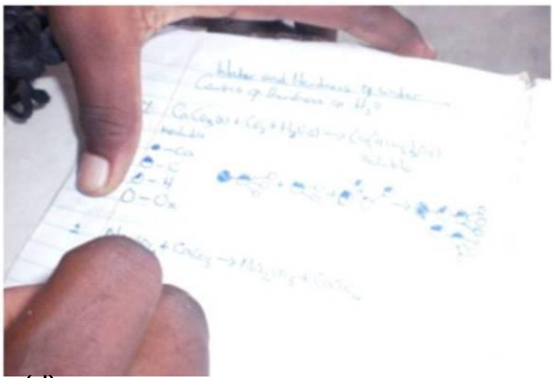
Sally defined hardness of water and explained various types of water hardness. She wrote an equation for the reaction on the board and then asked the students to construct a model of the following molecules: $Na_2SO_4$, Ca $(OH)_2$, $CaCO_3$, and $CO_2$ and also particulate representations of reactions related to temporary ($Na_2CO_3 + Ca_2SO_4$ to form $CaCO_3 + Na_2SO_4$) and permanent ([$CaCO_3 + CO_2 + H_2O$ to form $Ca(HCO_3)_2$]) hardness of water. The teacher and the students conducted an experiment to compare the hardness of various samples of water; however, there were not sufficient test tubes for all students to participate. The students also engaged in a role-play activity to demonstrate the reactions relating to temporary and permanent water hardness. Sally moved round from one group to the other during the lesson assessed the students' understanding as they responded to the challenge of engaging with and learning from multiple representations. Table 8.3 presented below summarises the observed lesson.

(a)

(b)




(c)



(d)

**Figure 8.3: Post intervention classroom activities during Sally's lesson**

(a) Student constructing model of calcium hydrogen carbonate
(b) Student performing an experiment to compare hardness of various sample of water
(c) Student constructing a particulate representation of calcium hydrogen carbonate
(d) Student constructing a particulate representation of calcium hydroxide

Table 8.4: Teaching strategies used by Sally in a double lesson after the second workshop

Lesson topic: Water and hardness of water

Date: 03/06/10

Lesson duration: 80 minutes/double period

| Teaching and learning strategies | Time |
|---|---|
| Teacher talking and writing notes on the board while students are writing the notes | 5 mins |
| Teacher and students interacting as a whole class during the lesson | 15mins |
| Students individually and in small group discussion during lesson | 0 mins |
| Teacher challenging and engaging students in class activities constructing representations (role-plays, particulates, models, doing an | 60 mins |

| | |
|---|---|
| experiment) | |
| Students copying an assignment | 0 mins |

After the second workshop, Sally spent 75% of the lesson challenging and engaging students in class activities using role-plays; constructing models and particulate representations, and also performing hands-on experiments. The students were individually putting the ideas on their worksheets to demonstrate their understanding of the concept. Enough time was provided during the lesson for the teacher and students to generate and negotiate representations of the reactions.

> Key findings 8.6
> Following the intervention, teaching and learning activities were based on the use of multiple representations. Sally's practice was student-centred and students were more actively engaged in role-play activities, developing concept maps, performing hands-on experiments, and constructing models. The teacher was able to identify students' needs and misconceptions while they were engaged with the learning tasks.

To identify teacher's and students' beliefs about effective chemistry teaching and learning after the intervention, and their responses to the new teaching and learning practices, a post lesson interview with the teacher and a focus group discussion with the students were conducted.

### Sally's beliefs about effective chemistry teaching and learning after intervention

To identify Sally's beliefs about effective chemistry teaching and learning, she was asked to respond to two questions "What do you believe are the most effective ways of students learning chemistry"? and "What can you recommend as the most effective way of teaching senior secondary chemistry"? (Final Teacher Interview, 03/06/10). Sally believed that the use of multiple representations strategy with active student engagement was an effective way of teaching chemistry. She stated:

> Multiple representations teaching strategy is the most effective way of teaching and learning chemistry through the use of particulate, model,

> role-play, concept maps and hands-on experiment. (Interview with Sally, 03/06/10)

On the Final Teacher Questionnaire she was asked “What do you believe are the characteristics of effective senior secondary chemistry”? and “What do you believe are the most effective ways of students learning chemistry”? She wrote:

> Active students’ engagement during the lesson through the use of model, particulate, concept maps, role-play representation and hands-on activities. This activity fully engages students’ higher thinking because it involves use of hands and brain. (Sally’s response from FTQ, 18/05/10).

To further identify changes to teacher’s beliefs, knowledge and practice, Sally was asked “Do you think it is possible to make chemistry classrooms interesting for students”? and “As a result of your participation in the professional development workshop, explain what benefited you most in the program”? (Final Teacher Interview 03/06/10). She responded that:

> By illustrating a chemistry concept in many ways that actively engages students to learn better. Chemistry classroom can be made interesting for student by active students’ engagement in the lesson and relating the concept to students’ daily life experiences (Interview with Sally, 03/06/10).

| |
|---|
| Key findings 8.7<br>Following the intervention, Sally believed that active student engagement through the use of multiple representations and relating the concept to students’ daily life experiences are important characteristics of effective chemistry teaching. |

## Students’ beliefs about effective teaching and learning of chemistry following the intervention

To identify students’ beliefs about effective learning of chemistry, they were asked “What can you recommend as the most effective way of learning chemistry”? and “What will actually help you to learn chemistry”? The students responded that:

> ST 1: Classroom activities like the role-play and drawing particulate representation. This will help to easily remember the activities performed in the classroom, memories are called rather than reading. The demo method is exciting, looks challenging, and we are involved. The concept maps constructed will help me to learn chemistry better.
>
> ST 2: Role-play and 3D models representation because it requires creativity. The particulate representation demonstrated and even the construction of models will help me to learn chemistry better.

ST 3: Particulate representation looks challenging. The role-play activities acted during the lesson will help me to learn chemistry better.
(Students' focus group discussions, 03/06/10)

| |
|---|
| Key findings 8.8<br>Students believed role-play activities, doing hands-on experiments, and constructing models and particulate representations during the lesson helped them learn better. |

**Chapter Summary**

Data from the teachers' questionnaire, interviews with Sally, focus group discussions with students in Sally's class, and, lesson observations were used to generate the key findings that summarise the main themes that emerged from the data.

## Challenges

Sally mentioned that lack of a laboratory and equipment, and students' poor science background knowledge were the main challenges to effective teaching and learning of chemistry (KF 8.1).

## Beliefs and Practice Prior to the Professional Learning Workshops

Prior to the workshop, Sally believed that effective teaching and learning of chemistry involves demonstration and relating concepts to students' daily activities and real world contexts (KF 8.2). She believed in assessing her students' understanding of a chemistry concept through oral questions and answers in an interactive way (KF 8.2).

Sally's classroom practice prior to the intervention was interactive and involved a mix of activity and giving notes. She was more student-centred than the other two case study teachers (KF 8.3).

## Changes to Beliefs and Practice Following the Workshops

Following the workshops, Sally believed that effective learning of chemistry involves students' active participation during the lesson, which places students at the centre of learning. Sally's responses to effective teaching approaches, as indicated from the final teacher questionnaire, revealed an activities oriented approach that used multiple representations (i.e. concept maps, models, flow charts, role-plays, graph and hands-on experiments). She also divided students into groups to discuss chemistry ideas among themselves and time was given for classroom interaction and students active engagement in activities that posed challenges to students' higher thinking. Importantly, students were then challenged to re-represent their ideas based on the understanding and knowledge of the concept learnt (KF 8.6). Individual students' needs and misconceptions were easily identified by the teacher through active engagement during a learning task. Sally believed that active students' engagement through the use of multiple representations strategy and relating the concept to students' daily life experiences resulted in the most effective chemistry teaching and learning (KF 8.7).

**Impacts on Students' Engagement in Learning**

Prior to the intervention, Sally engaged her students with copying notes and diagrams drawn on the board, responding to oral questions being asked during the lesson and sometimes to perform experiments where apparatus were available. Following the intervention the students were more engaged in role-play activity; developed concept maps; performed hands-on experiments; constructed models, particulate and graphical representations of the chemical reaction (KF 8.4 & 8.8).

# CHAPTER 9: CROSS-CASE ANALYSIS AND DISCUSSION

## Introduction

This study set out to investigate the implementation of a multiple representation teaching approach in low resourced African schools. The chapter presents and discusses the themes emerging from the data in this study. The data gathered from teachers' questionnaires, interviews, focus group meetings with students and lesson observations of the three case study teachers presented in Chapters 4 to 8 were used to generate the themes presented and discussed in this chapter. These themes are developed from the key findings of the previous chapters. The themes relate to: the context and challenges of teaching chemistry which shaped teachers' beliefs and practices before the intervention; impact of the intervention on teachers' beliefs and practice; and the impact of the intervention on the students' engagement with learning and their beliefs about effective teaching and learning. The chapter also discusses the findings of this study in relation to the research questions, the existing research literature and the conceptual framework guiding this study.

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## Context and Challenges of Teaching Chemistry

Teachers are often faced with difficulties that limit their effectiveness. The teachers involved in this study reported the various challenges to effective teaching and learning of chemistry in senior secondary schools. The teacher questionnaire data indicated that the main challenges are a lack of laboratory facilities and equipment to demonstrate experiments; a lack of instructional teaching materials; and, students lack of textbooks for further studies at home (KF 4.2). These challenges were corroborated by the case study teachers, and in addition, they reported that students' poor attitude to chemistry arising from their poor background of science at junior school and that they have to teach large classes posed further difficulties (KF 6.1, 7.1, 8.1). The challenges of inadequate teaching resources, large classes, the need to cover a content packed syllabus within a stipulated period of time and a necessity for students to copy notes every lesson to have as a resource for examination preparation, shapes their approach to teaching chemistry. Prior to the professional learning intervention, teaching was expository and teacher centred with a low level of student engagement. This finding is consistent with other research conducted in Nigeria which shows that many teachers are faced with the problem of large classes and teaching with inadequate resources which limits their classroom practice and students' academic performance (Aderounmu, et al., 2007). Contemporary learning theory indicates that, for students to develop understanding of concepts, there is a need for planned activities that actively engage and challenge students' higher thinking, enable students to construct knowledge through talk and other representational modes which leads to further development of their mental models (Carolan, et al., 2008; Cheng & Gilbert, 2009; Harrison & De Jong, 2005; Mortimer & Scott, 2003)

| |
|---|
| Assertion 9.1<br>Lack of laboratory facilities and equipment, instructional materials and textbooks, large class sizes with a crowded syllabus and students' poor foundation of science experiences from junior high school are the main challenges faced by senior secondary chemistry teachers. These challenges shaped approaches to teaching which were expository and teacher-centred. |

## Teachers' initial beliefs, practices and use of representation before the intervention

Keys (2005) explains that common reasons for expository teaching are that teachers are pressured to cover the syllabus, prepare students for examinations and teachers sometimes lack a proper understanding of the concepts they must teach. Teachers' beliefs about effective teaching and learning shape their decision-making about classroom practice. Teachers beliefs about what to teach, how to teach and how students learn influence their decisions about how they will plan organise and manage classroom activities (Hashweh, 1996; Keys, 2005; Pajares, 1992).

Chapters 6, 7 and 8 provided rich data about the case study teachers' beliefs, practice and use of representation prior to the intervention and the extent to which students were engaged in learning. Key findings emerging from these data are presented in Table 9.1.

Table 9.1: The three case study teachers' beliefs and practice prior to the intervention and level of student engagement

| Theme | Bob | Guy | Sally |
|---|---|---|---|
| Beliefs about effective teaching and learning of chemistry | (KF 6.2) Demonstration of experiment if resources are available. | (KF 7.2) Demonstration of experiment, and use of charts and models. | (KF 8.2) Demonstration of experiment and relate concepts to daily life activities. |
| Teachers' practice | (KF 6.3)Teacher talking and writing notes while students listening and copying notes. | (KF 7.3) Teacher talking and writing notes while students listening and copying notes. | (KF 8.3) Teacher talking, writing notes and interacting with students and students sharing ideas in groups. |
| Range of representations used for teaching chemistry | (Fig 6.1a & 6.1b) Use of chemical symbols, formulae and equations. | (Fig 7.1a & 7.1b) Use of chemical symbols, formulae and equations. | (Fig 8.1) Use of formulae and equations. |
| Student assessment | (KF 6.2) Oral questions and answers, written tests, students' projects. | (KF 7.2) Oral questions and answers, written tests. | (KF 8.2) Oral questions and answers, written tests. |
| Student engagement | Moderate level of student engagement. | Moderate level of student engagement. | Moderate level of student engagement. |

**Teachers' beliefs prior to the intervention**

Findings from the teacher survey revealed that a large majority of the teachers believed that chemistry teaching and learning is effective when there is provision of a school laboratory with adequate facilities and equipment and other teaching aids (KF 4.2). Also mentioned by the teachers was the need for students to do hands-on activities and teachers to possess a depth of knowledge of the subject matter. Based on the data gathered from the case study teacher interviews, they all believed that demonstration is an effective teaching method if the teaching resources are available (KF 6.2, 7.2 & 8.2). Guy also valued charts and models, and Sally believed it is important to relate concepts to daily life. If they had the resources the teachers would use more visual ways of representing chemistry (Harrison & Treagust 1999; Prain & Waldrip, 2006).

Various researchers (Hackling & Prain, 2005; Hashweh, 1996; Keys, 2005; Levitt, 2001) indicate that the beliefs teachers hold influence their teaching practice and students' learning. It has been argued that if teachers believe that effective chemistry teaching is merely giving clear explanations and reading a textbook for students they are likely to believe coming to the classroom to explain and write notes on the board for students to copy is their role. Likewise, if they believe effective chemistry teaching is developing students' knowledge through experimentation and inquiry they are likely to believe that their role should be to involve students in authentic tasks that actively engage them in learning and constructing knowledge in a meaningful way. Making meaning according to Njoku (2004) is not simply doing hands-on activities related to a topic, or learning the meaning of vocabulary words from the textbooks but through active student engagement in meaningful learning tasks.

### Teachers' practice prior to the intervention

Teacher survey data indicated that the teaching strategies most frequently used were consistent with expository teaching and included explaining, drawing diagrams, plotting graphs and writing notes on the board, demonstrating experiments while students played passive roles of listening, observing, copying diagrams and taking notes (KF 4.5). The case study teachers Bob and Guy, used a conventional chalk and talk method of teaching (KF 6.2 and 7.2). There was a moderate level of student engagement in the case study teachers' lessons prior to the intervention. These findings support a recent study about knowledge transmission pedagogy in Thailand (Hongsa-ngiam, 2006) who asserted that "Teachers, who structure and control learning activities, reduce the level of engagement of students and limit opportunities for deeper and meaningful learning" (p. 7). Bob's teaching style was largely based on lecturing which provided no room for students to be actively engaged during the lessons (KF 6.3) while Guy's teaching was based on writing notes and talking while students copied notes (KF 7.3). Sally believed in relating science concepts to students' daily life experiences and demonstration in an interactive mode (KF 8.2). Her teaching style was more interactive than that of Bob and Guy. Students were allowed to collaborate and share ideas during Sally's lesson as she believed that it develops students' confidence and problem solving skills (KF 8.3).

It is likely the teachers taught in an expository style because of the large class sizes, lack of laboratory facilities and instructional materials and pressure to cover a content laden syllabus (KF 7.1). Contemporary research indicates that teaching is not simply telling or mere delivery of instruction in a verbal mode but effective teaching requires active cognitive engagement of students in authentic tasks that challenge their existing ideas, build on their ideas through classroom discourse and conversation in a social context to support the construction of meaning (Hackling, Peers, & Prain, 2007; Hackling, Smith, & Murcia, 2011). Tytler and Hubber (2004) argue that teachers should use a range of strategies that actively challenge students to construct ideas during learning. Tytler, Peterson and Prain (2006) argue that rather than copying representations constructed by the teacher, students should be challenged to construct their own which means representational construction of knowledge should be the major classroom activity. This also creates a more relaxed and friendly classroom environment for students to explore and share their ideas in a meaningful way, and provides opportunities for students to re-evaluate and clarify their existing ideas.

Conventional talk and chalk methods of teaching will not facilitate students' understanding of chemical reactions which need to be considered at the three levels of representation. In the observed lessons of the case study teachers, the equation of the reactions were written on the board for students to copy and students' knowledge was not revealed to the teachers as students were only listening and copying. Students' interpretation of the behaviour of atoms and molecules in a chemical reaction were not revealed, which limited opportunities for the teachers to monitor students' learning and provide feedback. Gilbert and Treagust (2009) explain that chemistry students find the three levels of representation (macro, sub-micro and symbolic) difficult to understand which is attributed to a lack of experience with macroscopic representation; misconceptions about the behaviour of matter at the particulate level; lack of understanding of the complex conventions used to represent reactions as equations; and, inability to relate between the three levels of representation.

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| Assertion 9.2<br>Large classes, lack of an equipped laboratory and pressure to cover the syllabus resulted in teacher-centred approaches to instruction. Prior to the intervention, explaining and note giving occupied most of the lesson time resulting in little interaction between the teacher and students, and students passively copying notes in most of the lessons. The case study teachers believed that demonstration of experiments is an effective chemistry teaching strategy, however, resource constraints, limited the number of demonstrations that could be performed. Most of the representations of chemistry (notes, explanations, graphs etc) were constructed by the teachers and these were limited opportunities for the teachers to monitor students' learning. |

**Impact of the Intervention on Teachers' Knowledge and Beliefs, Teaching Practice and Use of Representations**

Recent research indicates that the multiple representations strategy offers opportunities to make abstract science concepts accessible and real for students, (Carolan, et al., 2008; Cheng & Gilbert, 2009; Gilbert & Treagust, 2009; Haslam, et al., 2009; Waldrip & Prain, 2006). Ainsworth (1999) argues that the use of multiple representations engages students and motivates them to develop a deeper understanding of the concept being taught. She also explains that deep understanding of abstract ideas requires a full understanding of the relationships between different levels of representations which is particularly significant in chemistry with its macroscopic, sub – microscopic and symbolic levels of representation.

The professional learning workshops set out to enrich teachers' knowledge and beliefs for using multiple representations to enhance the teaching and learning of chemistry. The multiple representations strategy was the focus of the professional learning workshops as it was considered the most appropriate approach to enhanced student engagement in learning for poorly resourced Nigerian schools. The design of the professional learning intervention was informed by the research of Ingvarson, Meiers and Beavis (2005) to ensure that it would be effective. Research data about the impact of the intervention on teachers' beliefs, practice and on students' engagement were reported in Chapter 6 - 8, and key findings are summarised in Table 9.2

Table 9.2: Summary of case study teachers' beliefs and practice after the intervention and level of student engagement

| Theme | Bob | Guy | Sally |
|---|---|---|---|
| Beliefs about effective teaching and learning of chemistry | (KF 6.7) Demonstration method, active student engagement through the use of multiple representations strategy and clear explanations. | (KF 7.7) Role-play activities, developing a concept map, constructing models and particulate representations. | (KF 8.7) Active student engagement through the use of multiple representations and relating the concepts to students' daily life experiences. |
| Teachers' practice | (KF 6.6) More student-centred, the teacher engaged students in representational | (KF 7.6) More student-centred, the teacher engaged students in representational | (KF 8.6) More student-centred, the teacher engaged students in representational |

| | | | |
|---|---|---|---|
| | challenges and provided opportunities for small group discussion. | challenges and provided opportunities for small group discussion. | challenges and provided opportunities for small group discussion. |
| Range of representations used for teaching chemistry | (KF 6.6, Fig 6.2, 6.3 & Table 6.3) Students performed a hands-on experiment, acted out a role-play, developed concept maps, constructed models and particulate representations, and students shared ideas in small/whole group discussions. | (KF 7.6, Fig 7.2, 7.3, & Table 7.4b) Students performed a hands-on experiment, acted out a role-play, developed concept maps, constructed particulate and flow charts representations, and students shared ideas in small/whole group discussions. | (KF 8.6, Fig 8.2 & 8.3) Students performed a hands-on experiment, acted out a role-play, developed concept maps, constructed models, and students shared ideas in small/whole group discussions. |
| Student assessment | (KF 6.6, Fig 6.2 & 6.3) The particulate representation constructed by the students made it easier for the teacher to assess students' misconceptions and understanding of the chemical reactions. | (KF 7.6, Fig 7.2a) The particulate representation constructed by the students made it easier for the teacher to assess students' misconceptions and understanding of the chemical reactions. | (KF 8.6, Fig 8.2 & 8.3) The particulate representation constructed by the students made it easier for the teacher to assess students' misconceptions and understanding of the chemical reactions. |
| Student engagement | (Fig 6.2, 6.3 & 6.4) High level of student engagement. | (Fig 7.2 & 7.3) High level of student engagement. | (Fig 8.2 & 8.3) High level of student engagement. |

### Teachers' knowledge and beliefs

Although teachers' beliefs can be difficult to change, Pajares (1992) explains that exposing teachers to a series of challenging activities may have a direct positive impact on their beliefs. Keady's (1999) research showed that building teachers' pedagogical content knowledge was necessary to bring about changes in practice and beliefs. Prior to the intervention, the teachers had little knowledge about the use of representations to engage students and develop their understanding of chemical reactions. During the workshops the teachers developed concept maps and constructed symbolic, particulate, role-play, graphical and flow chart representations to further develop their knowledge about representation and the use of a multiple representations teaching strategy. The workshops were designed to develop teachers' pedagogical content knowledge (PCK) for teaching chemistry with multiple representations. The workshop also focused on the three levels of representation and the relationships between the macroscopic, sub-microscopic and symbolic levels.

Findings from the post-intervention teacher questionnaire revealed that a large majority of the teachers who participated in the professional learning believed that chemistry teaching and learning is effective when students are actively engaging with the use of multiple representations and doing experiments (KF 5.2; Table 5.1). The teachers also recognised the need to possess a deep knowledge of the subject matter and plan lessons thoroughly. Feedback on the intervention during Workshop 2 revealed that teachers recognised that students need to be actively engaged in learning and that abstract concepts need to be made accessible for students through representations (KF 5.1). The teachers also explained that the use of multiple representations had impacted positively on their confidence to teach chemistry concepts, broadened scope of teaching methodology and higher thinking (KF 6.5, 7.5 & 8.5)

Based on the data gathered from the final case study teacher interviews, the teachers changed their beliefs about the characteristics of effective chemistry teaching from involving students during practical lesson or when illustrating a concept through demonstration method to student actively engaging in challenging activities with multiple representations (KF 6.7, 7.7 & 8.7). When asked whether it is possible to make chemistry classrooms interesting for students. Bob related that this can be made possible through hands-on experiments, creating concept maps and students acting out role-plays (Final Teacher Interview, 01/06/10). Guy and Sally also believed in active student engagement through constructing particulate representations (KF 6.7 & 7.7). Sally also believed that it is important to relate concepts to students' daily life activities (KF 8.7). Their beliefs had changed to a belief about active student engagement during lessons which contrasted sharply with the students performing passive roles of listening, answering questions and taking down notes prior to the intervention.

**Teachers' practice**

Data from the cohort of teachers who completed the final teacher questionnaire indicated that the most frequently mentioned teaching approaches used after the intervention included teachers explaining the concepts, using equations, diagrams, 3D models, flow charts, concept maps, role-play activities, demonstrating experiments, and, small group and whole class discussions. Writing notes and reading of textbooks were less frequently used after the intervention (Table 5.2; KF

5.3). The classroom observations revealed that Bob, Guy and Sally clearly explained the concepts; students were involved in small group discussions; students engaged in role-play activities; developed concept maps; constructed models; and, performed experiments (KF 6.6, 7.6, 8.6). Most of the representations provided opportunities for students to develop their understanding of the re-arrangement of atoms and molecules in a chemical reaction which would help them to better understand chemistry at the particulate level of representation.

Prior to the intervention, students' copied symbolic representation of chemical reactions written on the board by the teachers which limited their opportunity to develop an understanding of the re- arrangement of atoms at the sub-microscopic level. Research asserts that a deep conceptual understanding of a chemistry at the three levels of representation requires teachers communicating and engaging students beyond the symbolic level (Gilbert & Treagust, 2009; Johnstone, 1991). The teachers' use of multiple representations in this study enriched students' opportunities to understand and link between the macro (experiments), sub-micro (particulate representations) and symbolic (equations) levels of representation of chemical reactions which students usually find difficult to conceptualise (Johnstone, 1991). Moreover, the students' experiences of constructing particulate representations should support more accurate symbolic representation if the teacher explicitly makes links between regrouping of reactant atoms into product molecules and the construction of equations. Marais and Jordaan's (2000) research work shows that students have great difficulty understanding the way that chemical reactions are represented symbolically.

Following the intervention, the students were actively engaged individually and also in small groups. The small group discussions provided opportunities for the students to negotiate meanings and express themselves in the language of the subject matter which is another mode of representation. The students' engagement in learning engendered enthusiasm in them and this appeared to increase their confidence with learning chemistry (Fig 6.2, 6.3, 6.4, 7.2a, 7.3, 8.2 and 8.3). Students' construction of particulate and role-play representations in particular challenged students' knowledge of the chemical reaction at the sub-microscopic level of representation and this in turn assisted the teachers to further assess their students' understanding during learning tasks. For example, during Bob's observed lesson when the students were asked to construct a particulate representation of the decomposition reaction of hydrogen peroxide ($H_2O_2$), a student misrepresented the $H_2O_2$ molecule as two separate hydrogen and oxygen atoms rather than as an entire molecule being bonded together

(Figure 6.2). The teacher was able to address this misconception because the students constructed representation made the error accessible to the teacher.

Students' understanding of chemical reactions requires a deep knowledge of the behaviour of reactants and products at the particulate level and the meaning of the language used to represent the reaction as an equation. The particulate representations constructed by the students during the lesson made their understanding about the concept accessible for the teachers so that it could be used for formative assessment (Paul Black, et al., 2004; Paul & Dylan, 1998). Formative assessment according to Black and William (1998) is a powerful tool designed for an effective feedback as it provided opportunities for students to explore and express their understanding during classroom instruction. Black and William's research provides strong evidence that improving formative assessment raises student achievement and if properly implemented helps teachers improve on their practice and students learn better during the learning process.

The teachers' implementation of the multiple representations teaching strategy was broadly consistent with the six pedagogical principles described by Hubber, Tytler and Haslam (2010):

1. Multiple representations were introduced and utilised when teaching reaction rates, and water pollution and solubility.
2. The teachers allowed students to generate their own representations rather than copying representations constructed by the teachers and this supported students to function more independently.
3. Particulate and symbolic representations of chemistry were used as tools for thinking about chemical reactions.
4. There was discussion of the adequacy of representation at both whole class and small group levels which enabled the teachers to access students' understanding and performance during learning.
5. The teachers made links between perceptual (macroscopic) and graphical experiences (particulate and symbolic) of the chemistry.
6. The teachers provided time to explore students' ideas and representations when teaching the concept of reaction rates.

Bob, Guy and Sally's practices after the intervention were consistent with the constructivist view (Driver, et al., 1994; Tytler, 2004) that students need to be actively engaged with learning tasks that create opportunities to challenge their higher order thinking and for constructing meaning. Rather than the teacher doing all the talking they should be acting as a facilitator to encourage the students to discuss and make sense of ideas, scaffolded by engaging representational challenges, without depending on the teacher to provide all the required information.

The teachers recognised the importance of engaging students in constructing knowledge rather than simply reproducing knowledge provided to them as notes and explanations which was typical of practice prior to the intervention. This finding corroborates Grennon-Brooks and Brook's (1993) views which assert that curriculum activities need to encourage students to work in groups and engage critical activities that challenge and explore their thinking in authentic contexts. The teachers also recognised the role of small group discussions that allow most students to demonstrate what they know, share ideas freely with each other which help link prior knowledge to the learning tasks (Hackling, et al., 2011).

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| Assertion 9.3<br>The intervention had positive impacts on teachers' beliefs and practice. Prior to the intervention teachers' believed that demonstrations and access to good resources were essential for effective teaching. Following the intervention beliefs focussed on the use of representations complemented with experiments. Teaching approaches prior the intervention involved talking and writing notes on the board for students to copy and the teacher demonstrating experiments while students observed what was being demonstrated. This changed to the use of a multiple representations strategy which engaged students in representational challenges complemented with experiments and small group discussions. Students' understandings were easily accessed by teachers through their constructed representation that revealed information about their knowledge of chemical reactions particularly at the sub-microscopic level. Teachers' confidence to teach chemistry concepts has greatly improved and broadened skills of higher thinking |

### Impact of the Intervention on the Students' Beliefs about Effective Teaching and Learning of Chemistry and their Engagement in Learning

Students' beliefs have a great impact on their learning and influence the way they respond to learning tasks (Hashweh, 1996). If they believe that learning a concept is difficult, it is likely they will show less interest or pay less attention when the concept is being taught. A body of research findings on student learning focuses on the "ideas students brings with them to the classroom, and how these affect how and what they learn" (Tytler, 2004, p. 19). Tytler explained further that these alternative conceptions are a barrier to effective learning. Research reports assert that engaging students in learning processes: promotes higher order thinking; encourages collaborate learning with peers in the classroom; increases the level of academic challenge; increases students' enthusiasm to participate in the activities; and, that students show curiosity and interest in the subject matter which eventually leads to deep understanding of the material to learn and students have a meaningful personal connection to the topic (Fletcher, 2005; Hake, 1997; Kuh, Cruce, & Shoup, 2008; Skinner & Belmont, 1993). Therefore, engaging students actively in learning goes beyond chalk and talk methods and requires that the teachers design activities that promote active engagement in order to keep students' interest through challenging tasks that are relevant to students' daily life experiences.

Research indicates that the more time students spent engaged in learning activities, the more they learn and there is a need for clear and constructive feedback from teachers to encourage students to be more active participants and reflective about whatever they are learning (Carrini, et al., 2006; Fletcher, 2005; Linnenbrink & Pintrich, 2003).

## Impact on students' beliefs about the most effective ways of learning chemistry

Prior to the intervention a large majority of the students reported that when the teacher's explanation of concepts relates to real life examples it made it easier to learn chemistry (KF 4.7). It was also mentioned by the students in the survey that hands-on experiments, the teacher providing clear explanations of the concept and take-home assignments are the characteristics of effective teaching and learning of chemistry (KF 4.8). When the students in the classes of the case study teachers were asked to recommend the most effective ways of learning chemistry after the intervention, they explained that active participation in demonstration of experiments and engaging in multiple representation activities are the most effective way of learning chemistry (KF 6.8, 7.8 & 8.8). Following the intervention, students' beliefs about effective teaching and learning focussed on their agency in the learning process which contrasts with their prior beliefs about receiving clear and relevant explanations. Schommer-Aikins (2004) explains that beliefs highly influence every facet of learning which includes how students learn and how teachers teach and hence, teachers need to be aware of their students' beliefs and they should adopt techniques that will lead to effective learning and performances.

### Impact on students' engagement in learning

Prior to the intervention, classroom observations indicated that the students played passive roles of listening, observing and copying notes (KF 4.9). Lessons observed after the intervention revealed that students were actively engaged with representational challenges including role-plays, concept maps, flow charts, 3D models, particulate and graphical representations (KF 6.6, 7.6 & 8.6). Students also collaborated and shared ideas in groups and learning was more student-centred. Some literatures suggested that this type of classroom environment made the concept learnt easier to understand, real and accessible as the representations created during learning engages students in constructive and higher order thinking (Ainsworth, 1999; Carolan, et al., 2008; Haslam, et al., 2009; Jonassen, 1999). Research has clearly shown that to enrich students' understanding of chemistry concepts requires that students have the competence to translate what they study in the classroom and laboratory to the real world context using different modes of representation (Talanquer, 2011).

The learning theorists conclude that learning occurs in the context of activity and students learn better when they can construct knowledge on their own rather than receiving factual information disseminated in the classroom by the teacher thus, building and developing confidence to be responsible for their own learning (Atherton, 2009; Bruner, 1961; Driver, et al., 1994; Hubber & Tytler, 2004). The teacher's role in the classroom is to facilitate students' learning not practicing an authoritarian approach that results in a traditional teaching style which disengages students from learning and students feeling that they are not supported during lessons (Tobin, et al., 1994). Tobin et al. (1994) further observed that when opportunity is provided for students to engage in learning tasks, it develops their problem solving skills and allows them to be more creative in life challenges.

Assertion 9.4
Prior to the intervention, students believed that hands-on experiments, clear explanation from the teacher and take-home assignments were effective ways of teaching and learning chemistry. Following the intervention, they believed that learning with multiple representations and participating in experiments were effective ways of learning. The changes in students' espoused beliefs reflected their active engagement in role-play, constructing particulates, models and flow charts, and, developing concept maps rather than being passive and disengaged during learning prior the intervention.

**Effectiveness of the Professional Learning Intervention**

The professional learning intervention program for teachers in this study took account of the factors that make professional learning effective (Ingvarson, et al., 2005). The intervention in this study impacted on teachers' beliefs, knowledge and practices which flowed-on to impact on students' beliefs and engagement. The three case study teachers actively engaged in all the activities during the workshop and trialled the approaches back in their classroom and found the new approach was useful because it encouraged students' active participation and reduced teachers' stress of talking, writing notes and drawing diagrams on the board (Interviews with Bob and Guy, 1/06/10 & Sally, 11/05/10).

The teachers perceived the need to change their classroom practices from conventional chalk and talk method to active student engagement through planned activities that will challenge students' higher thinking. They also discovered that when students constructed their own representations, it provided opportunities for students to express their understanding on a concept and this also increases classroom dialogue. It equally drew the teachers' attention to what their students were able to learn when they are actively engaged during a learning process. Therefore, the teacher demonstrated a capacity to change their practice whilst supplied with new activities. However, there is no evidence that they will have learned how to construct these types of activities for themselves, or that they transfer the intervention and this learning of multiple representations strategy to the next topic and future topics in chemistry.

**Synthesis around the Conceptual Framework**

This study applied findings from research on teaching with multiple representations conducted in western developed countries into a low resource African context and has greatly contributed to the body of knowledge on chemistry teaching in Nigeria. It was expected that the professional learning intervention on the multiple representations strategy provided in this study would enhance teachers' pedagogical content knowledge for teaching chemistry; influence teachers' beliefs about effective chemistry teaching and learning and impact on their classroom practice. The research data shows that the professional learning intervention brought about changes to the teachers' beliefs and practice which actively engaged students in challenging activities of constructing knowledge through multiple representations. Figure 9.1 elaborates the conceptual framework that was developed from the research literature when designing this study, with findings from the research.

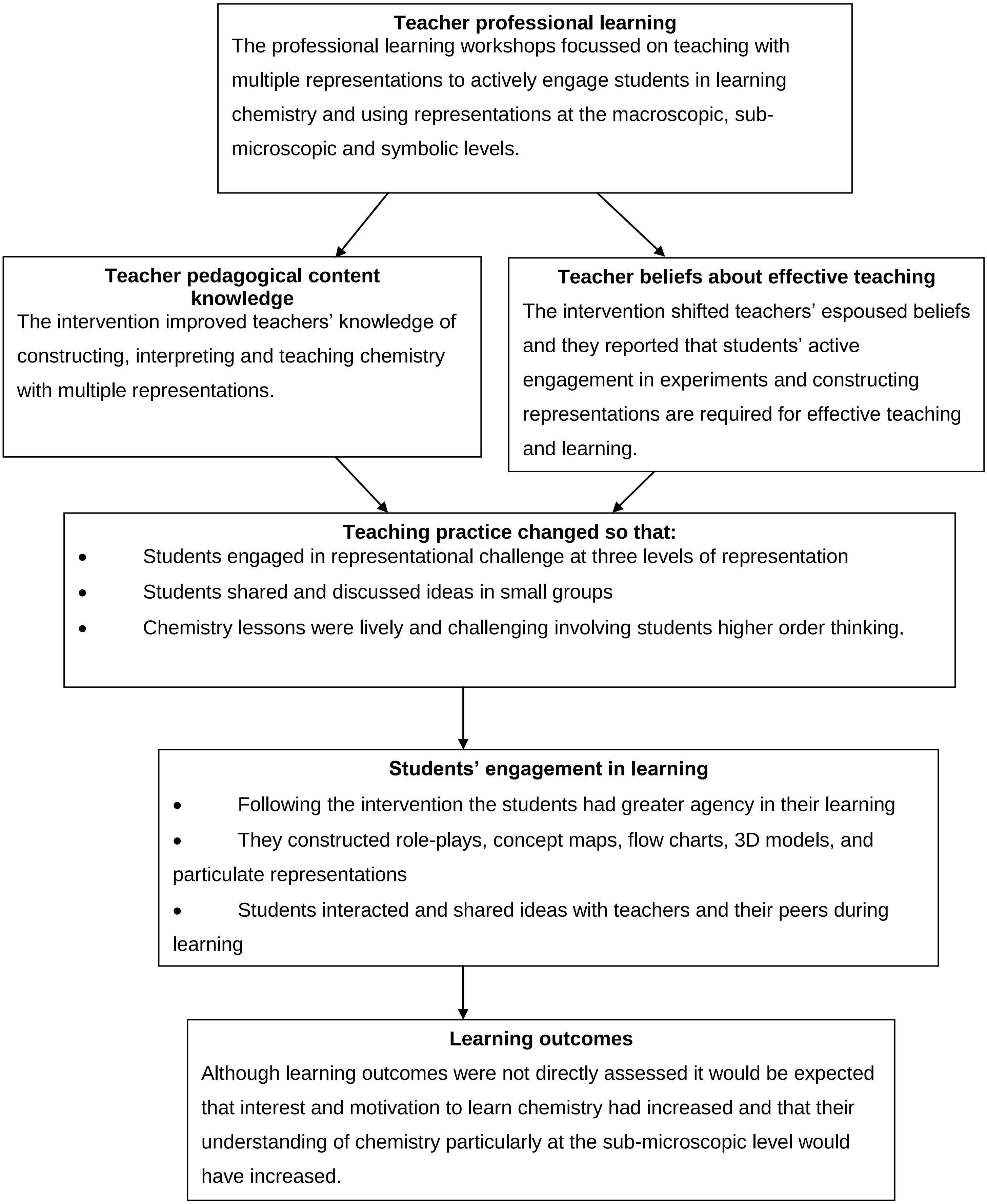


**Figure 9.1: The emerging model arising from the study**

# CHAPTER 10: CONCLUSIONS AND IMPLICATIONS

**Introduction**

This chapter presents an overview of the study which investigated the impact of a professional learning program for using multiple representations on chemistry teachers' knowledge, beliefs and practice, and also students' beliefs and engagement with learning. The chapter reports the conclusions and considers implications of the study and the contribution to knowledge provided by the research.

**Overview of the Research**

This study provided a professional learning intervention that involved teachers of chemistry in the senior secondary schools in a Local Education District (V) of Lagos State, Nigeria. The professional learning workshop focussed on enhancing teachers' knowledge to teach concepts of reaction rate and collision theory, and, water pollution and solubility using a multiple representations strategy. The workshops were expected to impact on teachers' knowledge, beliefs and practice related to students' active engagement in learning chemistry with multiple representations to enhance their learning outcome. The study used questionnaires to collect baseline data on teachers' chemistry teaching and learning, beliefs and practice and also, students' beliefs about the teaching and learning of chemistry. The final teacher questionnaire, interviews with teachers, student focus group discussions, lesson observations, teachers' lesson plans, and classroom artefacts were used to evaluate the impact of the intervention on teachers and students.

The percentage, frequency and mean rating of the scale items from teacher and student questionnaires were calculated using the SPSS 18.0 statistical package while responses from the open-ended questions were coded, grouped into categories and the generated categories were later grouped into emergent themes. The audio recordings from the teachers' interviews and students' focus group discussions were listened to, transcribed and participants' responses were grouped into categories. The categories were then grouped into themes and the data were reported in a narrative form. The lesson observations were recorded on a template and these field notes were supplemented with photographs of the classroom activities and classroom artefacts. These data were used to describe teacher practices before and after the intervention with a particular focus on the use of representations. The data analysed were used to generate key findings that have been aggregated into themes. The interpretation draws on the literature, leading to the generation of assertions, which form the basis of the conclusions.

## Conclusions

Four research questions provided a focus for the investigation, the first addressed the challenges facing teachers of chemistry; the second addressed teachers' existing beliefs about effective teaching and learning of chemistry, teachers' knowledge about using representation in chemistry teaching and their current teaching practice; the third identifying the impacts of the learning intervention on the teachers' beliefs, knowledge and practice; and, the fourth related to the impacts of the intervention on students' beliefs about teaching and learning of chemistry and their engagement with learning. The general assertions created in Chapter 9 have been used to answer the research questions in this chapter and shape the conclusions of the research.

### Research Question 1: What challenges do teachers face in the teaching of chemistry in Nigerian secondary schools?

Data from the teacher questionnaire revealed that the majority of the teachers reported the lack of resources such as; laboratory facilities and equipment, instructional materials and textbooks for students to further studies at home, large class sizes, a crowded syllabus and students' poor foundation of science experiences from JSS are the main challenges. These shaped their teaching approach, which was to be expository and teacher-centred in nature (Assertion 9.1, KF 6.1, 7.1 & 8.1). The feedback teachers provided during the small group discussions at the professional learning workshop indicated that most schools lack chemistry laboratories and sufficient apparatus to perform experiments and that the experiments are usually carried out by the teachers as a demonstration (Feedback from small group discussions, 29/04/10). There is also a problem of overcrowded classroom and the time allocated for chemistry lessons is insufficient.

### Research Question 2: What are the teachers' current beliefs about effective teaching and learning of chemistry, knowledge about using representation in chemistry teaching, and their current teaching practice?

This question was divided into two sub-questions related to beliefs and knowledge, and practice.

### (a) What were the teachers' beliefs and knowledge about using representation and teaching and learning of chemistry prior to the intervention?

The baseline data from the teacher questionnaire prior the intervention revealed that the majority of the teachers believed that chemistry teaching and learning is effective when there is adequate provision of school laboratory facilities and equipment, students do hands-on experiments and when teachers possess in-depth content knowledge of the subject (KF 4.2). This finding was elaborated during interviews with the case study teachers who believed that demonstration of experiments, relating concepts to students' daily life experiences and giving students notes to copy at every lesson are effective chemistry teaching strategies, however, resource constraints, limited the number of demonstrations that could be performed (KF 6.2, 7.2, 8.2, Table 9.1 & Assertion 9.2).

Prior to the intervention, the teachers who participated in the professional learning intervention had little knowledge about using representations in chemistry teaching. The teachers were only familiar with equations (Figures 6.1a, 7.1a & 8.1) for chemical reactions and diagrams and graphs which were drawn on the board. The teachers were not familiar with using role-plays, flow charts, models, particulate representations and concept maps to teach chemistry. The teachers lacked knowledge about preparing a lesson to actively engage students with learning tasks and being resourceful in using a local material to construct models (KF 6.3, 7.3 & 8.3).

### (b) What was the nature of the teachers' practice prior the intervention?

Prior to the intervention, the teachers used a conventional expository approach dominated by teacher activities (teachers talking, writing, drawing diagrams and reading from textbooks) while the students played mainly passive roles of listening, observing and copying notes in most lessons (KF 6.3, 7.3 & 8.3; Assertion 9.2). This was corroborated with evidence from observation of the case study teachers and the teacher interviews which reflected teacher-centeredness with a low level of student engagement (Tables 6.1, 7.1 & 8.1). Bob and Guy's practice was dominated by didactic activities of teachers talking all alone without encouraging students' participation during the lesson (KF 6.3, 7.3). The lessons involved the use of word equations and symbolic representations of chemical reactions. However, Sally's teaching was more student-centred; she employed whole-class discussion with questioning strategies during her lessons which sometimes allowed the students to freely express their views and ideas (KF 8.3). Assessment of students' understanding of chemistry was through oral questions and answers during lesson while only a few used assignments and projects (KF 4.5). These limited assessment strategies constrained the teachers' capacity to adequately monitor students' learning (Assertion 9.2).

### Research Question 3: What are the impacts of the professional learning intervention on the teachers' beliefs, knowledge and practice?

This question was divided into two sub-questions related to beliefs and knowledge, and practice.

#### (a) What was the impact of the intervention on teachers' beliefs and knowledge about chemistry teaching and learning?

The active engagement of teachers in constructing and interpreting multiple representations of chemistry concepts during the workshop had positive impacts on their knowledge and beliefs (KF 5.2). During the workshop, the teachers recognised that there is a need to place students at the centre of the learning through the use of multiple representations. Following the intervention, teachers' beliefs about effective teaching and learning of chemistry focussed on the use of demonstrations, active student engagement through the use of multiple representations (role-play activities, developing concept maps, constructing models and particulate representations) and relating the concepts to students' daily life experiences (KF 6.7, 7.7 & 8.7).

The intervention actively engaged the teachers with challenging activities that developed their skills on ways to plan and teach chemistry in more lively and challenging ways for students. The teachers had little prior knowledge of the representations learnt during the workshop. The intervention developed the teachers' knowledge on how to teach a chemistry concept with various modes of representation (KF 6.5, 7.5 & 8.5) such as; concept maps, particulates, flow-charts, 3D models and role-play (Figure 5.2, 5.3 & Figure 5.4) The water filter challenge activity (Figure 5.5) challenged teachers' higher order thinking and this was reflected in their responses when explaining that teachers of chemistry need to be creative, resourceful and possess a depth of content knowledge of the subject matter for effective teaching (KF 5.2, Feedback on the intervention during Workshop 2) and that abstract concepts need to be made accessible for students through active engagement (KF 5.1).

### (b) What was the impact of the intervention on teachers' practice?

The intervention had a positive impact on teachers' practice. The initial expository teaching approaches changed to the use of a multiple representations strategy, which engaged students in representational challenges complemented with experiments and small group discussions (Assertion 9.3). Students' understandings were more easily accessed by teachers through their constructed representation that revealed information about their knowledge of chemical reactions particularly at sub-microscopic level. This provided teachers with more opportunities to monitor students' learning and provide feedback. Significantly, the teachers used a much wider range of representations following the intervention which included hands-on experiments, acting out role-plays, developing concept maps, constructing models, flow charts and particulate representations, and they also shared ideas in small and whole group discussions (KF 6.6, 7.6, 8.5; Figures 6.2, 6.3, 7.2, 7.3, 8.2 & 8.3). There was also a shift from predominantly teacher constructed representations to student constructed representations.

Bob's teaching strategies observed after the workshop (Table 6.2 & 6.3) revealed that students spent more time during the lesson engaged with learning tasks rather than playing passive roles. Bob's practice was more student-centred, engaging students in representational challenges and providing opportunities for small group discussions which encouraged active learning of chemistry (KF 6.6).

The students' active involvement in Guy's observed post intervention lessons was quite different to their usual passive role. Guy actively engaged the students in class activities of constructing flow charts and particulate representations, developing concept maps and constructing a water filter (Figure 7.3). Guy's practise was more student-centred which involved the whole class, small groups and individual students responding to representational challenges and provided opportunities for small group discussions (Table 7.3, 7.4 & KF 7.6).

Following the workshops, Sally's lessons were more student-centred and challenging. She engaged students in class activities and at the same time interacted with students at the whole class level (Table 8.3 & 8.4). Students responded to challenges of making models, constructing particulate representations and developing concept maps (Figure 8.3, KF 8.6). Sally was able to teach confidently using the multiple representations strategy, as learnt during the workshop. Students appeared confident with their understanding of the concepts when they demonstrated their ideas for others on the blackboard as revealed in Figure 8.2 and 8.3. Therefore, the intervention impacted on the case study teachers' practice as they actively engaged students with constructing representations and involved them in whole class, small group and individual discussion to share ideas (Assertion 9.3).

### Research Question 4: What are the impacts of the professional learning intervention on students' beliefs about teaching and learning of chemistry and their engagement with learning?

This question was divided into two sub-questions related to students' beliefs and engagement with learning.

#### (a) What was the impact of the intervention on students' beliefs about teaching and learning of chemistry?

Following the intervention, students' beliefs focussed on learning with multiple representations (active engagement in role-play, constructing particulates, models and flow charts, and, developing concept maps) and participating in experiments (Assertion 9.4). The students in the classes of the case study teachers believed that chemistry teaching and learning is effective when doing experiments and sometimes when they engage in project work. The students also reported that they believed that the learning of chemistry was easier when teacher explanations involve relating the concept to a real life context (KF 6.4, 7.4 & 8.4).

#### (b) What was the impact of the intervention on students' engagement with learning?

Prior to the intervention, analysis of the student survey questionnaire and lesson observations revealed low levels of student engagement as they passively, copied notes and observed experiments demonstrated by the teachers (KF 4.5, 6.3 & 7.3). This teaching approach seemed to focus on memorisation of content to pass the examination. Following the intervention, the observed lessons indicate that students were actively engaged with representational challenges that included activities such as role-plays, models, concept maps, particulate, graphical and flow chart representation of chemical reactions and participating in small group and whole class discussions (Assertion 9.4).

### Limitations of the Study

This study involved chemistry teachers in senior secondary schools within one Local Education District of Lagos State, Nigeria. Forty of the chemistry teachers completed and returned survey questionnaires and three of these teachers were purposely selected for an in-depth case study. As a case study limited to one district and a relatively small number of teachers, the findings have limited generalizability. Although, other researchers have indicated that when students are much more actively engaged in constructing knowledge through representations, there is likely to be a positive impact on students' learning (Ainsworth, 1999; Carolan, et al., 2008; Haslam, et al., 2009; Hubber & Tytler, 2004), no pre or post-tests were administered for the students to provide evidence of how much learning occurred. Additionally, the Researcher trained the teachers to deliver some lessons constructed during the professional learning intervention and it appeared that they successfully implemented those lessons; however, it was not possible to continue the research to determine whether the teachers were able to implement the strategy in other topics without the support of supplied curriculum resources.

**Implications**

The findings from this study have implications for further research, for chemistry teaching in Nigerian schools, and for teacher education.

## Implications for further research

Further research is needed to address the limitations of this study. The current study was only able to address the teaching of a few selected concepts in chemistry. Further research is needed to extend the use of the multiple representations strategy to other concepts in chemistry and to other science disciplines in Nigerian secondary schools. The lesson plans for the selected concepts during the professional learning intervention were provided by the Researcher which the teachers then used to teach the students. Future research might allow teachers to prepare lesson plans for other concepts to be taught using multiple representations and also monitor teaching effectiveness. There is also a need to research the impact of the new strategies on student learning outcomes in a Nigerian context.

## Implications for teaching chemistry in high schools

Many concepts in the chemistry curriculum are sometimes considered as dull and abstract in nature by students. Therefore, the effective teaching of chemistry concepts requires students to be actively engaged with challenging activities. Chemistry teaching in Nigerian schools needs to move away from a conventional expository style of teaching that makes students passive during learning and in many cases students sleep or abscond from chemistry classes. The approach of teachers telling and students listening used to teach chemistry in Nigerian secondary schools, does not encourage students to develop an interest towards the subject and develop a meaningful conceptual understanding of the topics. Therefore, it is important that teachers adequately plan lessons, which include multiple representation challenging activities that actively engage students and use less blackboard teaching as this will help avoid simple rote learning.

This study has demonstrated the potential of the multiple representations teaching strategy to actively engage students in learning chemistry. Hence, this strategy could be more widely adopted in Nigerian chemistry classrooms.

### Implications for teacher professional learning

This study has developed, implemented and evaluated a professional learning intervention designed to enhance chemistry teaching using multiple representations. The research findings are encouraging and suggest that similar professional learning opportunities should be made available to chemistry teachers in other districts of Lagos State.

### Implications for initial teacher education

The traditional expository mode of teaching is common in Nigerian chemistry classrooms as teachers tend to teach in the same way that they were taught. The pre-service teachers should be taught the way in which they are expected to teach their own students in schools. This will require thorough planning and activities that challenge their higher order thinking and motivate them to teach in ways that actively engage their students in learning. The multiple representations strategy employed in this study if effectively utilised to teach different concept in chemistry should have positive impacts on pre-service teachers' beliefs about teaching chemistry. Their teaching styles need to change from teacher-centred to placing students at the centre of the learning using constructivist approaches and representational challenges.

### Resource implications

Effective teaching and learning of chemistry requires carefully planned lessons that actively engage students' higher order thinking through challenging representational activities, which would include locally available resources. The professional learning programme in this study on the multiple representations strategy for teaching and learning of chemistry made use of locally available materials. Teachers therefore, need to be resourceful, creative and develop skills of improvisation using available materials to support instruction. Teachers would also benefit from being supplied with curriculum resources that incorporate a multiple representations strategy.

## Contribution to Knowledge

There are few reports in Nigeria on teachers' beliefs about effectiveness and their classroom practice (Benjamin, et al., 2002), students attitude and performance towards chemistry (Akintunde & Lawal, 2008; Keshinro, 1998), effective teaching strategies (Adenekan, et al., 2006; Keshinro, 2006; Olaleye, 2005; Olaleye, et al., 2009; Olaleye, et al., 2008; Richard, 2008), but there are no detailed reports and investigations about teachers' professional development related to the use of multiple representations strategy for teaching chemistry in African countries. This is the first study that attempts to transform chemistry teaching practice in low resource African schools so that students are more actively engaged in learning based on a multiple representations strategy.

This study has also developed, implemented and evaluated an approach to teacher professional learning that has proved effective in this Nigerian context. This research makes an important contribution to the literature on teacher professional learning.

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# APPENDICES

## APPENDIX A: TEACHER SURVEY QUESTIONNAIRE

**Improving the quality of teaching and learning of chemistry in Nigerian senior secondary schools**

**Teacher initial Survey Questionnaire (TISQ)**

Dear teacher,

This questionnaire is to seek your opinions and concerns about effective teaching and learning of chemistry in senior secondary school. You are required not to write your name and the name of your school. Your response (s) to this questionnaire will remain confidential and any comment made will not be identified in this research.

This information provided will be used to improve the teaching and learning of chemistry in Nigerian senior secondary schools. By completing the questionnaire means you are consenting to take part in the research. Please carefully read all the instructions in each section before giving your response (s).

Thank you for your participation in this study.

**SECTION 1: Background information**

1.1 Local education district: ……………………………………………………………… (fill in the blank space)

1.2 Indicate sex: Male ☐ Female ☐ (tick one box)

1.3 Indicate age: 20 years or less ☐ 21 – 30 years ☐ 31 – 40 years ( ☐ (tick one box)

41 – 50 years ☐ 50 years and above ☐

1.4 Indicate all of your academic qualifications: NCE ☐ HND ☐ B.Sc ☐

B.Sc Ed ☐B.Ed ☐ PGDE ☐ M.Sc ☐ M.Ed ☐ PhD ☐ (tick boxes where applicable)

1.5 Years of teaching experience as a teacher: 0 – 5 years ☐ 6 – 10 years ☐ 11-15 years ☐

16 – 20 years ☐ 21 years and above (tick one box)

1.6 Years of teaching experience as a senior secondary chemistry teacher: 0-5years ☐ 6- 10 years ☐ 11-☐years 16-20 years ☐ 21 and above ☐ (tick one box)

1.6 What is the number of chemistry students in your SS2 class? ............ (Indicate on the line)

**SECTION 2: Please provide answers to these questions in the spaces below**

**2.1** What challenge(s) are you facing with teaching senior secondary chemistry effectively?

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**2.2** What do you believe are the characteristics of effective senior secondary chemistry teaching?

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2.3 What do you believe are the most effective ways of students learning chemistry?

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**2.**4 How often do you use the following approaches to teaching senior secondary chemistry? (tick one box on each line)

| **Approaches** | **every lesson** | **most lesson** | **some lesson** | **few lesson** | **Never** |
|---|---|---|---|---|---|
| Explaining chemistry ideas to students | | | | | |
| Writing notes on the board for students to copy | | | | | |
| Small groups of students discuss ideas | | | | | |
| Whole-class discussion of ideas | | | | | |
| Students read the chemistry textbook | | | | | |
| Teacher demonstrates a chemistry experiment | | | | | |
| Students do hands-on experiments | | | | | |
| I use diagrams to explain chemistry ideas | | | | | |
| Students develop their own diagrams to show their understanding of ideas | | | | | |
| I use concept maps to identify the key chemistry ideas for the topic | | | | | |
| I use 3D models to illustrate chemistry concepts | | | | | |
| I use role-plays to engage students in acting out chemical processes | | | | | |
| I draw graphs to show relationship between variables as in example of reaction rates, water pollution and sollubility | | | | | |
| I use flowcharts to illustrate processes | | | | | |
| I use equations to summarise chemical reactions | | | | | |

**2.5** How do you find out what your students know about chemistry? ……………….............

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2.6 How confident are you about the chemistry knowledge needed to teach chemistry? (tick one box)

| | Very confident | Confident | OK | Less confident | Not confident |
|---|---|---|---|---|---|
| SS2 Chemistry | | | | | |
| Reaction rates and collision theory | | | | | |
| Pollution and solubility | | | | | |

2.7 Please rate the extent to which your students are active and engaged in learning by ticking a box on the scale provided below

| Very active and engaged in learning | | | | | | | | | Very passive in learning |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

2.8 What benefit (s) is the use of diagrams, models, flowcharts, concept maps and photographs to the teaching and learning of chemistry?

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2.9 What time was the last science and chemistry professional development programmed you attended? 0 - 6 months ago ☐ 7 - 12 months ago ☐ 13 - months ago ☐ 19 – 24 months ago ☐ more than two years ☐

3.0 Indicate how interested in attending a chemistry workshop (tick a box)

| Very interested | Interested | Not interested |
|---|---|---|
| | | |

**Teacher final Survey Questionnaire (TFSQ)**

The final teacher survey questionnaire focused on knowing teacher's change in their beliefs about effective chemistry teaching and learning.

**Please provide answers to these questions in the spaces below**

**1.1** What do you believe are the characteristics of effective senior secondary chemistry teaching?

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1.2 What do you believe are the most effective ways of students learning chemistry?

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1.3 How often do you use the following approaches to teaching senior secondary chemistry? (tick one box on each line)

| **Approaches** | **every lesson** | **most lesson** | **some lesson** | **few lesson** | **Never** |
|---|---|---|---|---|---|
| Explaining chemistry ideas to students | | | | | |
| Writing notes on the board for students to copy | | | | | |
| Small groups of students discuss ideas | | | | | |
| Whole-class discussion of ideas | | | | | |
| Students read the chemistry textbook | | | | | |
| Teacher demonstrates a chemistry experiment | | | | | |
| Students do hands-on experiment | | | | | |
| I use diagrams to explain chemistry ideas | | | | | |
| Students develop their own diagrams to show their understanding of ideas | | | | | |
| I use concept maps to represent concept and identify the key basic chemistry ideas of the concept to teach | | | | | |
| I use 3D models as an illustration of chemistry concepts | | | | | |
| I use role-plays to engage students in activities describing their ideas in learning chemistry concepts | | | | | |
| I draw graphs for students to conceptualise chemistry concept | | | | | |
| I use flowcharts in conveying students' thinking on the chemistry concepts | | | | | |
| I use equations as an illustration of chemistry concepts | | | | | |

1.4 How do you find out what your students know about chemistry?

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1.5 How confident are you about the chemistry knowledge needed to teach chemistry? (tick one box)

| | Very confident | Confident | OK | Less confident | Not confident |
|---|---|---|---|---|---|
| SS2 Chemistry | | | | | |
| Reaction rates and collision theory | | | | | |
| Pollution and solubility | | | | | |

1.6 Please rate the extent to which your students are active and engaged in learning by ticking a box on the scale provided below

| Very active and engaged in learning | | | | | | | | | Very passive in learning |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

1.7 What benefit (s) is the use of diagrams, models, flowcharts, concept maps and photographs to the teaching and learning of chemistry?

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1.7 What difficulties did you have in teaching with multiple representations?

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1.8 What interested you most in this professional development workshop?

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2.0 What could have been done to improve the workshop?

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2.1 Will you recommend the workshop to be organising for other chemistry teachers?

Yes ☐ No ☐

Explain why:

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## APPENDIX B: STUDENT SURVEY QUESTIONNAIRE

**Student Survey Questionnaire**

**Students' perception about chemistry and learning in secondary schools**

Dear student,

Completing this questionnaire is to seek your opinions about the teaching and learning of chemistry in your school. You are required not to write your name and the name of your school. Carefully read the instruction in each section before giving your response (s).

There is no doubt that the information you provide will be useful to improve the teaching and learning of chemistry in Nigerian senior secondary schools. Your response (s) to this questionnaire will remain confidential and your name and school will not be identified in this research. Your answer will not affect your sores or grades. Therefore feel free to give your response (s) to all the questions.

Thank you for your participation in this study.

**Section A (Background information)**

1. Name of school: ……………………………………………………………………………….. (Fill in the blank space)

2. Age: 10 -13 years ☐ 13 – 15 years ☐ 15 – 17 years ☐ 17 -19 years ☐ (tick one box)

3. Sex: Male ☐ Female ☐ (tick one box)

**SECTION B:**

**Please indicate your agreement with the following statements by ticking the appropriate option in the table below SA= strongly agree; A= agree; D= disagree; SD = strongly disagree**

| | SA | A | UD | D | SD |
|---|---|---|---|---|---|
| **1. Why are you studying chemistry?**<br>• Chemistry is very interesting<br>• I derive pleasure in chemistry<br>• Chemistry makes me think deeply<br>• I would like to be a chemist/scientist<br>• Chemistry helps me understand the world around me | | | | | |
| **2. Do you enjoy studying chemistry?**<br>• It makes me bored<br>• Chemistry class is fun<br>• It makes me curious about a lot of things<br>• I enjoy chemistry lessons | | | | | |
| **3. How difficult do you find studying chemistry? Explain.**<br>• I don't remember what I learn<br>• It is the subject I understand mostly<br>• The language is too difficult to understand<br>• Chemistry is easy to learn<br>• Chemistry is difficult to learn<br>• I am confused in chemistry lessons | | | | | |
| **4. What opportunities does your teacher give you to apply chemistry to your daily life?**<br>• I understand my teacher's explanations because it relates it to world around me<br>• I can apply my knowledge of chemistry to solve everyday problems<br>• When faced with challenges in other science subjects, knowledge of chemistry provides me with solutions | | | | | |

5. What ways would you like your teacher to teach chemistry to help you learn?

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Please indicate how often you use the following approaches to teaching and learning in your chemistry class.

| **Approach** | **In every lesson** | **In most lessons** | **In some lessons** | **In a few lessons** | **Never** |
|---|---|---|---|---|---|
| Reading a chemistry textbook | | | | | |
| Copy notes on the board | | | | | |
| Teacher explains while we listen | | | | | |
| My teacher listens to my ideas | | | | | |
| I learn all alone in the class | | | | | |
| We discuss ideas in small groups | | | | | |
| Whole – class discussion of ideas | | | | | |
| Teacher demonstrates a chemistry experiment | | | | | |
| I do hands-on experiments | | | | | |
| I draw diagram to indicate my understanding on the chemistry taught | | | | | |
| I demonstrate my understanding using flowchart | | | | | |
| I draw graph of the chemistry concept taught to convey my thinking ideas | | | | | |
| I draw map to guide me identify specific and important ideas in the chemistry concept to learn | | | | | |
| We do role-play that engaged us in activities to describe our ideas of the chemistry concept we learn | | | | | |

**APPENDIX C: TEACHER INTERVIEWS AND STUDENT FOCUS GROUP QUESTIONS**

## Initial Teacher Interview Questions (ITIQ)

### Teachers' beliefs about effective teaching and learning of chemistry and their level of awareness on the use of representation

1. What are the main difficulties you face in teaching senior secondary chemistry?
2. Can you give example of how you explain and illustrate chemistry concepts to your students?
3. Which of these ways of teaching chemistry are most effective?
4. What learning activities are students typically doing in your chemistry lessons?
5. What do you consider the most important in your planning to enable you facilitate your student learning? And Why?
6. How do you assess your students' learning?
7. What indicators do you consider as evidence of effective learning in chemistry?
8. To what extent are your students actively engaged in learning?

## Post-lesson Teacher Interview Questions (PTIQ)

### Teachers' experiences and challenges with the use of multiple representations and extent to which students were actively engaged during the lesson

1. Describe the process (s) you used to actively engage your students' higher thinking during your lesson?
2. Do you face any challenges during these processes?
3. How do you overcome these challenges?
4. Were the students actively engaged and feel supported during the learning process?
5. What factors do you think motivate students to learn in chemistry lesson?
6. Do you consider the use of multiple representational teaching strategies difficult or easy? Explain
7. Explain the impact of the professional development workshops on your teaching practice?
8. Have the workshops affected your confidence for teaching chemistry?

## Final Teacher Interview Questions (FTIQ)

### To identify changes in teachers' practice and beliefs about effective chemistry teaching and learning

1. What do you believe are the most effective ways of students learning chemistry?
2. What can you recommend as the most effective ways of teaching senior secondary chemistry?
3. Do you think it is possible to make chemistry classrooms interesting for student? How
4. As a result of your participation on the professional development workshop, explain what benefited you mostly in the program?
5. Do you think this type of professional development workshop should be organising for other chemistry teachers and teachers in other areas of discipline? Why?
6. What other things can you suggest could have improved the workshop?

## Student Focus Group Questions (SFGQ)

**To identify the important things that helped students to learn during the lesson**

1. What is it like learning chemistry?
2. What helps you to learn chemistry?
3. Did the teacher teach differently in this topic? how
4. Did the graphs, pictures, models help you learn? Explain how?
5. What would you like your chemistry teacher to do differently and why?

**APPENDIX D: CLASSROOM OBSERVATION CHECKLIST**

This contains information on teacher's use of representation and students' active engagement in the learning process to confirm the expected impacts of the professional learning program on teacher's practice and students' engagement.

<table>
<tr><th>Date</th><th>School</th><th>Class</th><th>Teacher's name</th><th>Lesson topic</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Classroom setting</td><td></td><td>Resources used</td><td colspan="2"></td></tr>
<tr><td colspan="5">Learning and teaching purposes</td></tr>
<tr><td>Time (mins)</td><td colspan="2">Teacher activity</td><td colspan="2">Students' activity</td></tr>
<tr><td>5</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>10</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>15</td><td colspan="2"></td><td colspan="2"></td></tr>
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<tr><td>30</td><td colspan="2"></td><td colspan="2"></td></tr>
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</table>

## APPENDIX E: MAJOR FOCUS ACTIVITIES FOR THE WORKSHOPS

**Activities**

| **Day 1** | **Day 2** | **Day 3** |
|---|---|---|
| Welcome address and introduction<br><br>Workshop objectives<br><br>*constructing an effective multimodal text of a chemical concept<br><br>*improving teachers' knowledge for teaching chemical concept in an engaging manner<br><br>*assessing students' understanding of a learning concept through representation | Teachers constructing and interpreting multimodal representation<br><br>*symbolic representation<br><br>*particulate representation<br><br>*graphical representation<br><br>*3D model<br><br>*role-play<br><br>*demo | Feedback (teachers' successes, difficulties and ways to improve) on the challenge of engaging with and learning a multimodal representational strategy |
| Small group discussion<br><br>*Difficulties in teaching chemistry and engaging students in learning | Planning for classroom teaching<br><br>* planning a lesson format for single and double period using a multimodal representational technique | Whole group discussion *feedback from small group discussion |
| Whole group discussion: feedback from small group discussion | Reflection and sharing ideas<br><br>*planning lesson using a multimodal representation | Planning for next topic<br><br>*key features of water pollution and solubility |

| | | |
|---|---|---|
| | *identifying the easiest modes to use within the stipulated period<br><br>*getting access to resources/materials needed for each concept | |
| Range of representation – difficulties and benefits<br><br>*concept mapping<br><br>*symbolic representation<br><br>*particulate representation<br><br>*graphical representation<br><br>*role-play | Planning for school visits | Teachers constructing and interpreting multimodal representation<br><br>*concept mapping<br><br>*symbolic representation<br><br>*particulate representation<br><br>*water filter challenge<br><br>*3D model<br><br>*role-play<br><br>*flowchart |
| Creating representation<br><br>*key features of reaction rates and collision theory | Teachers' evaluation reports and responses on the intervention<br><br>*what learnt in the workshop<br><br>*what difficult and reason (s)<br><br>*what could have been improved<br><br>*how to apply the knowledge gained in the workshop | Planning for classroom teaching<br><br>*planning a lesson format for single and double period using a multimodal representational technique |
| Reflection and sharing ideas<br><br>*making abstract ideas in chemistry accessible<br><br>*engaging students actively using representation | | Reflection and sharing ideas<br><br>* extending knowledge gained to other teachers in the field |

*developing students' skills of the three levels of chemical representation

Focus group discussion

*teachers' beliefs about effective teaching and learning of chemistry

*possible ways to make chemistry classroom interesting for students

*What benefited teachers mostly during the workshop

*teachers' opinion on recommending workshop extension to other chemistry teachers and teachers in other subject areas

*suggestions for the workshop improvement

Distribution of final teacher survey questionnaire

Planning for the next school visits

## APPENDIX F: WORKSHOP MATERIALS

## WORKSHOP THEME: LEARNING HOW TO INTERPRETE & CONSTRUCT MULTIPLE REPRESENTATIONS TEACHING STRATEGIES IN CHEMISTRY

## Day 1: Lesson outline

**Aims**: to demonstrate reaction rates and collision theory using concept maps, diagrams, graphs, and role play representational teaching strategies.

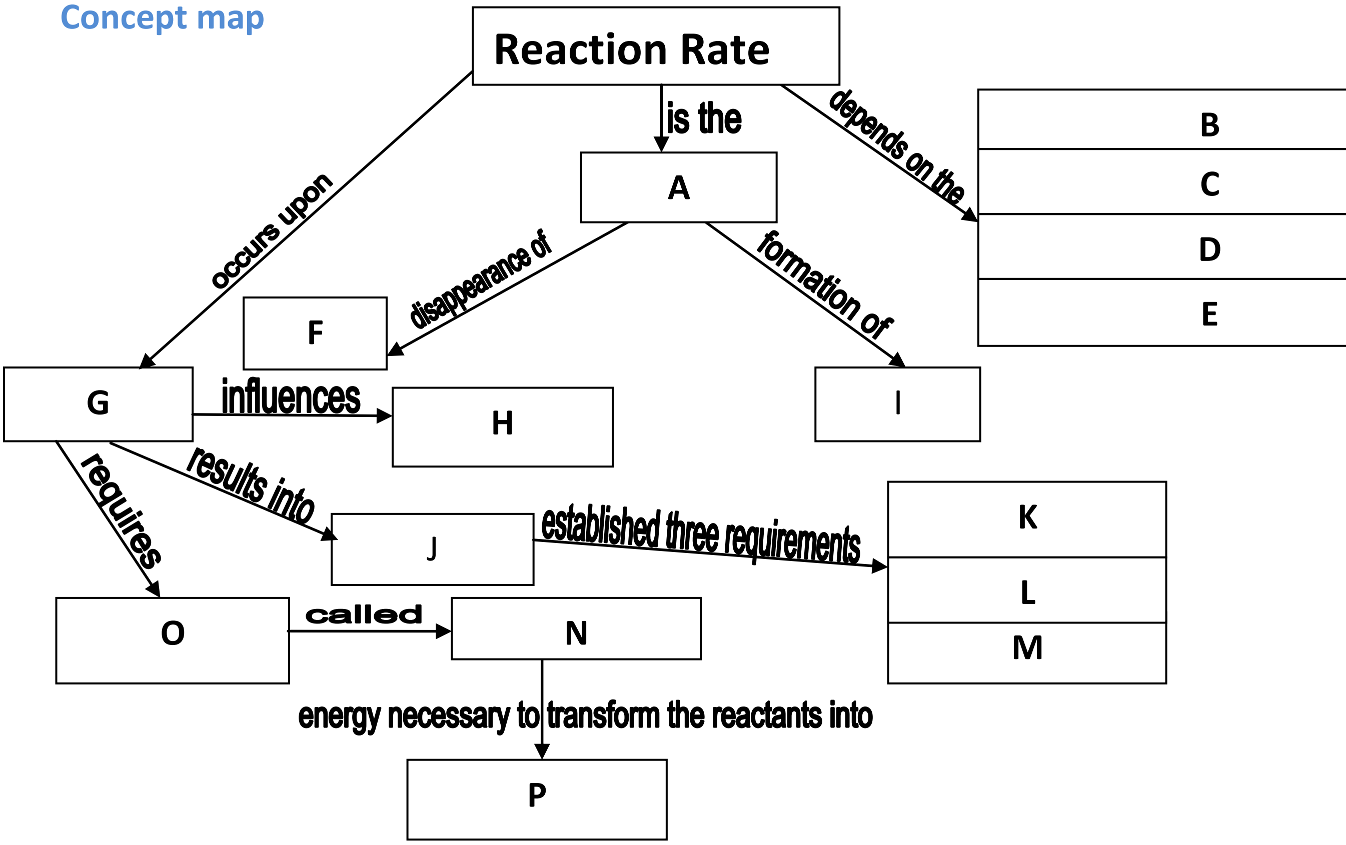
### Objectives: At the end of the lesson, you will be able to construct and interpret:

- concrete models and symbols to signify what is happening when molecule collides
- a representation of reaction rate at a molecular level
- energy profile diagrams that include activation energy barriers and label the activated complex or transition state
- a diagram to determine reaction rate in terms of changes in concentration over time
- representation indicating variables or factors that can affect rates of reactions

### Getting started on the demonstration

Step 1: We all have been teaching a concept on reaction rates and collision theory. Individual will develop a list of concepts maps on reaction rates and then a collision theory. Use the label on the written cardboard provided to develop the concept map as represented below.

Concept map




**Concept map showing key features of reaction rate concept**

**KEY FEATURES:**

**Reactants** **Reaction speed** **Measure of**
**Products** **Sufficient energy** **Activated**
**complex**

**Collision of two molecules** **Collision theory** **Activated**
**energy**
**Nature of reacting substances** **Effect of temperature changes** **Collision**
**Favourable geometry (orientation)** **Possession of a minimum energy** **Effect of**
**concentration**
**Effect of catalyst**

# Content

**Question: Consider two molecules $A_2 + B_2 \longrightarrow$ 2AB, how do these molecules react using a collision theory?**

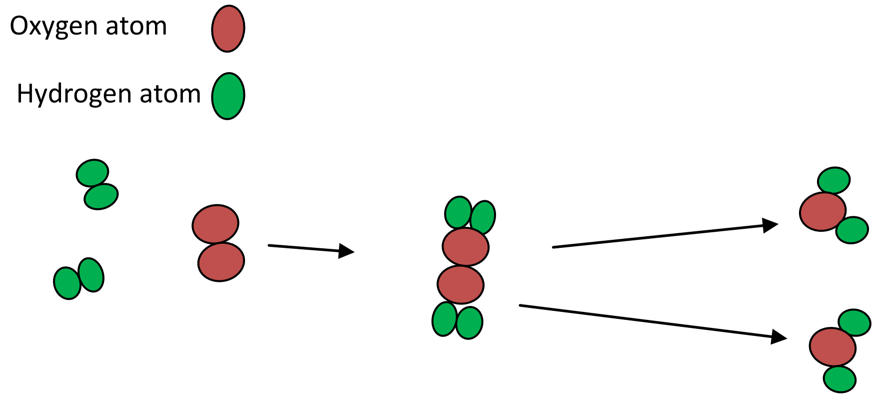
**For example, reaction between hydrogen gas and oxygen gas to produce liquid water**

## Symbolic representation

$2\ H_{2\ (g)} \quad + \quad O_{2\ (g)} \longrightarrow \quad 2H_2O\ (l)$

Note: The molecules collide with sufficient energy to disrupt the bond in the reactants particles and at proper orientation. For every oxygen atom that combines with a molecule of hydrogen, there is one molecule of water produced.

## Particulate representation




forward reaction

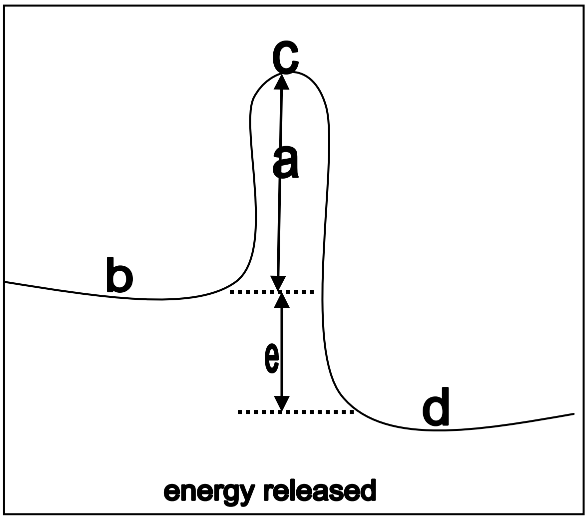
## Role play

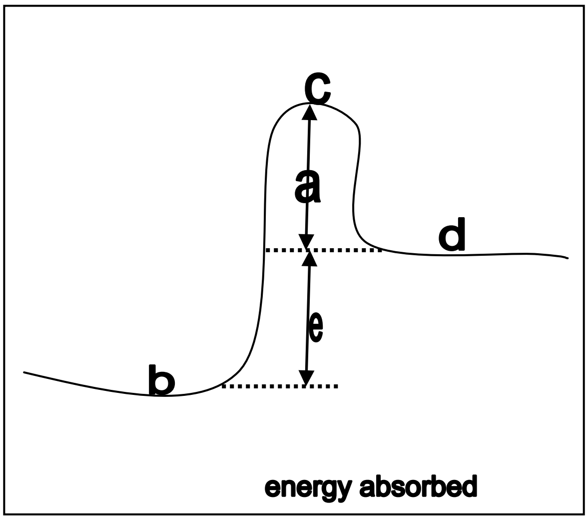
Six students acting a role play of the above colliding molecule. Pair into three groups: two pairs representing two hydrogen molecules and one pair representing oxygen molecule. What happens at the colliding molecules?

**Discussion: Introducing ideas of a progressive reaction rates using energy profile diagrams**

**Collision theory**: Energy diagrams explaining activation energy, transition state, endothermic and exothermic reaction

### Graphical representation of energy profile diagrams




**Explain what each letter represents in the above diagrams.**

**Indicate which of the diagrams is endothermic or exothermic.**

### Focus questions

1) **State three things that are necessary for the reaction to proceed**
2) **Construct energy profile graph for the reaction between hydrogen molecule and oxygen molecule represented above, indicate whether the reaction is exothermic or endothermic for the forward and reverse reaction.**
3) **Construct a particle representation under the energy profile graph**
4) **The reaction below is a symbolic representation of the reaction between nitrogen and hydrogen molecules:**

   $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

   i. **Sketch the particulate representation of the reaction**

   ii. **Show how you would role-play the reaction**

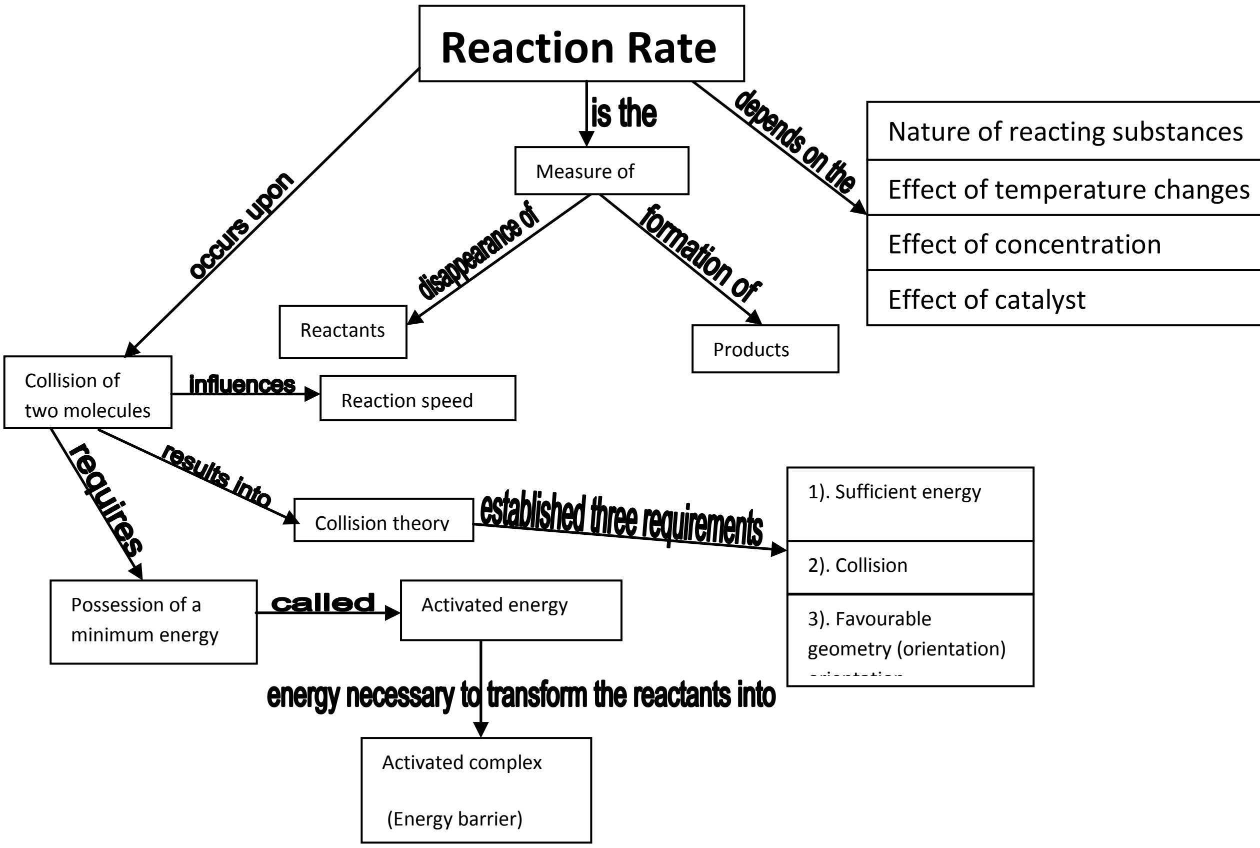
   iii. **Construct energy diagram for the reaction showing the relative potential energies of the reactants and the products and the transition state using a particulate representation for endothermic and exothermic reactions.**

## Day 1: TEACHER'S GUIDE ON LESSON OUTLINE

Three things necessary for a reaction to proceed

1. The reacting particles must collide (collision)
2. The collision between the reactant particles must occur with enough energy to disrupt the bonds in the reactant particles (sufficient energy)
3. The particles must collide with a favourable orientation (correct location)

### Concept map




**Concept map showing key features of reaction rate concept**

<u>**KEY & STATEMENT:**</u>

| | | |
|---|---|---|
| **F-Reactants** | **H-Reaction speed** | **A-Measure of** |
| **I-Products** | **K-Sufficient energy** | **P-Activated complex** |
| **G-Collision of two molecules** | **J-Collision theory** | **N-Activated energy** |
| **B-Nature of reacting substances** | **C-Effect of temperature changes** | **L-Collision** |
| **M-Favourable geometry (orientation)** | **O-Possession of a minimum energy** | |

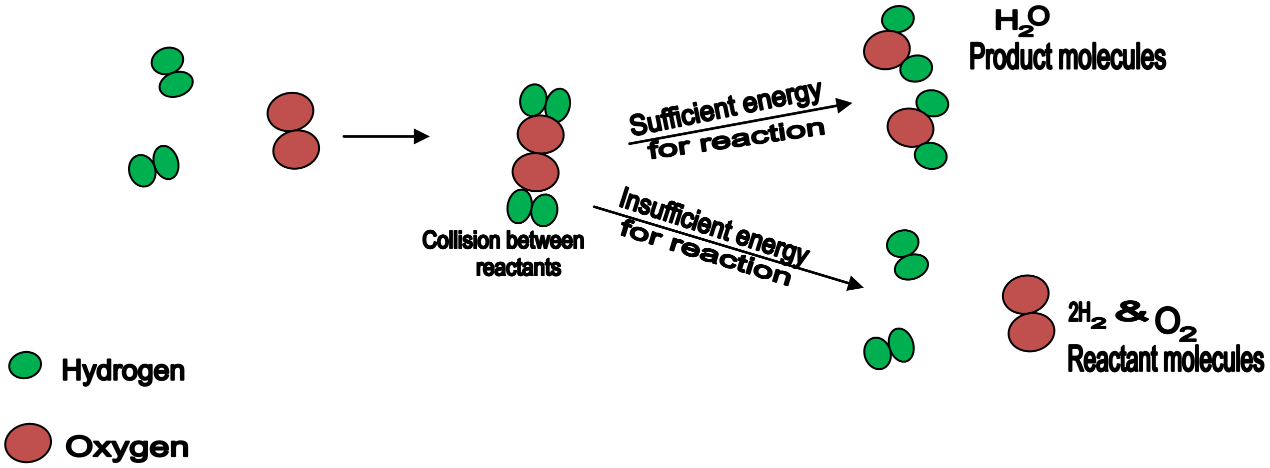
**D-Effect of concentration** **E-Effect of catalyst**

**For example, reaction between hydrogen gas and oxygen gas to produce liquid water**

### Symbolic representation

$2\ H_{2\ (g)} \quad + \quad O_{2\ (g)} \longrightarrow 2H_2O\ (l)$

### Particulate representation




### Role play

Six students acting a role play of the above colliding molecule. Pair the students into three groups, two pairs representing two hydrogen molecules and one pair representing oxygen molecule. What happens at the colliding molecules?

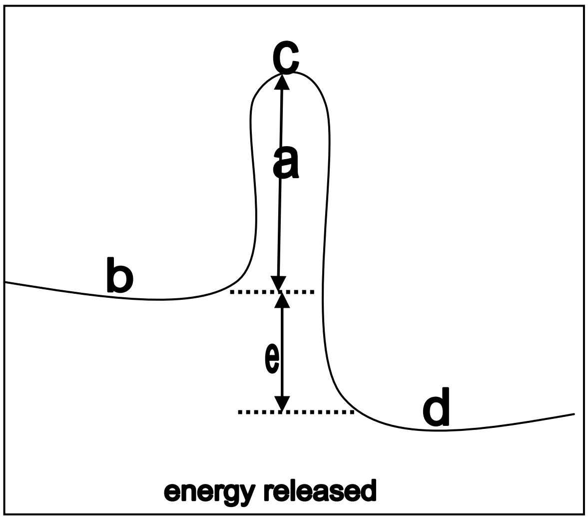
### Rehearse the role play:

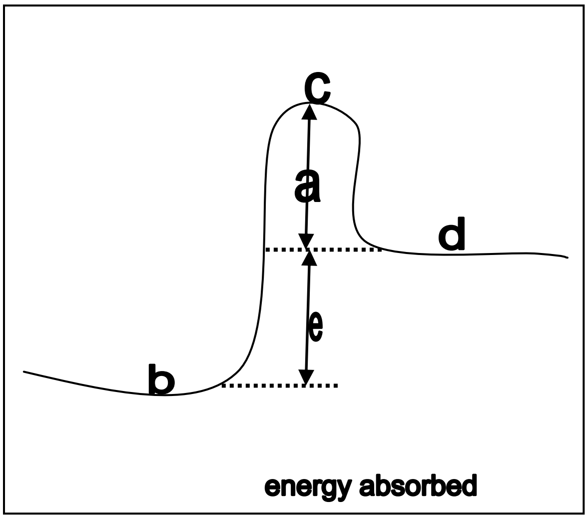
When flying $H_2$ and $O_2$ gas molecules collide, their negatively charged electron clouds repel each other and actually become distorted. If the collision energy is sufficient, electrons are rearranged, a water molecule forms, and energy escape (the reaction is exothermic)

$H_2 + O_2 \longrightarrow 2H_2O$ But if the kinetic energy of the collision is too low, the molecules simply bounce away.

$H_2 + O_2 \longrightarrow 2H + 2O$

### Graphical representation of energy profile diagrams




1. **Explain what each letter represents in the above diagrams.**
2. **Indicate which of the diagrams is endothermic or exothermic**.
3. **At which point the starting material and product form an activated complex**

**Possible ideas:**

1. Letter "a" refers to activation energy

   "b" refers to the Reactants

   "c" refers to Activated complex/Transition state

   "d" refers to Products

   "e" refers to Heat of Reaction

2. Energy released: Exothermic reaction

   Energy absorbed: Endothermic reaction

3. At letter "c"

**Focus questions**

1) **State three things that are necessary for a reaction to proceed**
2) **Construct energy profile graph for the reaction between hydrogen molecule and oxygen molecule represented above, indicate whether**

**the reaction is exothermic or endothermic for the forward and reverse reaction.**

3) **Construct a particulate representation under the energy profile graph**
4) **The reaction below is a symbolic representation of the reaction between nitrogen and hydrogen molecules:**

   $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

   iv. **Sketch the particulate representation of the reaction**
   v. **Show how you would role-play the reaction**
   vi. **Construct energy diagram for the reaction showing the relative potential energies of the reactants and the products and the transition state using a particulate representation for endothermic and exothermic reactions.**

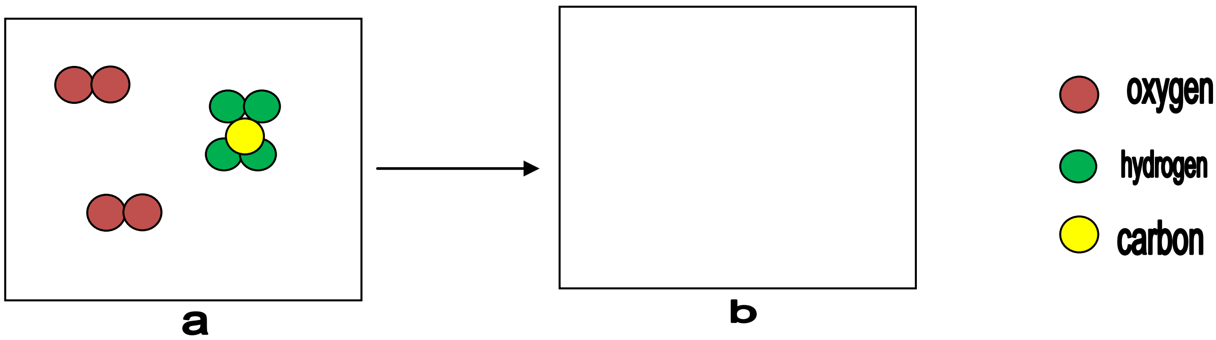
## Day 2: Lesson outline

**Activity 1**

Use a symbolic representation and particulate representation to write a balanced molecular equation for the reaction between methane gas, ($CH_4$) and oxygen gas to produce carbon dioxide and water

Show the energy profile diagram for the above reaction. Indicate whether the reaction is endothermic or exothermic (Briefly describe your reasoning).

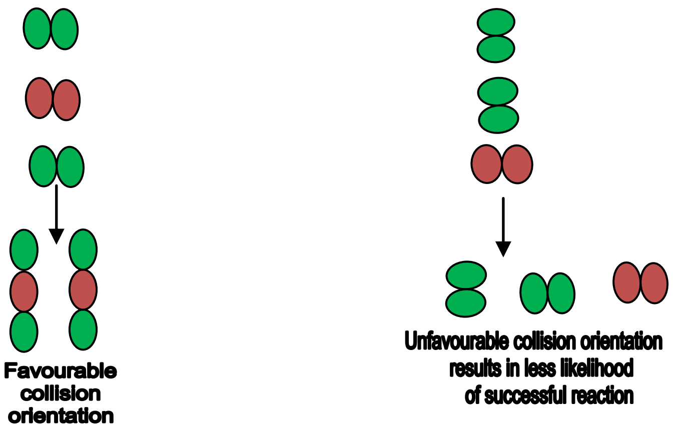
Draw using a particulate representation of the contents of the container in "b" after the reaction




**Activity 2**

**Demonstrating collision geometry of a reacting molecule (e.g. Reaction between a hydrogen molecule and oxygen molecule).**

### Graphical representation




A diagram on the effect of collision orientation and the likelihood of a reaction occuring

**Role play:** Demonstrating effect of collision geometry in the above reaction.

### Model

Use balls and sticks provided in the bag to model a reaction between carbon dioxide ($CO_2$) and water ($H_2O$) to produce hydrogen carbonate ($H_2CO_3$). Use the green ball to represent hydrogen atom, red ball as oxygen atom and the yellow ball to represent the carbon atom.

Represent what happen using a particulate drawing

 = oxygen atom

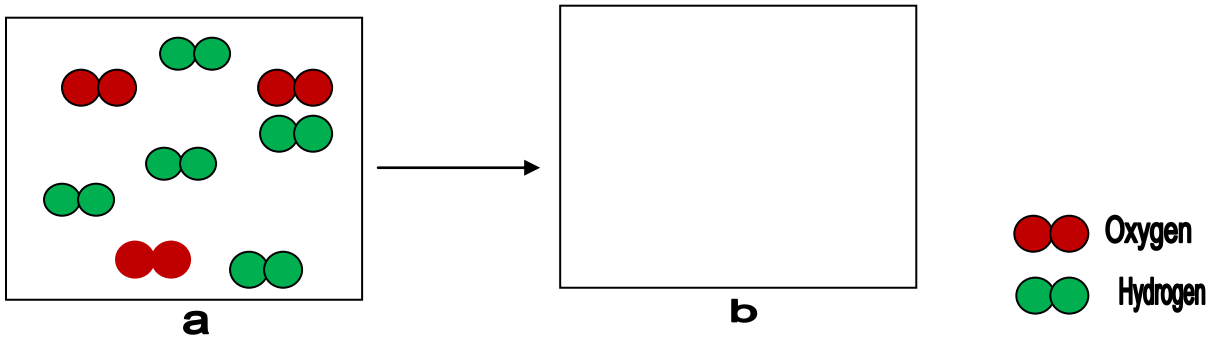
 = hydrogen atom

 = carbon atom

Use your drawing to explain the collision geometry of the reacting molecules.

### Activity 3

Hydrogen and oxygen react to form water. Consider the mixture as shown in the diagram



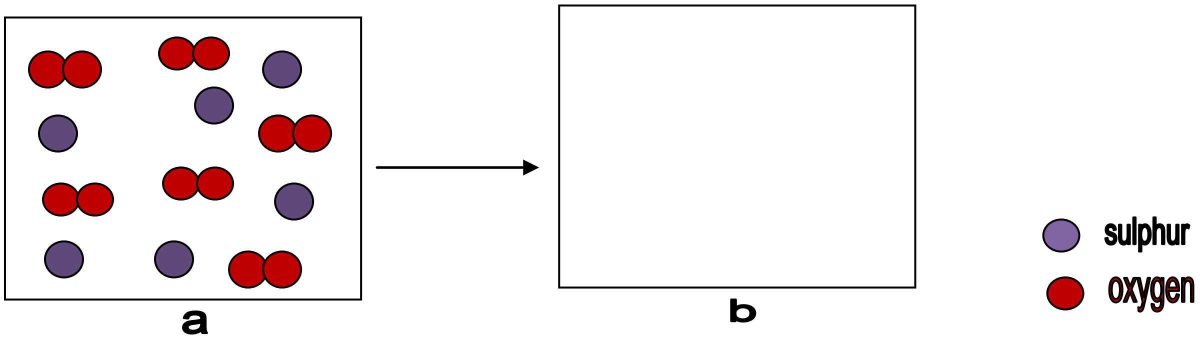

- Write a balanced equation for this reaction
- What is the limiting reagent in this reaction?
- What is the maximum number of water molecules that can be formed in this reaction?
- Draw a particulate representation of the contents of the container after the reaction

### Activity 4

**Role play:** to demonstrate limiting reagent in the above reaction

## Activity 5

Consider the mixture of sulphur (S) and oxygen gas ($O_2$) in a closed contaner (a). The equation for a reaction is $6\ S + 6\ O_2 \longrightarrow 6\ SO_2$. Represent using sub microscopic drawing in (b) to show what happen at the completion of the reaction.




**Discussion:** Some reactions are slow, while some are fast. Can we explore several factors that control the speed of a reaction and give example(s)?

### Activity 6

What time measurement can you assign to the following activity

I. Explosion of household gas and oxygen
II. Burning of candle/wood/log
III. Burning of paper/sawdust
IV. Rotting of wood
V. Rusting of iron

## Activity 7

### DEMO

**Objective**: to determine reaction rate for the decomposition of hydrogen peroxide

**Materials**: $250cm^3$ measuring cylinder, a large tray to catch any foam that spills over the top of the cylinder, $25cm^3$ of hydrogen peroxide solution to make $150cm^3$ of 50 volume solution, 0.5g of powdered manganese (iv) oxide, and stopwatch or clock for timing.

**Description**: Decomposition reaction of hydrogen peroxide, $H_2O_2$ to produce oxygen gas and water, $H_2O$ occur at a very slow rate but the addition of a small amount of manganese dioxide, $MnO_2$ causes the hydrogen peroxide solution to bubble vigorously due to the catalytic effect of the $MnO_2$.

**Procedure**: In $250cm^3$ measuring cylinder, place about $1cm^3$ of washing up liquid. Add 0.5g of powdered manganese (IV) oxide into the cylinder containing washing up liquid. Then add 25cm$^3$ of hydrogen peroxide solution. Start timing how long foam takes to rise to the top of the cylinder. Place a glowing spill in the foam; it will re-light confirming that the gas produced is oxygen.

- Use a symbolic representation to indicate the reaction
- Use a graphical representation to indicate steepness of the curve showing concentration of reactant and product vary with time
- Draw and label the catalysed and uncatalysed energy profile diagram for both reactions

**Activity 8:** Planning for classroom teaching

## Reflection questions and sharing ideas

- How do I plan my lesson activities using a multimodal representational technique learnt in this workshop?
- Which of these modes will be easy to use within the available stipulated lesson period?
- What resources/materials needed for each concept and how do I get access to these resources/materials
- What activity will help assessing students' learning of the concept

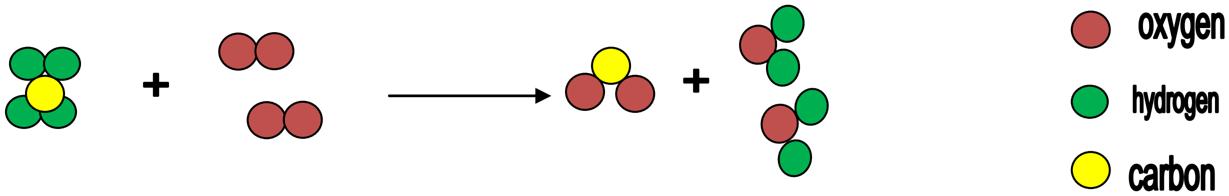
## Day 2: TEACHER'S GUIDE ON LESSON OUTLINE

**Activity 1**

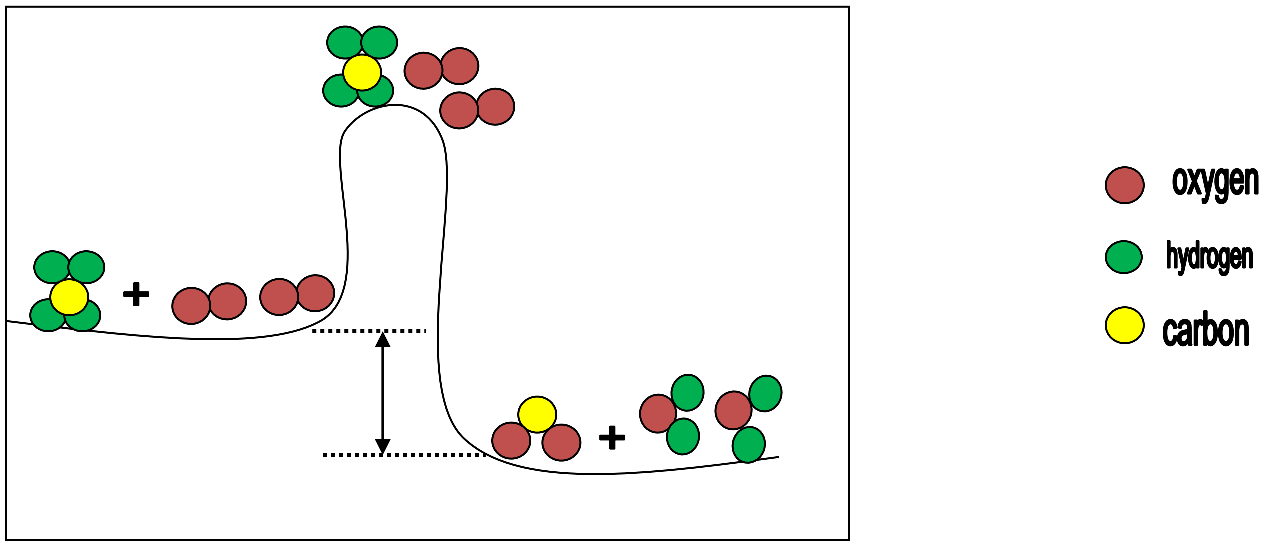
**Symbolic representation**

$$CH_{4\,(g)} + 2O_{2\,(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

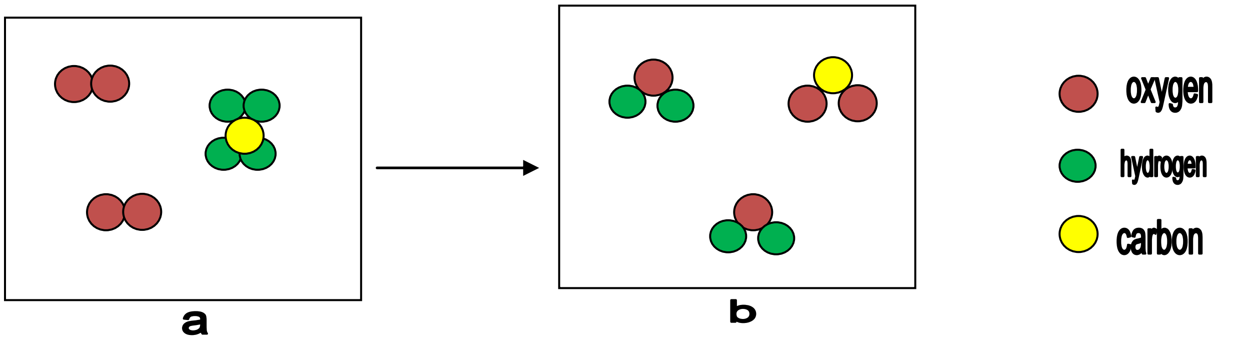
**Particulate representation**




**Graphical representation of energy profile diagrams**



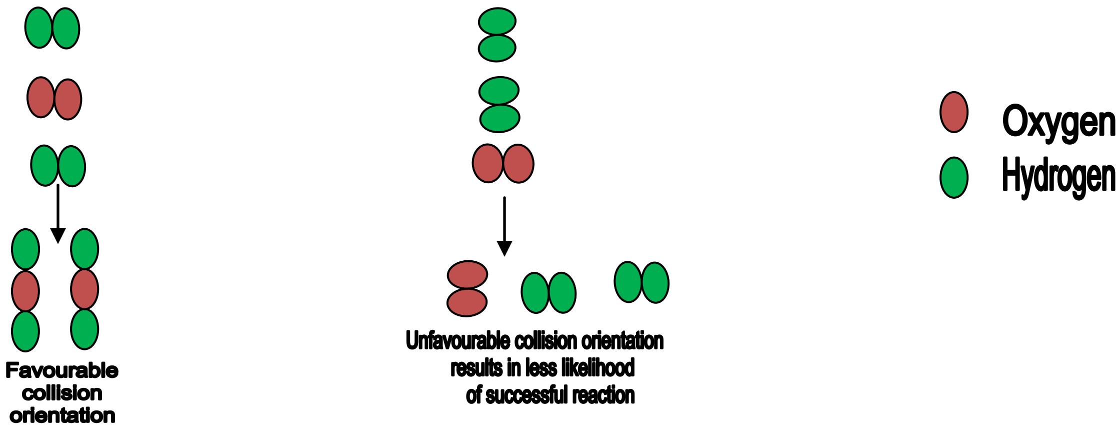

The reaction between $CH_4$ and $O_2$ is exothermic and is comparatively slow due to bond breaking and bond forming processes.




**Activity 2**

2.1: Demonstrating collision geometry of a reacting molecule (e.g. Reaction between a hydrogen molecule and oxygen molecule).

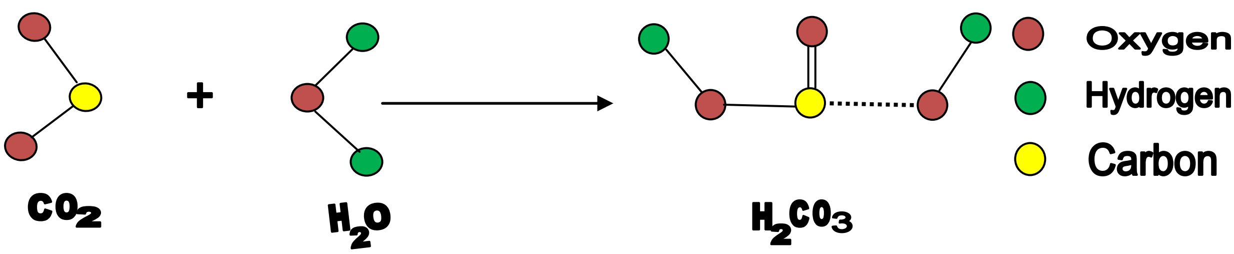
**Particulate representation**




A diagram on the effect of collision orientation and the likelihood of a reaction occuring

**2.2: Role play to demonstrate effect of collision geometry (orientation) in the above reaction**

**2.3 Model representation**



Carbon dioxide is far more soluble in water than are similar gases such as oxygen or nitrogen. It can also react with the water to form dihydrogen carbonate (carbonic acid). it consists of one central carbon atom surrounded by three oxygen atoms in a trigonal planar arrangement, with two hydrogen atom attached to two of the oxygens.

In chemistry, trigonal planar is a molecular geometry with one atom at the center and three atoms at the corners of a triangle all in one plane.

$$H_2O_{(l)} + CO_{2(g)} \rightleftharpoons H_2CO_{3(aq)}$$

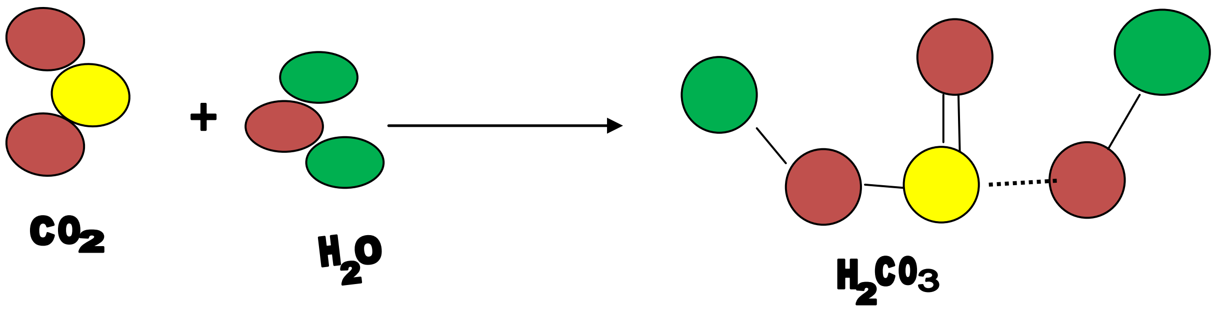
This reaction is reversible, it is continuously occurring in both directions, carbonic acid is being made and destroyed all the time. This means that if you increase the amount of carbon dioxide by increasing the pressure you will increase the speed of the production of carbonic acid reducing the amount of gas.

Similarly if you reduce the pressure you will slow the creation of carbonic acid, but it will keep on splitting up to form carbon dioxide gas. This is why if you rapidly reduce the pressure on a carbonated drink it can rapidly turn into foam

**2.4 (a) Symbolic representation**

$$H_2O_{(l)} + CO_{2\,(g)} \longrightarrow H_2CO_{3\,(aq)}$$

**2.4 (b) Particulate representation**




**Activity 3**

**3.1 Symbolic representation**

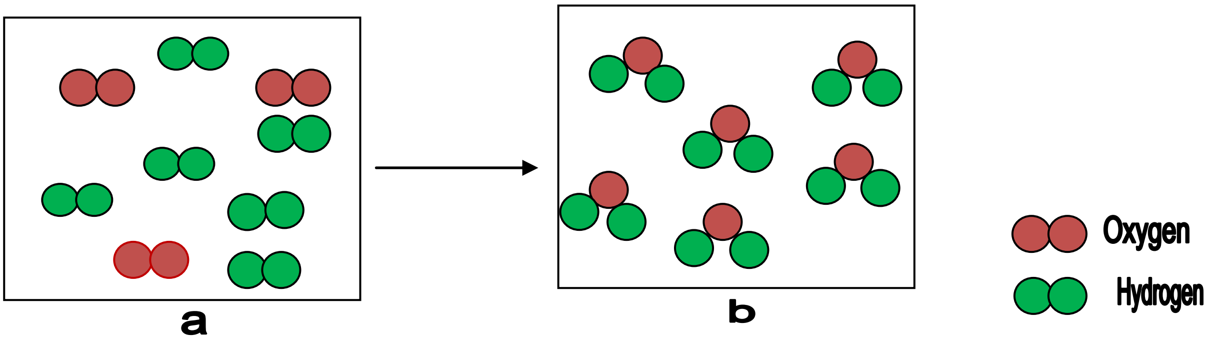
$$6H_2 + 3O_2 \longrightarrow 6H_2O$$

**3.2** The limiting reactant is the reactant that will run out first as a reaction progresses. The limiting reactant, also called a limiting reagent limits the amount of product that can be made in a reaction—once this reactant is consumed, the reaction will stop. Hydrogen would be the limiting reactant because it takes twice as many moles of hydrogen atoms than oxygen atoms to make water. In other words, each oxygen atom needs two hydrogen atoms in order to make water. The hydrogen would run out before the oxygen does, and once that happens, the reaction would stop.

**Hydrogen is the limiting reagent in the reaction**

**3.3 Maximum number of Six (6) water molecules**

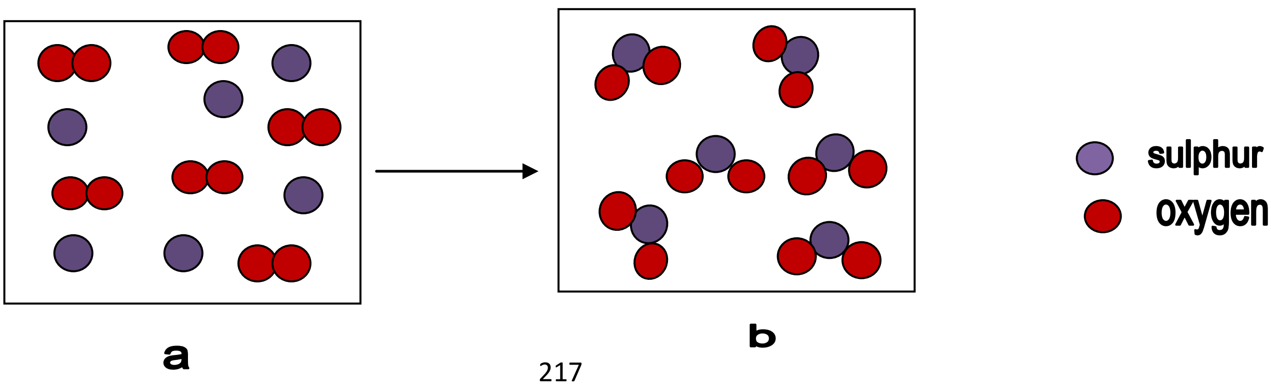
**3.4 Particulate representation**




**3.4 Role play: to demonstrate limiting reagent in the above reactio**

**Activity 4**

4.1 Consider the mixture of sulphur (S) and oxygen gas ($O_2$) in a closed contaner (a). The equation for the reaction is $6S + 6O_2 \longrightarrow 6SO_2$. Represent using particulate representation in (b) to show what happen at the completion of the reaction.



**4.2 Discussion:** Some reactions are slow, while some are fast. Can we explore several factors that control the speed of a reaction and give example(s)?

### Possible ideas

Nature of reactants: Slower reactions will have higher activation energies than faster reactions. This is related to the ease with which bond-breaking and re-forming processes occur. For example, the low reactivity of nitrogen gas ($N_2$) is related to the large amount energy needed to break the N-N triple bond

Temperature: An increase in temperature makes particles move faster which forces reactants to collide and react more frequently. Gas molecules and oxygen molecules mix readily but do not have enough energy to react at room temperature. The flame raises the temperature and the energy of collisions, so the reaction rate increases. The heat released by the reaction maintains the high temperature, and the reaction continues spontaneously.

Concentration: Reaction rate depends upon the concentrations of the reactants. For example in air, a lighted splint glows and soon goes out because of the limited supply of oxygen but when place in pure oxygen, the splint bursts into flame. This is because increased concentration of oxygen greatly speeds up the combustion reaction.

Surface area: A log burns more slowly but small pieces of wood burns quickly. Also, vegetable cut into slices cook more quickly than a whole vegetable. This is because increase in surface area increases the amount of the reactant exposed for reaction, which further increases the collision frequency and the reaction rate.

Catalyst: A catalyst increases the rate of a reaction by lowering the activated energy barrier because it supplies more energy for the reactants to form product within a given time. For example, combination reaction of hydrogen and oxygen at room temperature is negligible, but in a trace of finely divided platinum (Pt) as a catalyst, the reaction is rapid.

### Activity 5

VI. Explosion of household gas and oxygen (microseconds)
VII. Burning of candle (seconds)
VIII. Burning of wood (minutes)
IX. Burning of log (minutes)
X. Burning of paper (seconds)
XI. Burning of sawdust (seconds)
XII. Rotten of wood (months)
XIII. Rusting of iron (days)

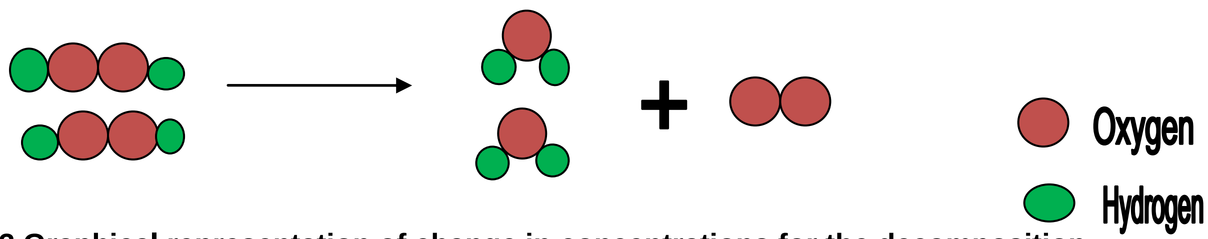
### Activity 6

#### 6.1 Symbolic representation

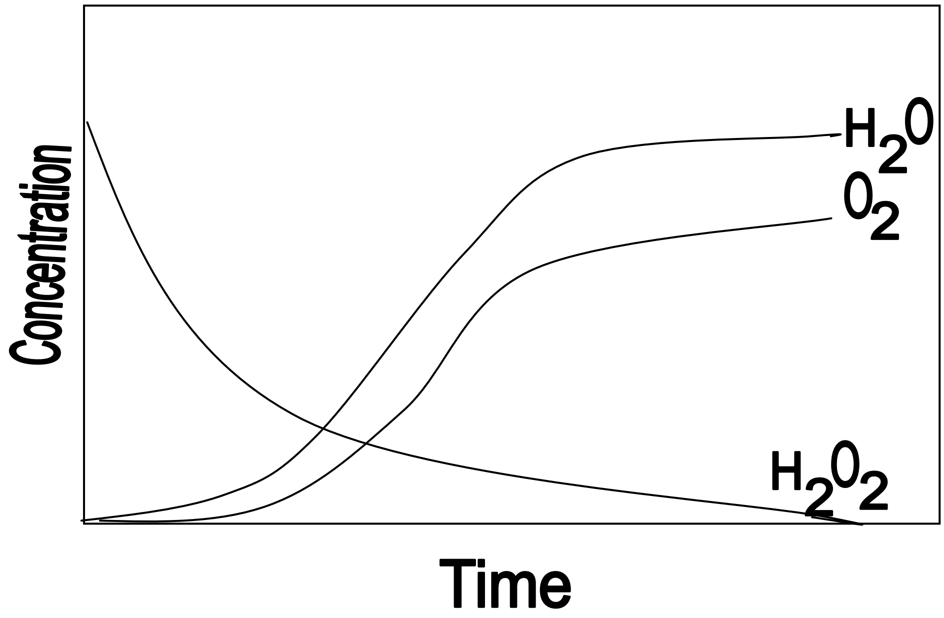
$$2H_2O_2 \longrightarrow 2H_2O + O_2 \text{ (Very slow)}$$

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2 \text{ (Very fast)}$$

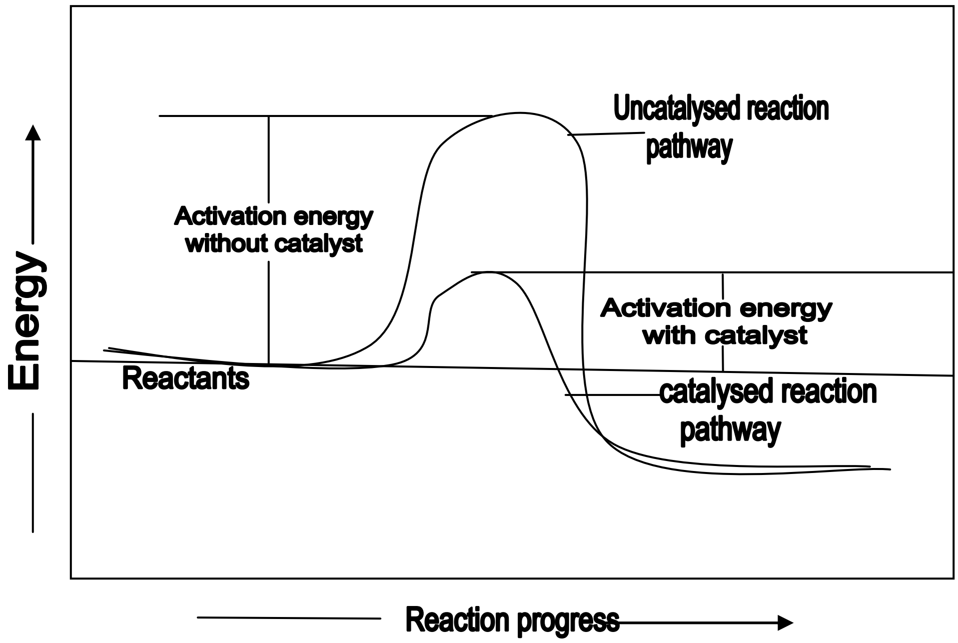
### 6.2 Particulate representation




### 6.3 Graphical representation of change in concentrations for the decomposition of $H_2O_2$




### 6.4 Catalysed and Uncatalysed energy profile diagram for both reactions




**Activity 7:** Planning for classroom teaching

### Reflection questions and sharing ideas

How do I plan my lesson activities using a multimodal representational technique learnt in this workshop?

Which of these modes will be easy to use within the available stipulated lesson period?

What resources/materials needed for each concept and how do I get access to these resources/materials

What activity will help assessing students' learning of the concept

HANDOUT FOR TEACHERS' RESPONSES AT THE END OF DAY 2 ON THE CHALLENGE OF ENGAGING WITH AND LEARNING HOW TO INTERPRET A MULTIMODAL REPRESENTATIONAL STRATEGY

| |
|---|
| Using multiple representations to engage students in learning |
| What did you learn from this workshop? |
| What do you think is difficult? Why? |
| What do you think could have been improved in this workshop? |
| How do you intend to apply what you gained in this workshop? |

## DAY 3: WORKSHOP ACTIVITIES

## Handout for teachers' responses on the challenge of engaging with and learning how to interpret a multimodal representational strategy

| |
|---|
| Using multiple representation to engage students in learning |
| What was successful? Why? |
| What was difficult? Why? |
| How would you improve? |

## DAY 3: LESSON OUTLINE

### Group discussions (1 hour)

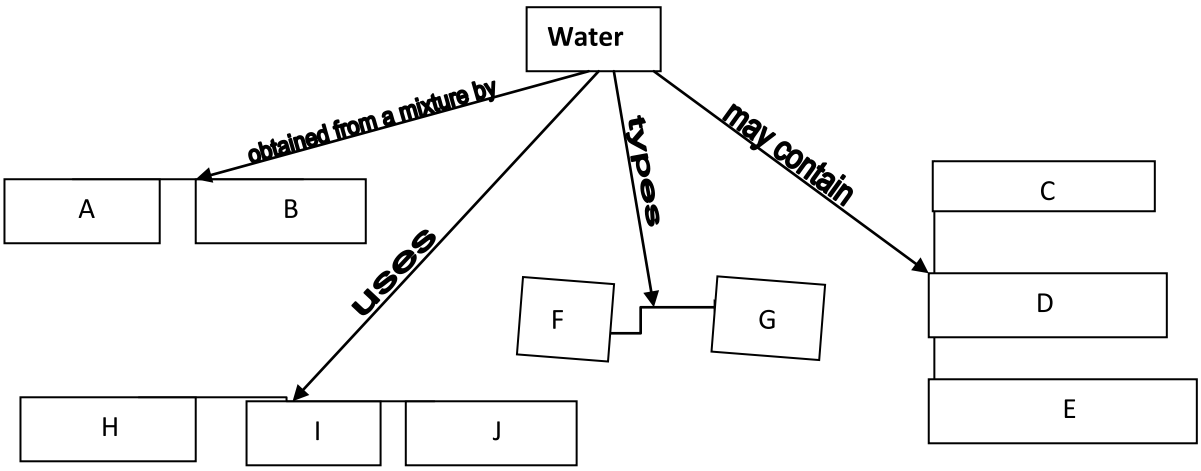
**Step 1:** teachers reporting on the challenge of engaging with and learning how to interpret multiple representations of the same concepts (successes, difficulties/challenges and ways of improvement).

Reporting tips:

- What was successful? Why
- What was difficult? Why
- How would you improve?

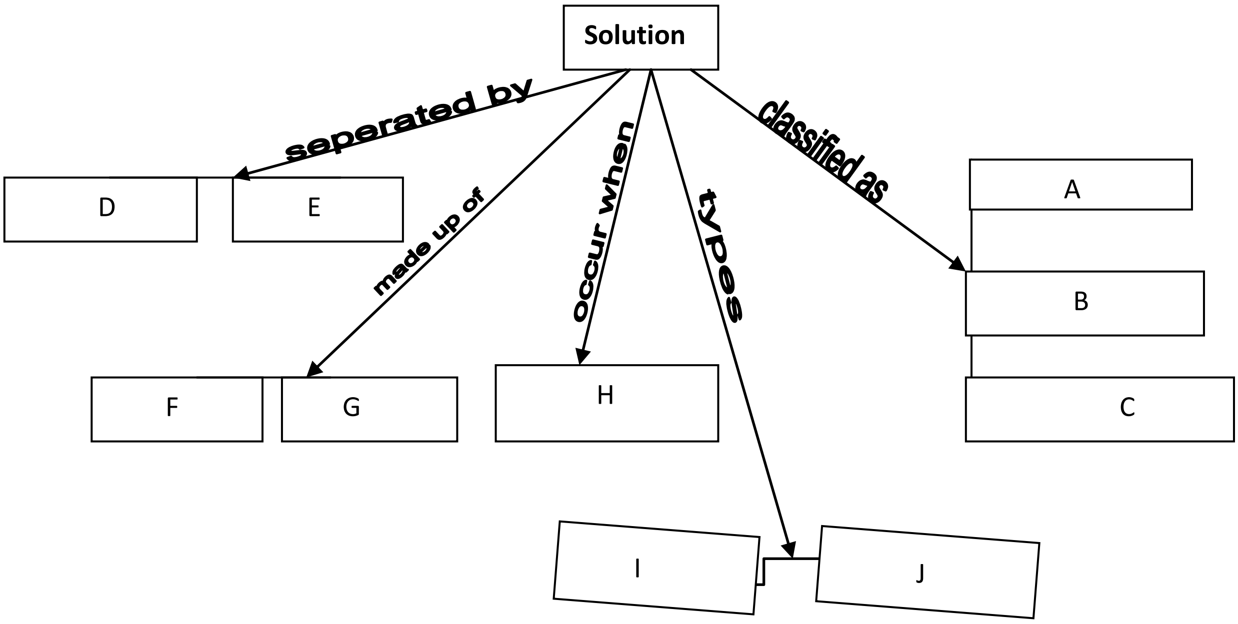
**Step 2**: planning for next topic (**Water pollution and solubility**)

**Step 3**: Create a **concept map** on water and solution




**Key and statements**

Dissolved solid    Dissolved gases    Undissolved solid    Soft
Hard    Filtration    Distillation    Agriculture
Power    Drinking




**Key and statements**

A solute dissolves in a solvent   Homogeneous   Heterogeneous

Solvent

Supersaturated   Distillation,   Filtration

Saturated   Unsaturated

Solute

**Discussion (30 minutes**): identifying key ideas on the concept

- Distinguish between heterogeneous and homogeneous mixtures using a diagram
- Give examples of solutions that contains solids or gases
- Explain how polarity of water enables it to dissolve many different substances
- Describe ways to increase the rate at which a solute dissolves in a solvent
- Explain the meaning of solubilities and compare the solubilities of various substances
- Describe dilute, concentrated, saturated, unsaturated and supersaturated solutions
- Describe method used to remove hardness of water

General ideas

- Water is called universal solvent because it dissolves more substances than any other liquid.
- The path of water through the environment is described by the water cycle
- Solutions are composed of solutes and solvents
- In general, solutes dissolve in solvents that are similar in polarity
- The polarity of water molecule allows hydrogen bonding
- A material is soluble if it dissolves to an appreciable degree and insoluble if not. A substances maximum possible concentration is called its solubility.

- Soluble, solution, solute, and solvent are terms used to describe various parts of the solubility process
- A solution is saturated when it contains the maximum amount of dissolved solute at a given temperature
- An unsaturated solution is a solution that contain less than the quantity of solute needed to saturate it under the existing conditions.
- A supersaturated solution is a solution that contains more solute than a saturated solution could normally hold under the existing set of conditions
- The rate of dissolution is affected by the size of the solute particles, the temperature of the solvent and by agitation
- When ionic substances dissolve in water, they separate into positive and negative ions

**Group discussion (30 minutes)**: linking ideas on the possibility of water sources, water circle, water pollution and its control.

1. Identify different states of water
2. Why water is refers to as universal solvent?
3. Where does our water come from?
4. Healthy water is pure water. Why is it important that we are aware of the chemistry of water?
5. What are the causes of water pollution?
6. What are the effects of water pollution?
7. How do we make water pure?
8. How do we treat contaminated water?

**Activity 1**

Draw and explain using particulate representation to show phase changes of water molecule.

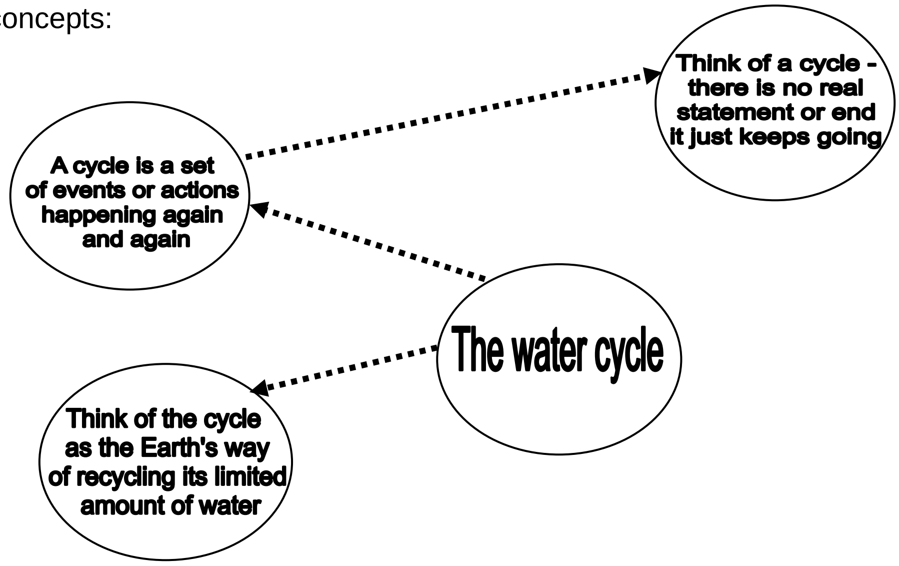
**Illustration**: Using pictures of water cycle and water treatment plants for discussion

**Activity 2 (25 minutes)**

**Construct a water filter capable of separating the visible dirt from the plastic bottle full of muddy water. Provide well labelled diagram of the constructed filter and reason for the choice of the materials.**

**Activity 3 (15 minutes)**

Water cycle concepts:




**Flow chart representation**

(Water, plants, animals, sunshine, evaporation, transpiration, rain, water vapour, clouds, cooling, condensation, precipitation, soaks into ground (run off), ground water, lakes, rivers, oceans)

**Challenge**: Develop a list of flow chart using each word on a piece of cardboard provided.

**Activity 4**

**(A) Role plays (30 minutes)**

**Objectives:** To describe the movement of water within the water circle (adapted from the project: water circle game). Students will investigate the parts of a water cycle and discuss how water travels through the entire system.

**Procedures:** Divide students into groups of 10 or more. Make cardboard name tags that list the water cycle parts (use words as in water cycle concepts listed above) and have the students hang the nametags around their necks or safety pin them to their shirts. Make a tag out of pink cardboard or construction paper that says water. To start the game, sit the children down in a circle with everyone facing the centre. State that during the game the water will cycle through the system. One player (the plant) will take the water tag and walk around the outside of the circle. At some point the plant will drop the water behind a seated player and will then run around the circle. The seated player will pick up the water, run after the cycler, and try to tag him or her. The cycler tries to get back to the spot where that player was seated without being tagged. If the cycler is tagged, then he/she remains the cycler, takes back the water card, and begins the game again. At the end of the game, discuss some of the paths that water took. Will water continually travel through the system? Will it ever disappear? What does the word cycle mean? Reinforce the idea that the water we use today has been used by plants and animals for millions of years.

### Solubility concept

Discussion: To discuss solubility concept

A solution is any homogenous mixture of two or more substances. In other words, a substance dissolves in a liquid; the combination is called a solution. The liquid is the solvent and the dissolved material is the solute.

SOLUTE + SOLVENT = SOLUTION

Salt or sugar dissolves in water is an example of a solid solute in a liquid solvent. Salt and sugar are the solute and water is the solvent.

Different substances can exhibit very different solubilities in a particular solvent and this is affected by the nature of the solute and the solvent

NaCl is readily soluble in water while oxygen is less soluble and sand is virtually insoluble. Also solubility of a particular substance can be different in different solvents. Olive oil, for example is insoluble in water but quite soluble in kerosene.

Solvents and solutes are often classified as polar and non polar. Like tends to dissolves like. A polar substance will tend to dissolve in a polar solvent, but not in a non polar solvent. Similarly, a non polar substance will tend to dissolve in a non polar solvent but not in a polar solvent.  . For example, sugar will dissolve in water, but not in cooking oil, and butter will dissolve in cooking oil, but not in water. Water and sugar are example of polar substances while oil, butter kerosene, and petrol are example of non polar substances.

**(B)**

i. Draw what a saturated and unsaturated solution of NaCl would look like
ii. Construct a diagram to represent what happens when $AgNO_3$ solution is mixed with NaBr solution.
iii. Explain using a diagram when 210g of sugar is mixed with 100g of cold water.

### Activity 5 (10 minutes)

Show symbolic and particulate representations of 1M solution of magnesium chloride (MgCl)

**ACTIVITY 6 (15 minutes)**

## Use of model

Construct a ball and stick model of water molecule ($H_2O$) using green colour of balls provided in the bag to represent the hydrogen atom and the red colour as the oxygen atom. Use the toothpicks as the stick joining the atoms together.

Apart from water molecule, build up a ball and stick model of methane ($CH_4$), methanol ($CH_3OH$), and ethanol ($CH_3CH_2OH$) molecules, the yellow colour in the bag represents carbon atom.

Once you have completed your models, draw on your worksheets a representation of each of your constructed models. Ensure you make a key to indicate the colour that represents each atom.

**Activity 7**

Consider solute sodium chloride (NaCl) in a solvent (water)

- Construct a model using the cardboard nametags in the bag provided for the ionic solid of sodium chloride dissolved in water. Explain your model.
- Draw a representation of your model and make a key to represent your drawing.

**Activity 8 (20 minutes)**

Describe using diagram whether the following mixtures is homogeneous or heterogeneous.

a) Oil and water
b) Food colouring and water
c) Mixture of clay and water
d) Sugar and kerosene

Discussion: sharing ideas on solubility of different ionic compounds.

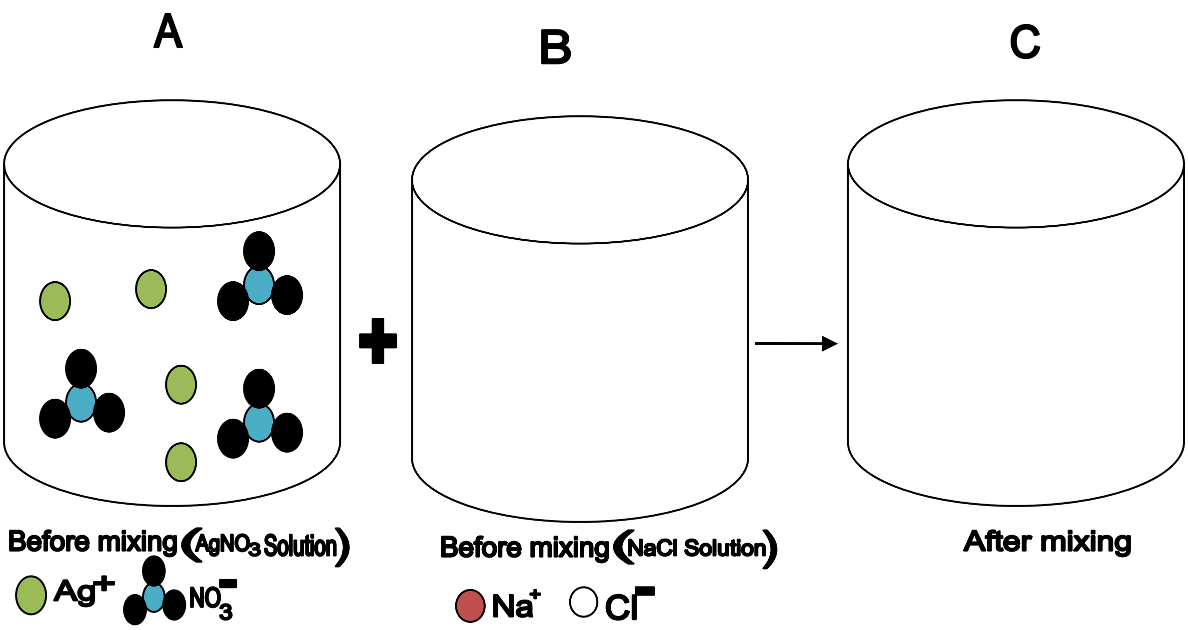
**Activity 9 (30 minutes)**

Described in beaker “A” below is a representation of 100ml of a 1M silver nitrate solution.

i. Draw a representation of 100ml of a 1M sodium chloride solution in beaker “B” by using the drawing key
ii. Use a symbolic representation to write a balanced equation of the reaction for the two mixtures

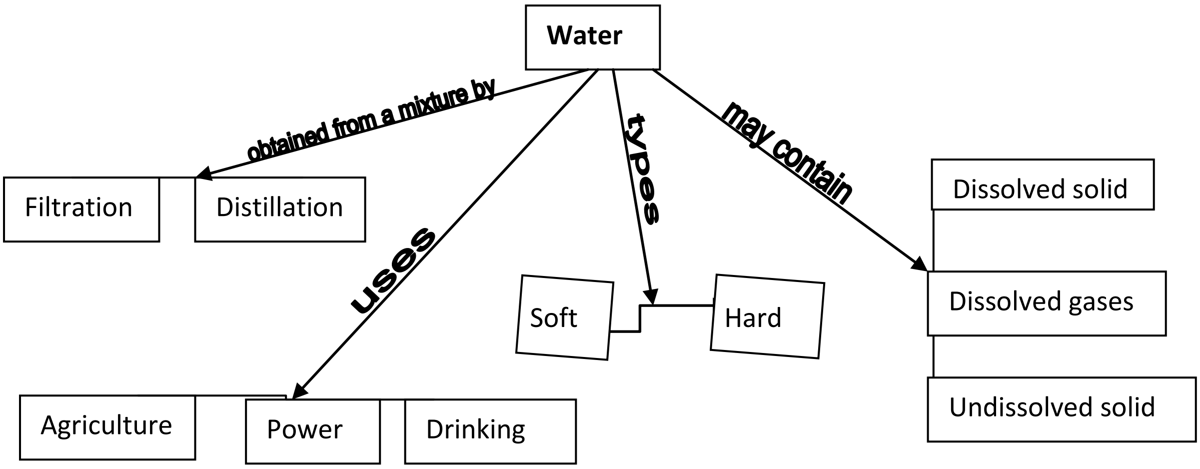
iii. Draw the results of mixing the two solutions in beaker "C" using a particulate representation

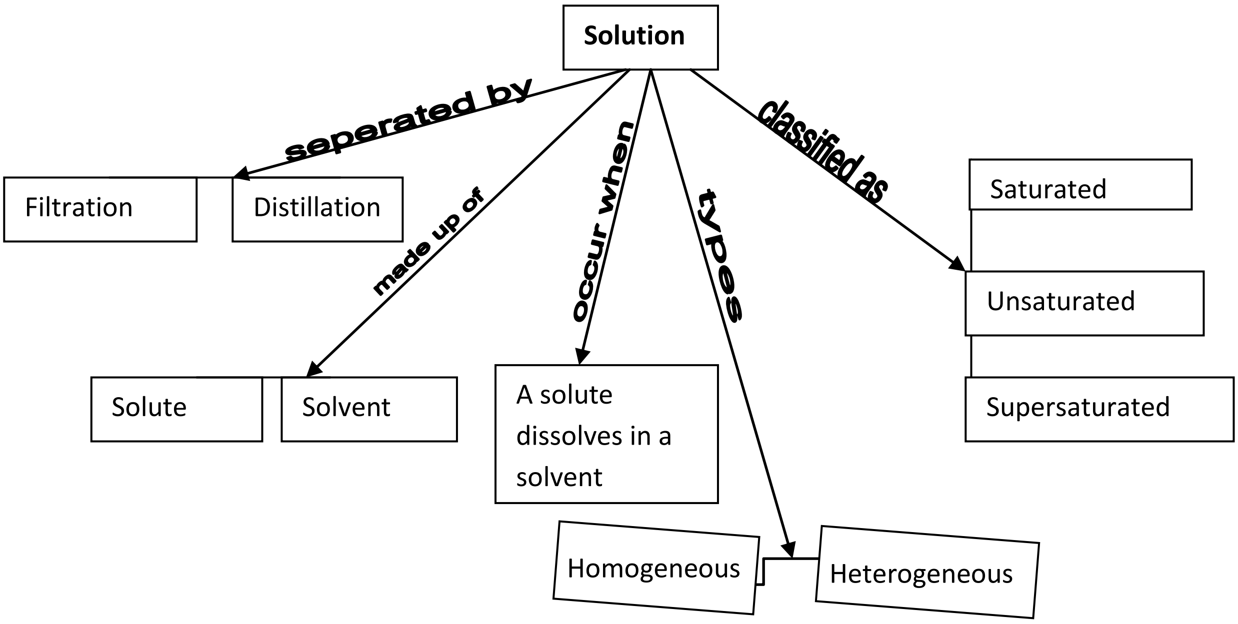
iv. Briefly describe your reasoning to interpret the diagram in beaker "C" when the two solutions were mixed.



## DAY 3: TEACHER'S GUIDE ON LESSON OUTLINE

### Concept Map on Water and Solution




General ideas

- Water is called universal solvent because it dissolves more substances than any other liquid.
- The path of water through the environment is described by the water cycle
- Solutions are composed of solutes and solvents
- In general, solutes dissolve in solvents that are similar in polarity
- The polarity of water molecule allows hydrogen bonding

- A material is soluble if it dissolves to an appreciable degree and insoluble if not. A substances maximum possible concentration is called its solubility.
- Soluble, solution, solute, and solvent are terms used to describe various parts of the solubility process
- A solution is saturated when it contains the maximum amount of dissolved solute at a given temperature
- An unsaturated solution is a solution that contain less than the quantity of solute needed to saturate it under the existing conditions.
- A supersaturated solution is a solution that contains more solute than a saturated solution could normally hold under the existing set of conditions
- The rate of dissolution is affected by the size of the solute particles, the temperature of the solvent and by agitation
- When ionic substances dissolve in water, they separate into positive and negative ions

## Group Discussion

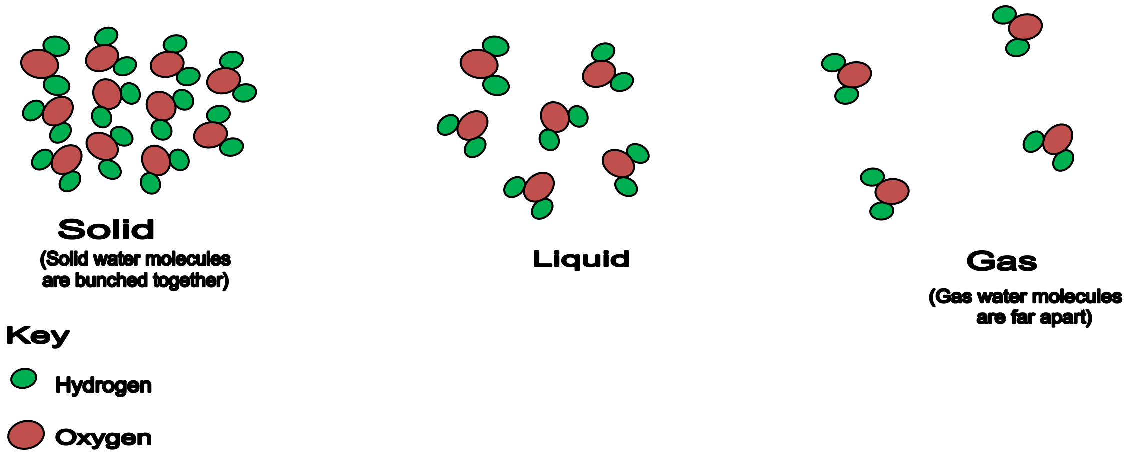
Possible ideas

1. Water exists in three states: These are solid, liquid and gas. The changes from a solid to a liquid to a gas or from a gas to a liquid to a solid are called a phase changes. Water changing from solid to liquid is said to be melting. When it changes from liquid to gas, it is evaporating. Water changing from gas to liquid is called condensation. When it changes from liquid to solid it is freezing.
2. Water is called universal solvent because its bipolar molecule enables it to dissolve a wide variety of substances than any other liquid.
3. Water is found on earth in all three forms. Earth water is always in movement and the water cycle describes the continuous movement of water on, above, and below the surface of the earth. When it rains, most of the water soaks into the earth as ground water. The rest runs off the land and into streams, rivers and lakes as surface water, much of which seeps back into the oceans. We take water from two sources:
   - Surface water in rivers, lakes and reservoirs
   - Ground water in underground wells
4. It is necessary to be aware of chemistry of water because water covers about 75% of the Earth's surface. It plays a significant role in all of our day-to-day lives. We drink it, enjoy it for recreation, and use it as part of a manufacturing process. Water is an integral part of every ecosystem and many industrial processes. More importantly, to avoid contaminated water
5. The following are the causes of water pollution:
   - Oil spillage, Industrial waste, human waste, soil erosion, dumping of refuse into rivers and oceans, sewage, pesticides and waste from farms.
6. The pollutants encourage bacterial/microbes/germs growth. It also leads to dissolved chemicals and undissolved solid particles.

7. Most of the water in streams and rivers is unsuitable for drinking. It has probably fallen as rain through polluted air, and then run along muddy fields or dirty streets. Water is cleaned before we use it; this takes place at water works or water treatment plant.

8. Boiling, distilling and filtering.

**Activity 1**




Explanation: Water molecules in solid (e.g. ice) are bunched together and do not move freely. Whereas, liquid water molecules are moving fast enough to break free though still attached to each other. This allows liquid water to assume the shape of its container. When water is a gas, the molecules are free to move about.

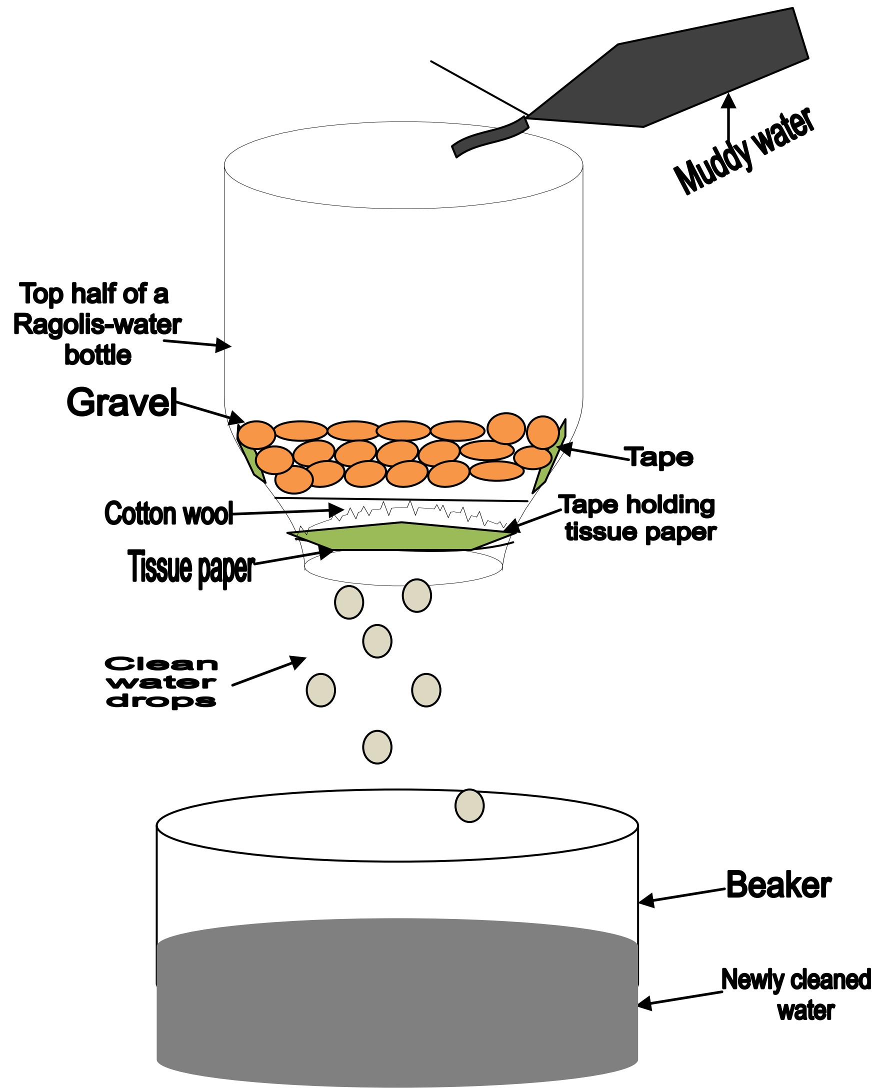

**Activity 2**

**Aims**: To construct a water filter capable of separating the visible dirt from a glass full of muddy water

Materials

- Top half of a plastic water bottle
- 200mls of very dirty water
- sand
- gravel
- tissue paper

- One cotton wool and Cello tape

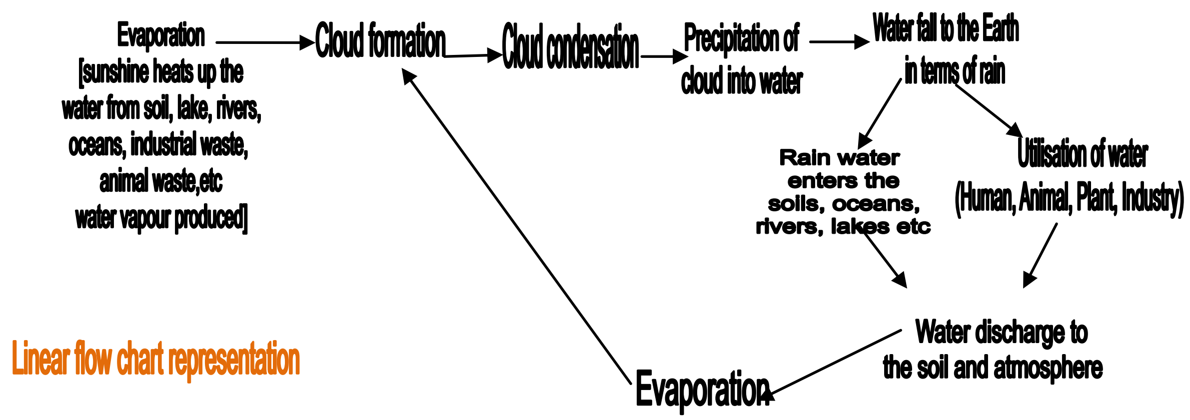


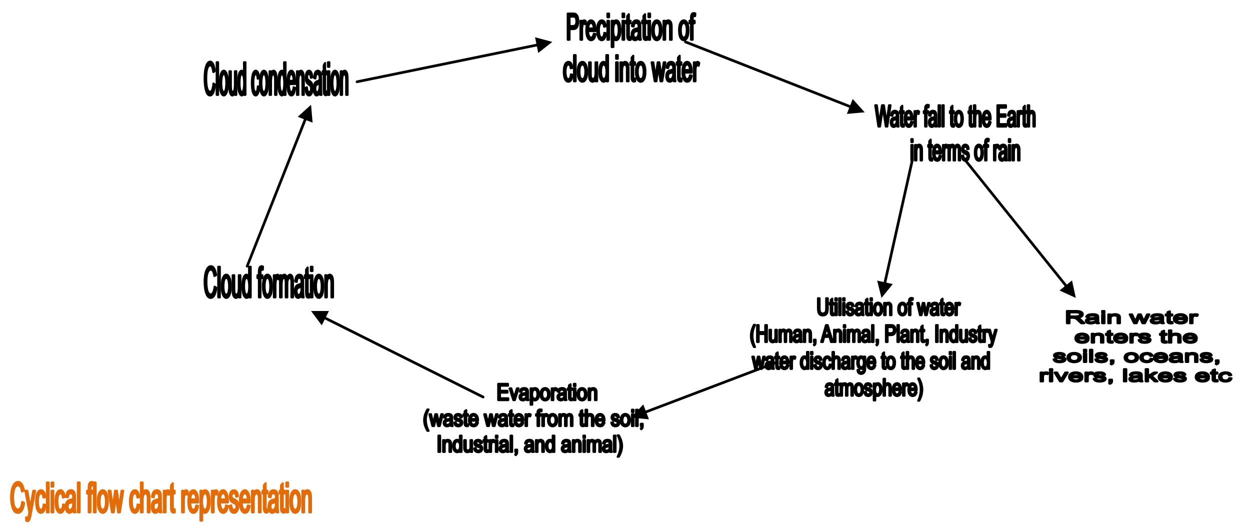

Choice of materials

- sand, to filter out what the gravel will not.
- gravel, to catch most of the dirt.
- Cotton wool, to filter out what the gravel and sand will not.
- tissue paper, to see clearly the dirt in it.

### Activity 3

### Flow chart representation of a water cycle



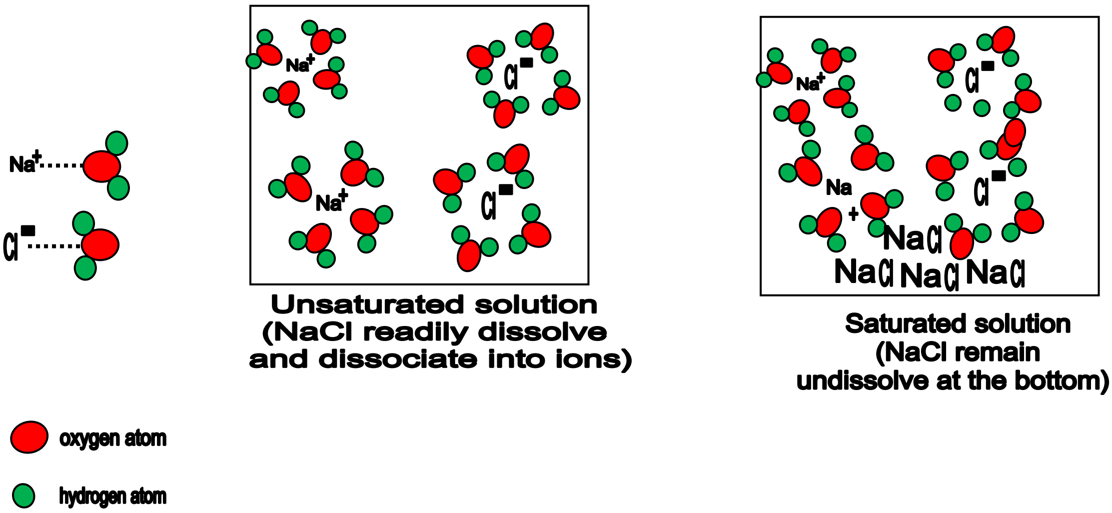




### Activity 4

**Role play** of a water cycle concept

**Procedures:** Divide students into groups of 10 or more. Make cardboard name tags that list the water cycle parts (use words as in water cycle concepts listed above) and have the students hang the nametags around their necks or safety pin them to their shirts. Make a tag out of pink cardboard or construction paper that says water. To start the game, sit the children down in a circle with everyone facing the centre. State that during the game the water will cycle through the system. One player (the plant) will take the water tag and walk around the outside of the circle. At some point the plant will drop the water behind a seated player and will then run around the circle. The seated player will pick up the water, run after the cycler, and try to tag him or her. The cycler tries to get back to the spot where that player was seated without being tagged. If the cycler is tagged, then he/she remains the cycler, takes back the water card, and begins the game again. At the end of the game, discuss some of the paths that water took. Will water continually travel through the system? Will it ever disappear? What does the word cycle mean? Reinforce the idea that the water we use today has been used by plants and animals for millions of years.

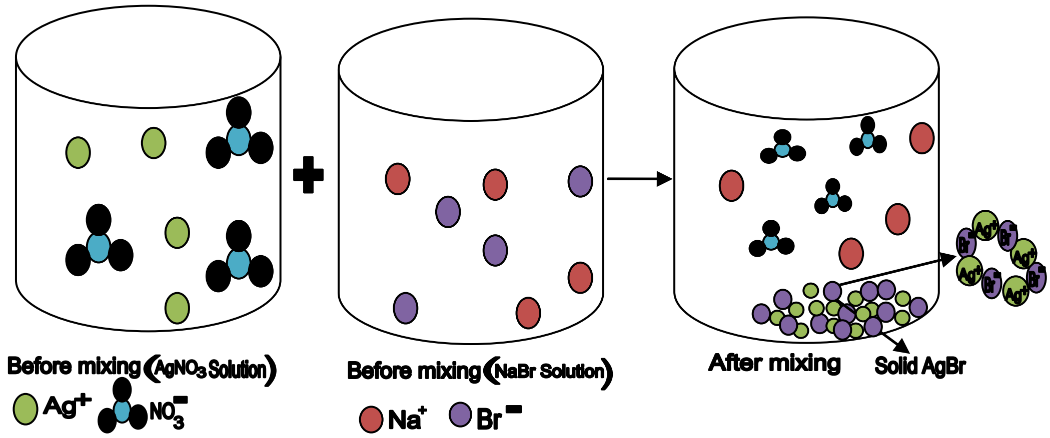
4B(i)



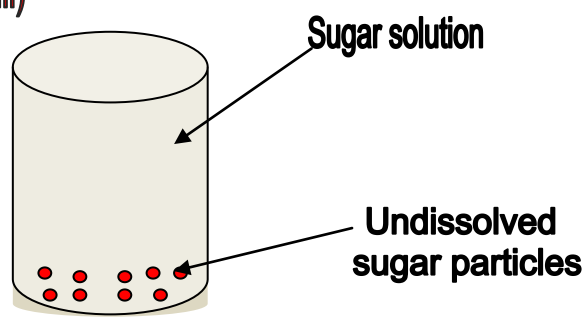

Unsaturated solution (NaCl readily dissolve and dissociate into ions)

Saturated solution (NaCl remain undissolve at the bottom)

4B(ii)




4B (iii)



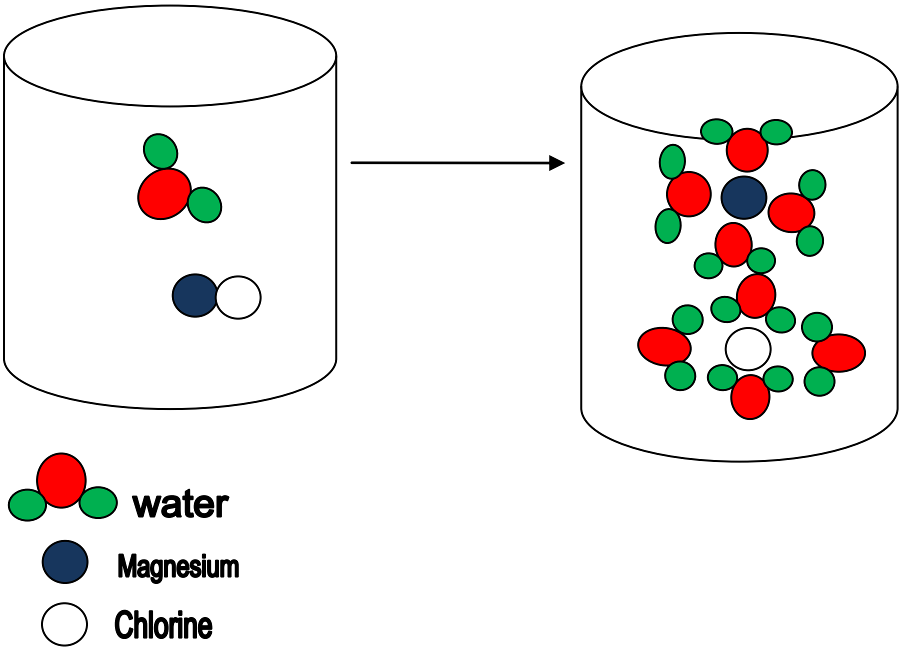

Saturated sugar solution (Sugar particles remain undissolve at the bottom)

**Activity 5**

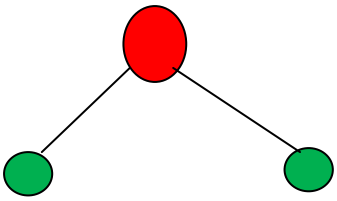
**Symbolic representation** of 1M solution of magnesium chloride (MgCl)

$MgCl_{2\,(s)} \xrightarrow{H_2O} MgCl_{2\,(l)} \longrightarrow Mg^{2+} \quad 2\,Cl^{-}$

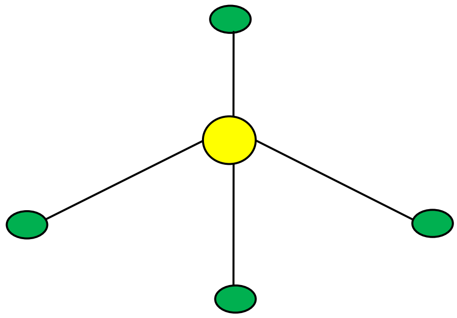
**Particulate representation**



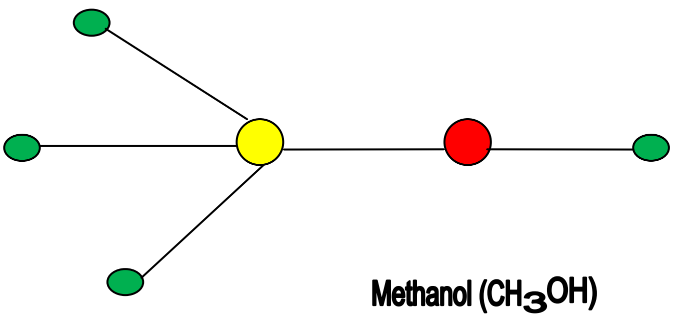

**ACTIVITY 6**



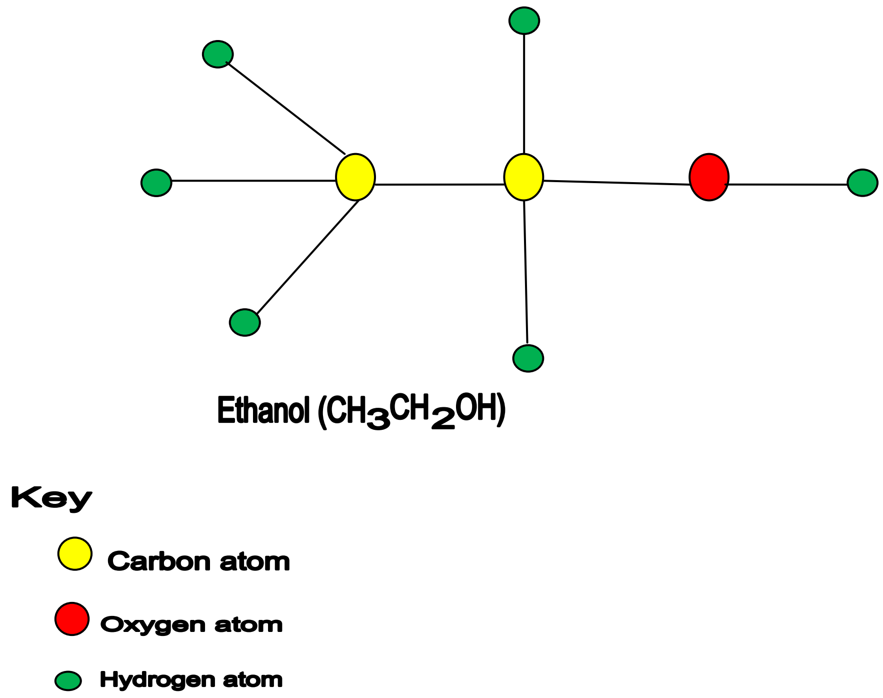
Water ($H_20$)



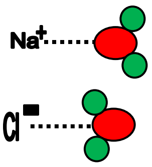
Methane ($CH_4$)

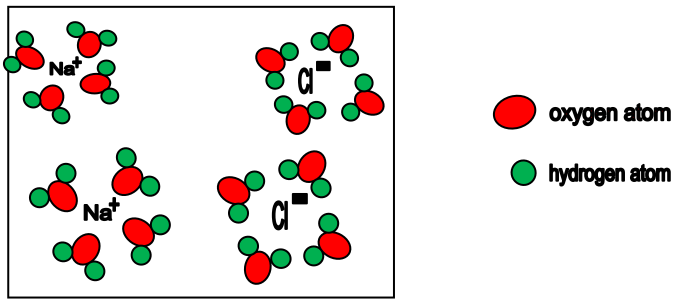


Methanol ($CH_3OH$)



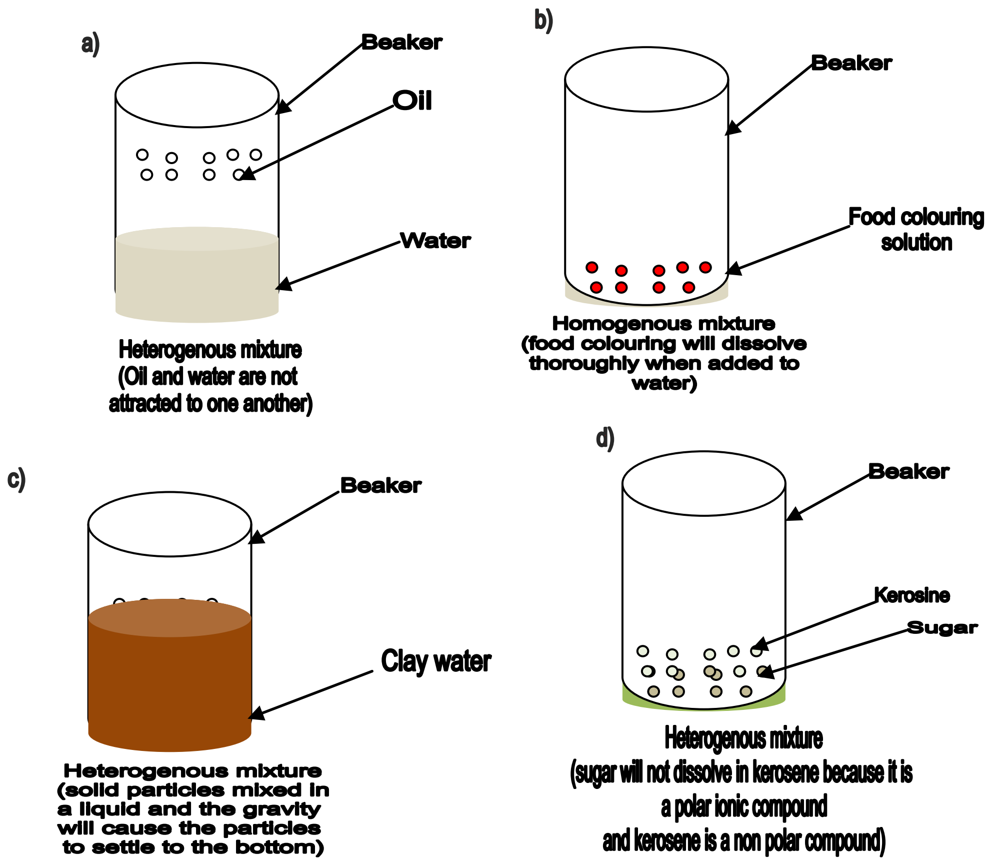

## Activity 7



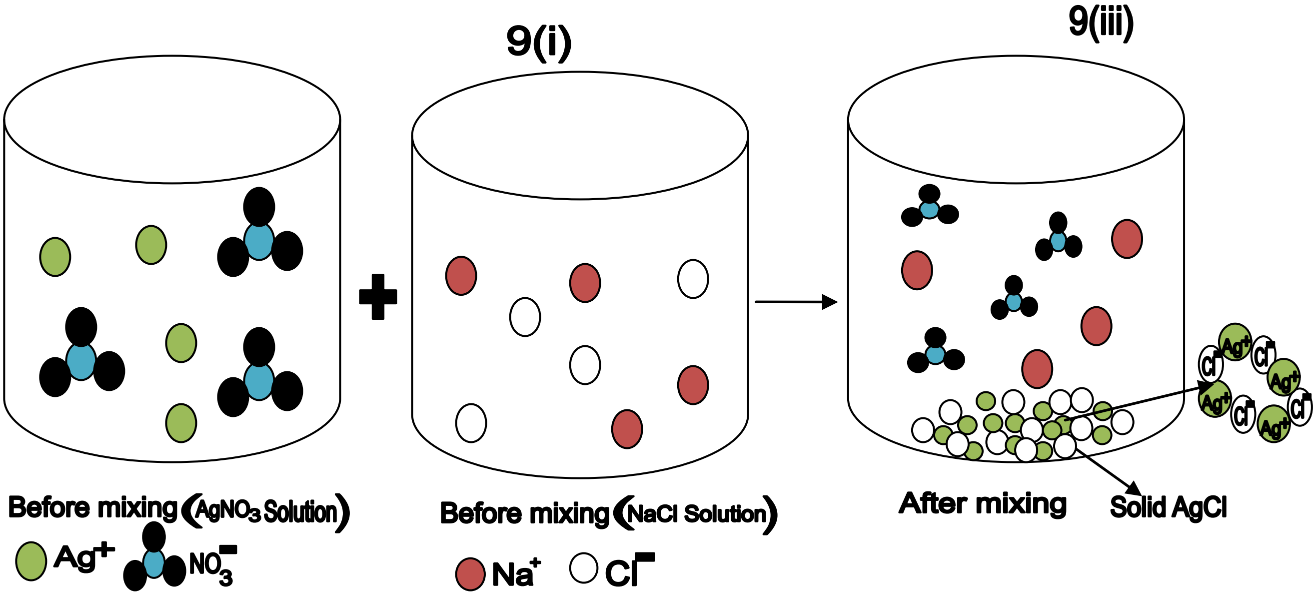




Sodium chloride (NaCl) in a solvent (water) dissociates into single $Na^+$ cations and $Cl^-$ anions each being surrounded by water molecules. The relatively small size of water molecules typically allows many water molecules to surround one molecule of solute. The partially negative dipole ends of the water are attracted to positively charged components of the solute, and vice versa for the positive dipole end.

## Activity 8 (30 minutes)



**Activity 9**




9(ii) **Symbolic representation**

$AgNO_{3(aq)} + NaCl(s) \longrightarrow AgCl(s) + NaNO_{3(l)}$

9(iv) When solution of silver nitrate is added to a sodium chloride solution, a white solid, silver chloride is produce immediately while sodium nitrate is soluble in the water.

# Lesson Format for Teachers

**Reaction rates and collision theory Lesson plan format for Teachers**

**Single period (40 minutes)**

| **Concepts** | **Objectives** | **Activities** | **Strategies to engage the learner** |
|---|---|---|---|
| Reaction rates and collision theory | At the end of the lesson, student should be able to Construct and interpret<br>• a representation of reaction rate at a symbolic level<br>• a particulate representation of a colliding molecules<br>• a representation demonstrating effect of collision geometry of a reacting molecule | Consider two molecules $A_2 + B_2 \longrightarrow 2AB$, how do these molecules react using a collision theory?<br><br>For example, a reaction between hydrogen gas and oxygen gas to produce liquid water. | **1. Symbolic representation** of the colliding molecules<br><br>**2. Particulate representation**<br><br>**3. Role-play** of reaction laying emphasis on bond breaking and making bonds<br><br>**4. Role-play** to show collision geometry of the reacting molecules |

Key questions

1. What represents an atom?
2. What represents a molecule?
3. What represents a bond?
4. How do you tell a new substance has been formed?
5. How does energy make reaction go?

**Double period (80 minutes)**

| Concepts | Objectives | Activities | Strategies to engage the learner |
|---|---|---|---|
| Reaction rates and collision theory | At the end of the lesson, student should be able to construct and interpret:<br>• energy profile diagrams that include activation energy barriers and label the activated complex or transition state<br>• a graph to determine reaction rate in terms of changes in concentration over time<br>• representation indicating variables or factors that can affect rates of reactions. | The decomposition reaction of hydrogen peroxide | 1. **Demo**<br><br>2. **Symbolic representation**<br><br>3. **Particulate representation**<br><br>4. **Graphical representation** of concentration versus time to predict what is happening<br><br>3. **Construct energy profile diagrams** of the reaction progress predicting shape of the graph<br>I. without catalyst<br>II. when catalyst ($MnO_2$) is added to the reaction |

**Key questions**

1. Predict lines of graph showing change in concentrations for the decomposition of water
2. Compare concentration of the reactant at formation of the product
3. Draw energy profile diagrams showing the relatives potential energies of the decomposition of hydrogen peroxide. Label the graph to indicate the reactants, products, activation energy and the transition state.
4. Draw the catalysed and uncatalysed energy diagrams for the decomposition reaction of hydrogen peroxide

## Water Pollution and Solubility Lesson plan format for Teachers

**Single period (40 minutes)**

| Concepts | Objectives | Activities | Strategies to engage the learner |
|---|---|---|---|
| Water pollution and solubility | At the end of the lesson, student should be able to:<br>• identify sources of water<br>• identify various ways water could be contaminated<br>• state advantages of water treatment plant<br>• explain processes of water purification and why these are necessary | 1. Water contaminants (bacterial/microbes/germs), dissolved chemicals and undissolved chemicals<br><br>2. Water purification (boiling/distilling/filtration) | 1. Social stories on the chemistry of water (healthy water is pure water)<br><br>2. Significant awareness of the chemistry of water<br><br>3. Identifying water contaminants and how these could be remove<br><br>4. Use a drawing to construct a representation of water filter capable for separating visible dirt from bowl full of muddy water Processes of water treatment |

**Key questions**

1. Where does water come from?
2. Why it is that not all water are suitable for drinking?
3. Why is it important that we are aware of the chemistry of water?
4. What causes water pollution?
5. What is pure water?
6. How do we make water pure?
7. How do we treat contaminated water?

**Double period (80 minutes)**

| Concepts | Objectives | Activities | Strategies to engage the learner |
|---|---|---|---|
| Water pollution and solubility | At the end of the lesson, student should be able to:<br>• explain different physical states of water<br>• why water is refers to as universal solvent<br>• describe the movement of water within the water cycle<br>• explain what happen ionic compound dissolved in water using particulate representation<br>• draw what a saturated and unsaturated solution of sodium chloride (NaCl) would look like | 1. Describe water in its three physical states.<br>2. Description of water movement within the water cycle.<br>3. A molecular model of water molecule.<br>4. Consider solute (sodium chloride) in a solvent (water), dissociate in water into single $Na^+$ and $Cl^-$ which bind with the water molecules. | 1. **Particulate representation** of water in its three physical states.<br><br>2. **Role-plays** to demonstrate the physical state of water.<br><br>3. **Flow chart representation using Cardboard nametags** to demonstrate water cycle concepts.<br><br>4. **Cardboard nametags** to demonstrate a dissolved ionic substance.<br><br>5. **Symbolic and Particulate representations** of a dissolved ionic substance. |

**Key questions**

1. What atoms make up water?
2. Describe the three physical states of water
3. Explain reason(s) why water is refers to as universal solvent
4. Explain what happen when ionic substance is dissolved in water for example NaCl
5. Describe the movement of water within the water cycle

## APPENDIX G: LETTER OF REQUEST TO DISTRICT DIRECTOR

### Enhancing the Quality of Chemistry Teaching in Nigerian Secondary Schools

MOUNT LAWLEY CAMPUS
2 Bradford St
Mount Lawley
WA 6050
AUSTRALIA

The Zonal Director,
District V Local Education District,
Agboju-Amuwo,
Lagos-Nigeria.

Dear Sir/Madam,

### Request for permission to conduct a research study

I am currently a research PhD student at Edith Cowan University conducti on enhancing the quality of chemistry teaching in Nigerian senior seconda The study aims to improve teachers' practice and students' engagement learning. It is planned to conduct the study in the second and third term – 2010 school year.

The intended participants are the chemistry teachers and students in sen secondary school 2 in your Local Education District. Forty chemistry teach asked to complete a survey questionnaire. Ten out of the 40 chemistry te be invited to participate in a three-day professional development worksh out of these teachers will be observed in their classroom practices. Childr classes of each of the 5 case study chemistry teachers will also be observe contributions to class activities will be recorded during three chemistry le Photographs of teacher's work written on board and students' group acti during the learning process will be taken from the back of the classroom record of activities. The photograph will not affect the lesson taught. Tea be interview at the end of the lesson to share their experiences of the ne techniques. In addition, some students will be interviewed as a group to their response to the new teaching approach. Teachers' lesson plans and notebooks will also be photocopied for analysis.

It is expected that the study will develop teachers' understanding of how plan and teach chemical concepts in more effective and engaging manne will also develop a professional learning module that will be useful for im chemistry teaching and learning in Nigeria. I therefore seek for your kind conduct the study and a letter of introduction to school principals in the facilitate my gaining access to secondary schools and meeting the partici this study.

I will send separate information letters and consent forms to teachers and students including school principals and parents of the students participating in this study. Reports of this study will not name teachers, schools or any students. The participants are free to choose not to participate or withdraw at any time should they change their mind about participating. All research data will be confidential and transcripts, observational notes will be stored securely and will be destroyed five years after the completion of this study.

I am happy to discuss any questions you may have about the research study and you may contact me, Bolanle Omotoke Olaleye, on 08033265406 or by my office address: School of Science, Chemistry Department, Room 238, Adeniran Ogunsanya College of Education, Otto/Ijanikin, Lagos. You may also email me using Olaleye.bolanle@yahoo.com, or you may contact my supervisor Professor Mark Hackling by email or phone:
Email: m.hackling@ecu.edu.au; Phone:+61 8 6304 5170

If you have any further concerns about the study or would like to talk to an independent person, you may contact the Research Ethics Officers at:
Human Research Ethics Office
Edith Cowan University
270 Joondalup Drive
Joondalup WA 6027
Email: research.ethics@ecu.edu.au
Phone: +61 8 6304 2170
If you are happy to grant the approval to conduct this study in your Local Education District, could you please sign the consent form attached to this information letter and return it to me with the letter of introduction.

Yours sincerely,
Bolanle, O. Olaleye
School of Education

Professor Mark Hackling
Associate Dean( Research and Higher Degrees)

**APPENDIX H: DIRECTOR'S CONSENT FORM**

59

**Enhancing the Quality of Chemistry Teaching in Nigerian Senior Secondary Schools**

***DIRECTOR'S CONSENT FORM***

I have read the attached information letter and any questions I have asked have been answered to my satisfaction. I understand that the participants may withdraw at any time from the study if they wish.

I give my approval for this study to be conducted in my Local Education District.

I also agree that the research data gathered for this study may be published provided that my name and Local Education District are not identifiable and that no student, teacher or school are identified in the reports.

Director's name: ANYANWU, E. O
DEPUTY DIRECTOR, PERSONNEL

Local Education District: EDUCATION DISTRICT V
AGBOJU AMUWO
LAGOS NIGERIA

Director's signature:

Date:

...tor General/Permanent Sec.
EDUCATION DISTRICT V
18 Agboju, Lagos.

---

Please return the signed consent form to:
Mrs Olaleye Bolanle Omotoke at
Adeniran Ogunsanya College of Education
Otto/Ijanikin, Agbara,
Lagos-State

## APPENDIX I: LETTER OF INTRODUCTION FROM THE DISTRICT DIRECTOR

**LAGOS STATE GOVERNMENT**
EDUCATION DISTRICT V
(BADAGRY, OJO, AMUWO-ODOFIN & AJEROMI/IFELODUN LGAS)

OLD OJO RD,
AGBOJU,
LAGOS - NIGERIA.

FAX: ..................
TELEPHONE: 07028309865
P.M.B ..................

EDV/C/ITA/014/58

18th January, 2010

The Principal
..................................
..................................
..................................

**LETTER OF INTRODUCTION**
**MRS OLALEYE BOLANLE OMOTOKE**

I am directed to introduce to you Mrs. Olaleye B.O. a PHD student of Edith Cowan University Australia.

She wants to conduct a Research on the Topic "Enhancing the quality of Chemistry Teaching in Nigerian Senior Secondary Schools"

She has chosen District V as area of coverage and your school has been selected as one of the schools for the research.

Please accord her necessary assistance.

Thank you.

ANYANWU, E.O
*FOR: TUTOR-GENERAL/PERMANENT SECRETARY*

MISSION STATEMENT OF THE DISTRICT
*Inspiring educational excellence in Secondary Schools through efficient service delivery, quality teaching, conducive teaching/learning environment in collaboration with all stakeholders.*

## APPENDIX J: INFORMATION LETTER AND CONSENT FORM FOR PRINCIPALS

### Enhancing the Quality of Chemistry Teaching in Nigerian Senior Secondary Schools

14th December, 2009.

The Principal

Dear Sir/Madam

I am currently a PhD student at Edith Cowan University, Western Australia, conducting a study on enhancing the quality of chemistry teaching in Nigerian senior secondary schools. The study aims to improve teachers' practice and students' engagement with learning. I seek your consent for your school's participation in this research study.

Research data will be collected during the second and third term of the 2009/2010 school year. The study will involve teachers completing a questionnaire about their chemistry teaching practice. Some of these teachers will then be provided with a two-day workshop that will show them how to use different ways of representing chemistry concepts (diagrams, models, role play etc) so that students are more actively engaged in learning. These teachers will also be provided with a follow-up one-day training workshop.

Five teachers who participate in the workshops will be invited to participate in case studies. This will involve the Researcher observing chemistry lessons and collecting the following data:

i. Teacher's lesson plan and students' notebooks will be photocopied for analysis.
ii. Digital photographs of teacher's work written on board and students' group activities will be taken from the back of the classroom three times per lesson.
iii. Lesson observations will be recorded as field notes.
iv. The teacher will be interviewed at the end of each observed lesson to share personal experience of the new techniques. In addition, some students in the teacher class will be interviewed as a group to determine their response to the new teaching approach.

I will send information letters and consent forms to teachers and parents of the students participating in this study. The teachers and students are free to choose not to participate or withdraw at any time. All research data will be confidential and transcripts, observational notes will be stored securely and will be destroyed five years after the completion of this study. Reports of this study will not name teachers, schools or any students.

The study will develop teachers' and students' skill and knowledge of constructing and interpreting representations of chemistry concepts. The study will also develop a professional learning module that will be useful for improving chemistry teaching and learning in Nigeria.

I am happy to discuss any questions you may have about the research study and you may contact me, Bolanle Omotoke Olaleye, on 08033265406 or by my office address: School of Science, Chemistry Department, Room 238, Adeniran Ogunsanya College of Education, Otto/Ijanikin, Lagos. Otherwise, you could mail me using Olaleye.bolanle@yahoo.com. You may contact my supervisor Professor Mark Hackling by email or phone:

Email: m.hackling@ecu.edu.au

Phone:+61 8 6304 5170

If you have any further concerns about the study or would like to talk to an independent person, you may contact the Research Ethics Officers at:

Human Research Ethics Office

Edith Cowan University

270 Joondalup Drive

Joondalup WA 6027

Email: research.ethics@ecu.edu.au

Phone: +61 8 6304 2170

If you are happy for your school to participate in this study, could you please sign the consent form attached to this information letter and return it to me. Please note that your school is free to withdraw from the study at any time.

Yours sincerely,

Bolanle, O. Olaleye
School of Education

Professor Mark Hackling
Associate Dean (Research and Higher Degrees)

**Enhancing the Quality of Chemistry Teaching in Nigerian Senior Secondary Schools**

## Principal consent form

I have read the attached information letter and any questions I have asked have been answered to my satisfaction. I give my consent for my school to participate in this research study and I understand that my school's participation is voluntary and that I may withdraw my consent at any time.

I give consent for:

- Chemistry teachers at my school completing a questionnaire Yes ☐ No ☐
- Any teacher who is selected and willing to attend the training workshops has my consent to participate ☐ Yes ☐ No
- Any chemistry teacher who is willing to participate in the case studies has my consent to participate Yes No ☐ ☐

Principal name:

Name of school:

Principal signature:

Date:

---

## APPENDIX K: TEACHERS INFORMATION LETTER AND CONSENT FORM

**Enhancing the Quality of Chemistry Teaching in Nigerian Senior Secondary Schools**

30th December, 2009

Dear Colleague

I am currently a PhD student at Edith Cowan University, Western Australia, conducting a study on enhancing the quality of chemistry teaching in Nigerian senior secondary schools. The study aims to improve teachers' practice and students' engagement with learning. I seek your consent for your participation in this research study.

Research data will be collected during the second and third term of the 2009/2010 school year. The study will involve teachers completing a questionnaire about their chemistry teaching practice. Some of these teachers will then be provided with a two-day workshop that will show them how to use different ways of representing chemistry concepts (diagrams, models, role play etc) so that students are more actively engaged in learning. These teachers will also be provided with a follow-up one-day training workshop.

Five teachers who participate in the workshops will be invited to participate in case studies. This will involve the Researcher observing chemistry lessons and collecting the following data:

i. Teacher's lesson plan and students' notebooks will be photocopied for analysis.
ii. Digital photographs of teacher's work written on board and students' group activities will be taken from the back of the classroom three times per lesson.
iii. Lesson observations will be recorded as field notes.
iv. The teacher will be interviewed at the end of each observed lesson to share personal experience of the new techniques. In addition, some students in the teacher class will be interviewed as a group to determine their response to the new teaching approach.

I will send information letters and consent forms to teachers and parents of the students participating in this study. The teachers and students are free to choose not to participate or withdraw at any time. All research data will be confidential and transcripts, observational notes will be stored securely and will be destroyed five years after the completion of this study. Reports of this study will not name teachers, schools or any students.

The study will develop teachers' and students' skill and knowledge of constructing and interpreting representations of chemistry concepts. The study will also develop a professional learning module that will be useful for improving chemistry teaching and learning in Nigeria.

I am happy to discuss any questions you may have about the research study and you may contact me, Bolanle Omotoke Olaleye, on 08033265406 or by my office address: School of Science, Chemistry Department, Room 238, Adeniran Ogunsanya College of Education, Otto/Ijanikin, Lagos. Otherwise, you could mail me using Olaleye.bolanle@yahoo.com. You may contact my supervisor Professor Mark Hackling by email or phone:

Email: m.hackling@ecu.edu.au

Phone:+61 8 6304 5170

If you have any further concerns about the study or would like to talk to an independent person, you may contact the Research Ethics Officers at:

Human Research Ethics Office

Edith Cowan University

270 Joondalup Drive

Joondalup WA 6027

Email: research.ethics@ecu.edu.au

Phone: +61 8 6304 2170

If you are happy to participate in this study, could you please sign the consent form attached to this information letter and return it to me. Please note that you are free to withdraw from the study at any time.

Yours sincerely,

Bolanle, O. Olaleye — Professor Mark Hackling

School of Education — Associate Dean (Research and Higher Degrees)

**Enhancing the Quality of Chemistry Teaching in Nigerian Senior Secondary Schools**

## TEACHER CONSENT FORM

I have read the attached information letter and any questions I have asked have been answered to my satisfaction. I understand that my participation is voluntary and that I may withdraw at any time.

I am willing to complete the questionnaire Yes ☐ No ☐

I am willing to participate in three days of professional development workshops
Yes ☐ No ☐

I am willing to have my chemistry teaching observed and participate in a case study

Yes ☐ No ☐

Teacher's name:

School:

Teacher's signature:

Date:

---

**Please return the signed consent form to Mrs Olaleye Bolanle Omotoke at**

**Adeniran Ogunsanya College of Education**

**Otto/Ijanikin, Agbara,**

**Lagos-state**

## APPENDIX L: LETTER OF INVITATION TO PARTICIPATE IN THE PROFESSIONAL LEARNING WORKSHOPS

School of Education,

Edith Cowan University,

2 Bradford street,

Mount Lawley, Perth,

6050, Western Australia.

7th November, 2009.

Dear colleagues,

Based on your participation in the professional development workshop, you are one of the five case studies teachers to participate in this study.

The study will also involve the researcher coming into your classroom to collect data. The collection of the data will include

i. Work samples and data such as your lesson plan and students' notebooks will be photocopy for data analysis.
ii. Digital photographs of your work on the use of representation written on board and students' group activities three times during the learning process will be taken from the back of the classroom to form a digital record. The photograph will not affect the lesson taught.
iii. Selected work samples from the students will be collected. Chemistry lesson observation and field notes will be made by a researcher
iv. You will be interview at the end of each observed lesson to share your experience of the new techniques. In addition, some students in your class will be interviewed as a focus group meeting about their attitude to multi-modal representations strategies and how they learn chemistry with it.

It is expected that the outcome of the study will develop your understanding of how to plan and teach chemical concepts in an engaging manner. Secondly, how to develop students' skill and knowledge of constructing and interpreting multi-modal representations. Thirdly, learning different ways to use students' representations to assess student learning. Lastly, the outcome of the study will develop a professional learning module that will be useful for improving chemistry teaching and learning in Nigeria. You will be given opportunity to have input into the content of any material collected from your lessons. Reports of this study will not name teachers, schools or any students.

Note that you are free to choose not to participate or withdraw at any time should any incidents occur that might cause embarrassment to the teacher, school, or students. All research data will be confidential and transcripts, observational notes will be stored securely and will be destroyed five years after the completion of this study.

I am happy to discuss any questions you may have about the research study and you may contact me, Bolanle Omotoke Olaleye, on 08033265406 or by my office address:

School of Science, Chemistry Department, Room 238, Adeniran Ogunsanya College of Education, Otto/Ijanikin, and Lagos. Otherwise, you could mail me using Olaleye.bolanle@yahoo.com. If you have any further concerns about the research study or would like to talk to an independent person, you may contact my supervisors Professor Mark Hackling by email or phone:

Email: m.hackling@ecu.edu.au

Phone:+61 8 6304 5170

If you have any further concerns about the study or would like to talk to an independent person, you may contact the Research Ethics Officers at:

Human Research Ethics Office

Edith Cowan University

270 Joondalup Drive

Joondalup WA 6027

Email: research.ethics@ecu.edu.au

Phone: +61 8 6304 2170

If you are happy to participate in this study could you please sign the consent form attached to this information letter and return it to me.

Regards

Bolanle, O. Olaleye

Graduate school of education

Edith Cowan University, Perth, Western Australia

## Teacher consent form

I have read the attached information letter and any questions I have asked have been answered to my satisfaction. I agree to participate as one of the five case studies and also allowing my classroom to be observed and photographed and by participating in interviews. I understand that my participation is voluntary and that I may withdraw at any time.

Teacher’s name:

Teacher’s signature:

Date:

## APPENDIX M: CODING MANUAL FOR INITIAL TEACHER QUESTIONNAIRE

**CODING TABLE FOR ITSQ**

**Challenge (s) teachers facing with teaching senior secondary chemistry effectively**

| Question | Response category name | Response category description | Typical responses |
|---|---|---|---|
| 2.1 | 1. Laboratory facilities and equipment | Some schools lack laboratory, many lack adequate laboratory equipment/apparatus/reagents for practical classes | i. Lack of laboratory and laboratory equipment (3)<br><br>ii. Inadequate laboratory equipment (1)<br><br>iii. Lack of laboratory apparatus and reagents (11) |
| | 2. Teaching aids (charts, pictures, models) | Many schools lack teaching aids for chemistry concepts | i. Lack of teaching aids (8)<br><br>ii. Inadequate instructional materials (6)<br><br>iii. Non-availability of enough teaching aids (19) |
| | 3. Student attitude | Students have a negative attitude to learning chemistry | i. Students attitude to the subject is low (15)<br><br>ii. lazy attitude (21)<br><br>iii. lack of seriousness on the part of students (23) |
| | 4. Overcrowded curriculum | The curriculum/syllabus/scheme of work is too wide and contains more content than can be reasonably covered in the time allocated on the school time table | i. The scheme is too wide to be covered within the available time (21)<br><br>ii. Voluminous curriculum (4)<br><br>iii. Teaching periods too few (27) |
| | 5. Large class size | Some schools lack enough classrooms to accommodate students and there is a high teacher to student ratio | i. High population of students in classroom (39)<br><br>ii. Number of students are many (15)<br><br>iii. Overcrowdings in the classroom (24) |
| | 6. Access to textbooks | Students don't have access to textbooks | i. Lack of textbooks among the students for further studies at home (13)<br><br>ii. Some of the student do not |

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| | | | have textbooks (3)<br><br>iii. There is no adequate textbooks (23) |
| | 7. Students prior knowledge | Students lack science background experience at the Junior School level. | i. Poor background of science experience by the students (36)<br><br>ii. Lack of good foundation in students (39)<br><br>iii. Inability of some of the students to easily understand some of the taught topics in chemistry (26) |
| | 8. Others | *Some schools lack an adequate supply of teachers<br><br>*Students low examination result demoralised teachers<br><br>*Many schools' environment/location are subjected to emotional stress/unhealthy classroom<br><br>*No laboratory assistants<br><br>* Chemistry concepts are abstract in nature | i. One (1) chemistry teacher for the school (38)<br><br>ii. High teacher – student ratio (9)<br><br>iii. No laboratory assistants (38)<br><br>iv. students' performances not encouraging (39)<br><br>v. environmental problems (10)<br><br>vi. It is a volatile subject and can easily be forgotten if not reviewed often with the students (33) |
| **Teachers' beliefs about the characteristics of effective senior secondary chemistry teaching** | | | |
| **Question** | **Response category name** | **Response category description** | **Typical responses** |
| 2.2 | 1. Laboratory facilities and equipment | Provision of school laboratory with adequate facilities and equipment for practical classes | i. Provision of laboratory equipment and apparatus (11)<br><br>ii. Provision of school laboratory and science equipment (25)<br><br>iii. Well equipped laboratory for demonstration (35) |
| | 2. Teaching aids | Provision of adequate and effective use of instructional materials in teaching chemistry concepts | i. Availability of instructional materials (40)<br><br>ii. Teaching aids should be |

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| | | | provided (8)<br><br>iii. Adequate use of instructional materials (19) |
| | 3. Hands-on experiment | Needs for practical oriented activity in a well equipped laboratory | i. The chemistry teaching must be practical oriented and must be taught in a well equipped laboratory (6)<br><br>ii. Practical should be taught regularly(38)<br><br>iii. Having practicals after each teaching (31) |
| | 4. Learning environment | Teaching and learning needs adequate and well organised conducive school environment | i. Conducive environment for enhance teaching and learning (15)<br><br>ii. Learning in a conducive environment (10)<br><br>iii. Learning environment (12) |
| | 5. Appropriate pedagogy | Needs for effective teaching approaches that accommodate or respond to students with diversity learning abilities. | i. Being resourceful (4)<br><br>ii. Involving students in a discovery method (13)<br><br>iii. It must be clear and well explanatory (17) |
| | 6. Teacher's content knowledge | Teacher needs to be competent and having knowledge of the subject matter | i. Teacher's having depth knowledge of the subject matter (4)<br><br>ii. Being able to teach chemistry as a practical science subject (22)<br><br>iii. Ability to impact knowledge to the students (39) |
| | 7. Students attitude | Encouraging students to develop interest and better attitude towards learning of chemistry | i. Students interest in the subject increase and they are encouraged to learn (21)<br><br>ii. The interest of the student and their attitude toward chemistry (3)<br><br>iii. Interest of students to always want to come to laboratory to learn (12) |
| | 8. Students participation | Creating and enabling active students participation during lesson | i. High students participation (9)<br><br>ii. Increase students participation in class (27) |

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| | | | iii. Active students' participation (38) |
| | 9. Others | *Motivating teachers through incentives and students through appraisal<br><br>*Provision of internet facilities for keeping teachers updated<br><br>*Inclusion of practical periods on school time table<br><br>*Reviewing curriculum and syllabus to create separate time for practical classes<br><br>*Provision of well equipped school library<br><br>*Needs to reduce class size<br><br>*Students taking out for an excursion for easy imagination of concept learnt in the classroom<br><br>*Teaching chemistry concepts with application to students' daily activities<br><br>*Developing teachers skill through regular workshops, seminars and conferences<br><br>*There should be effective teacher-students relationship<br><br>*Teaching should involves classroom interaction, students group and team work<br><br>*Students having good grade in examination | i. Motivation i.e. encourage both the teachers and the students in terms of prizes and praises (35)<br><br>ii. Provision of internet facilities to update teachers' knowledge and improve quality of teaching (11)<br><br>iii. Curriculum should be reviewed and the syllabus must include practical classes for effective teaching (14)<br><br>iv. Library well stocked (29)<br><br>v. Population of students should be less 40 students per class (8)<br><br>vi. In teaching chemistry it may appears abstract, relating chemistry with things students can easily imagine and seen (16)<br><br>vii. Continuous and frequent learning of new ideas through seminar and workshop by teachers (18)<br><br>viii. Effective and codial teacher-pupil relationship (9)<br><br>ix. Project and team work (38)<br><br>x. Discussion method, activity based method (1)<br><br>xi. Good performance of students when evaluated (12) |
| **Teachers' beliefs about the most effective ways of students learning chemistry** | | | |
| **Question** | **Response category name** | **Response category description** | **Typical responses** |
| 2.3 | 1. Hands-on experiment | Students doing practical activities | i. Students learn more when allowed to feel, touch and participate in experimental work (38) |

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| | | | ii. Laboratory method involving learning by doing (7)<br><br>iii. Demonstrating experiments for students and asking students to do or carry out the experiments on their own (31) |
| | 2.Learning from aids (charts, models, photographs, diagrams, flowcharts and audio-visual) | Use of instructional materials | i. Use of teaching aids some as models, charts and audio- visual (29)<br><br>ii. By making use of instructional materials(35)<br><br>iii. Teaching aids that can arouse the interest such as good modelling (15) |
| | 3. Discovery learning | Students challenging to find solution to a problem through a given topic, assignment or project work (Inquiry-discovery method of learning) | i. Allowing them to discover the answers to a given problem and then discuss in the class while others listen (13)<br><br>ii. Giving an assignment to the students at the end of any successfully classroom teaching (35)<br><br>iii. Guiding them to discover things on their own (34) |
| | 4. Demonstration method | Teacher demonstrating some concepts in place of real object while students observing during the lesson | i. Demonstration method<br><br>ii. Demonstrations by the teacher (10)<br><br>iii. Observational way of learning should be reinforced (14) |
| | 5. Group learning | Grouping students to learn from each other (collaborative learning) | i. Grouping of the students to accommodate every student (13)<br><br>ii. Through individual or group work (38)<br><br>iii. Putting students into group (31) |
| | 6. Excursion method | Taking students outside the schools' environment viewing application of what is being learnt theoretically in the classroom | i. Taking them out for excursion so that they can view the application(21)<br><br>ii. Field-trip to industries (6)<br><br>iii. Through excursion where they will see how things are being done and the processes and principle involved (17) |

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| | 7. Access to textbooks | Adequate textbooks for students | i. Provision of the required textbooks (13)<br><br>ii. Using their textbooks effectively (21)<br><br>iii. Availability of textbook (12) |
| | 8. Learning in well – equipped laboratory | Provision of laboratory facilities and equipment for practical classes | i. Well equipped laboratory (18)<br><br>ii. Adequate apparatus to work with (23)<br><br>iii. Correct apparatus for practicals (12) |
| | 9. Others | * Adequate teachers' knowledge of the subject matter<br><br>* Conducive classroom and laboratory environment<br><br>*Increase in students' studying habits<br><br>*Adjustment in the curriculum and scheme of work to accommodate more time for practical classes<br><br>* Students' active participation during learning<br><br>* * Balancing teacher-students ration<br><br>*Students learning by sharing ideas with one another in the class<br><br>*Teacher reviewing previous lesson with students before going into new lesson<br><br>*Students awareness to curriculum changes<br><br>*Teacher creating opportunity for interactive learning in the class<br><br>*Use of internet facilities for students to updating | i. When teachers have the knowledge of subject matter and can pass it across to student (5)<br><br>ii. The classroom environment and the laboratory must be conducive (3)<br><br>iii. The students must have interest on the subject (3)<br><br>iv. Constant reading by the students (11)<br><br>v. Curriculum and scheme of work should allocate more time for practicals (14)<br><br>vi. Student involvement in teaching and learning (34)<br><br>vii. One teacher to a class of 25 students (15)<br><br>viii. Discussion with their mates in the class (37)<br><br>ix. Previous topics should be reviewed before introducing new topics (33)<br><br>x. Exposure to current changes and development in chemistry (36)<br><br>xi. Interactive method<br><br>xii. Computer assisted instruction |

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| | | knowledge in chemistry | |
| **Mode of students assessment** | | | |
| **Question** | **Response category name** | **Response category description** | **Typical responses** |
| 2.5 | 1. Oral questions and answers during and after lesson | Asking students questions in the class verbally on previous lesson and new lesson to be taught | i. Through questioning and discussion method during and after lesson (18)<br><br>ii. Asking students questions randomly on the previous topics (33)<br><br>iii. By asking them questions on chemistry ideas (12) |
| | 2. Assignment | Given students take home assignment | i. Take home assignment (38)<br><br>ii. Given students assignment(8)<br><br>iii. Through assignment (1) |
| | 3. Tests and examinations | Application of test in the class on each topic taught | i. Given of impromptu test at times (35)<br><br>ii. By asking them verbally or asking them to write it (21)<br><br>iii. through oral question and answer as well as writing test (36) |
| | 4. Project work/Problem solving | Students given topic or solving problem to work on | i. Asking question on already taught topic, using past questions from WAEC and JAMB to test their knowledge (11)<br><br>ii. Given topics for presentation (29)<br><br>iii. Given them project work (21) |
| | 5. Practical work | Observing students' performances during the practical class | i. Observing their performances during practical class (38)<br><br>ii. Students are involved in practical courses to determine their knowledge (7) |
| | 6. Others | *Students evaluation through classroom interaction<br><br>*Dividing students into groups to answer questions (Quiz | i. Evaluating them through sharing the idea to the whole class (31)<br><br>ii. Quiz before commencement of |

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| | | competition)<br><br>*Students relating what is being learnt to real world context | new class (27)<br><br>iii. Asking student to relate chemistry with everyday activities(16) |
| **Benefit (s) of diagrams, models, flowcharts, concept maps and photographs to the teaching and learning of chemistry** | | | |
| **Question** | **Response category name** | **Response category description** | **Typical responses** |
| 2.8 | 1. Increases understanding | It enhance proper understanding of learning chemistry concepts | i. It make the concept easy to understand, remember than when explain in abstract (15)<br><br>ii. It enables students to understand the lesson fast because "what you see you don't forget easily" (18)<br><br>iii. It gives the students better understanding and deeper knowledge on the subject matter (17) |
| | 2. Increases memory retention | Knowledge retained and easily recall in students' memory | i. Make students to acquire knowledge in a good way and will always be retained for a long time (7)<br><br>ii. It fixes information about the concept in the students' memory or brain (22)<br><br>iii. Bring the ideas more familiar and easily recall (27) |
| | 3. Makes learning real and concrete | It make abstract chemistry concepts visual and concrete | i. It make abstract concepts look real and concrete (2)<br><br>ii. Help to convey abstract ideas effectively to the learners for better understanding (1) |

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| | | | iii. It helps the students in getting the real picture of what the topic entails (39) |
| | 4. Effective teaching and learning | Teaching and learning are made effective | i. They help to make teaching easier for the teacher and students assimilate better because what they see with their eyes can hardly be forgotten (33)<br><br>ii. It aids learning process and improve quality teaching (37)<br><br>iii. It aid teaching and learning process for fast and easy conceptualization (5) |
| | 5. Increases students' interest | Students interest to learning of chemistry concepts is increased | i. It catches students' interest (23)<br><br>ii. It will arouse students curiosity (38)<br><br>iii. Increases students' willingness to learn (30) |
| | 6. Increases students' confidence | Students' confidence are developed towards learning | i. It build up confident on the students (16)<br><br>ii. It helps to develop students confident in the subject (37) |
| | 7. Others | *Students become more active rather than passive during lesson.<br><br>Teacher is strong towards assessing students understanding of the concept<br><br>*It saves time and lesson objectives is achieved within a stipulated period<br><br>*Teacher stress of lengthy notes and explanation is reduced | i. Make teacher and students to be more active (28)<br><br>ii. It help teacher to achieve objectives of the lesson fast (13)<br><br>iii. It reduce teacher's stress of boring explanation (15) |
| | | | |

## APPENDIX N: CODING MANUAL FOR FINALTEACHER QUESTIONNAIRE

<table>
<tr><th>Question</th><th>Variable</th><th>Label</th><th>Codes</th></tr>
<tr><td>1.1</td><td>Effective teaching</td><td>F effective teaching</td><td>1=Active student participation<br>2=Teacher consent knowledge<br>3=Use of multiple representation strategy(models, concept maps ,role-play, flow charts, particulate and symbolic)<br>4=Adequate planning<br>5=Others</td></tr>
<tr><td>1.2</td><td>Effective learning</td><td>F effective learning</td><td>1=Students active engagement<br>2=Students-centred learning<br>3=Hands-on-experiment<br>4=Representation method(role-play, flowchart, model, concept maps)<br>5=Others</td></tr>
<tr><td>1.3</td><td>Teaching approaches</td><td>F teaching approaches</td><td><table><tr><td>In every lesson</td><td>In most lessons</td><td>In some lessons</td><td>In a few lessons</td><td>Never</td></tr><tr><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr></table></td></tr>
<tr><td>1.4</td><td>Students' evaluation</td><td>F students' evaluation</td><td>1=Oral questions and answers during and after lesson<br>2=Students engagement in activities<br>3=Test<br>4=Assignment<br>5=Others</td></tr>
<tr><td>1.5</td><td>Teacher's confidence scale</td><td>F teacher's confidence scale</td><td><table><tr><td>Very confident</td><td>Confident</td><td>Ok</td><td>Less confident</td><td>Not confident</td></tr><tr><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr></table></td></tr>
<tr><td>1.6</td><td>Students' engagement rate</td><td>F student engagement rate</td><td><table><tr><td colspan="7">Very active and engaged in learning</td><td colspan="3">Very passive in learning</td></tr><tr><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr></table></td></tr>
<tr><td>1.7</td><td>Representational benefits</td><td>F representational benefits</td><td>1=Increases memory retention<br>2=Increases student understanding<br>3=Encourages active student participation<br>4=Making learning real and concrete<br>5=Others</td></tr>
<tr><td>1.8</td><td>MR teaching difficulties</td><td>F MR teaching difficulties</td><td>1=Time constraint<br>2=Availability of materials<br>3=Others</td></tr>
<tr><td>1.9</td><td>Professional development workshop interest</td><td>F professional development workshop interest</td><td>1=Using different representation in teaching a concept(flow- charts, models, role-plays, concept maps, and particulate)<br>2=Teacher engagement<br>3=Others</td></tr>
<tr><td>2.0</td><td>Suggestions for workshop improvement</td><td>F suggestions for workshop improvement</td><td>1=More topics to be treated<br>2=More resources persons<br>3=More chemistry teachers<br>4=More practical activities<br>5=More days<br>6=More space<br>7=Use of projector<br>8=Timing length<br>9=Satisfactory and effective</td></tr>
<tr><td>2.1a</td><td>Workshop recommendation to other chemistry teachers</td><td>F workshop recommendation to other chemistry teachers</td><td>1=No<br>2=Yes</td></tr>
<tr><td>2.1b</td><td>Suggested reasons</td><td>F suggested reasons</td><td>1=It will improve teaching skills<br>2=Increasing attitude towards the subject</td></tr>
</table>

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| | | | 3=Empowering teachers' confidence<br>4=Enlighten teachers' knowledge in modern day teaching strategy<br>5=Encouraging continuity in the passage of knowledge |