EFFECTS OF CONCEPTUAL CHANGE TEXTS AND CONCEPT MAPPING IN REMEDIATING STUDENTS' MISCONCEPTION, ACHIEVEMENT AND ATTITUDE TOWARDS CHEMISTRY IN DELTA STATE

EMERHIONA, Francis

DELTA STATE UNIVERSITY, ABRAKA

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EMERHIONA, Francis
PG/18/19/252063
M.Ed Sci. Edu (Chemistry), DELSU, 2018
B.Sc(Ed) Chemistry, DELSU, 2012
N.C.E Biology/Chemistry, COEWA, 2008

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SEPTEMBER, 2021

DECLARATION

I, **EMERHIONA, Francis,** declare that this thesis was written by me in the Department of Science Education, Faculty of Education, Delta State University, Abraka, and that the original work submitted is mine except as specified in the references and acknowledgements; neither the thesis, nor the original work contained here has been submitted to this University or any other institution for the award of a degree.

EMERHIONA, Francis **Researcher**	**Date**

CERTIFICATION

This is to certify that this thesis was written by **EMERHIONA, Francis,** in the Department of Science Education, Faculty of Education, Delta State University, Abraka.

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Prof. O. P. Ajaja (Supervisor)	**Date**
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Prof. E. Kpangban (Supervisor)	**Date**
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Dr. S. B. Ijeh (Ag. Head of Department)	**Date**
………………….....	…………………
Prof. E. Kpangban (Dean, Faculty of Education)	**Date**

DEDICATION

This thesis is dedicated to my parents, Mr. and Mrs. H. E. Obonofiemro.

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ABSTRACT

The general purpose of the study was to examine the effects of conceptual change texts and concept mapping in remediating students’ misconception, achievement and attitude towards chemistry in Delta State. Twelve research questions and twelve hypotheses guided this study. The study adopted 3x2pre-test, post-test control group quasi-experimental factorial designs. The population for this study consisted of18,879 chemistry students in 473 public secondary schools in Delta State. 328 SSII chemistry students in six public co-educational secondary schools intact classes made up the sample of the study. The six intact classes were selected using simple random sampling technique. Two-Tier Chemistry Test (TTCT) and Chemistry Attitude Scale (CAS) validated by three experts with reliability values of 0.80 (TTCT for achievement), 0.83 (TTCT for misconception) and 0.89 (CAS) respectively were the instruments used for data collection in this study. The data obtained were analyzed using means, standard deviations, t-test, ANOVA and ANCOVA. The results showed that: there was a significant effect of conceptual change texts, concept maps and lecture method on students’ misconception, achievement and attitude towards chemistry; there was a significant difference in the mean misconception, achievement and attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture method, in favour of conceptual change texts followed by concept mapping and lecture method; and there was no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students’ misconception, achievement and attitude towards chemistry. The study concluded that conceptual change texts and concept mapping are effective instructional strategies for remediating students’ misconceptions, and improving students’ achievement and attitude towards chemistry. The adoption of conceptual change texts and concept mapping by chemistry teachers in teaching chemistry concepts at the secondary school level was recommended.

CHAPTER ONE

INTRODUCTION

Background to the Study

In the Nigerian educational curriculum, chemistry is a science subject studied at both secondary and tertiary education levels. Students are first introduced to chemistry at the senior secondary school level. Chemistry is a branch of science that studies the properties, composition, reactions and uses of matter. It is expected that the knowledge of chemistry will advance the students' understanding of the composition, properties, changes and uses of matter that form the environment around us. The chemistry curriculum at the secondary school level according to Nwanze and Okoli (2021), presents chemistry as a practical subject structured around four themes: the chemical world, chemistry and environment, chemistry and industry, and chemistry and life. These four themes depict that the study of chemistry cuts across nearly all the fields of human endeavour. Chemistry as a subject is divided into a number of branches, including biochemistry, organic chemistry, inorganic chemistry, physical chemistry, medical chemistry, nuclear chemistry and environmental chemistry.

Chemistry is of great relevance to national development. Jimoh (2007) noted that the importance of chemistry in the development of any nation cannot be underrated, especially in Nigeria where the national income rests on petroleum and petrochemical industries. Chemistry is at the centre in the drive for global sustainable economic development. It plays a major role in food (fertilizers and insecticides), clothing (textile fibres), housing (cement, concrete, steel, bricks), medicine (drugs), transportation (fuel, alloy materials), and many more such as cosmetics, paints and soaps. In addition, various careers exist in chemistry in the health sector, food processing industries, extractive industries, petroleum and petrochemical industries, among others.

Considering the role of chemistry in national development, the Federal Ministry of Education (1985) stated the following as the objectives of teaching chemistry in secondary schools: to facilitate a transition in the use of scientific concepts and techniques acquired in integrated science to chemistry; to provide the students with basic knowledge of chemistry concepts and principles through efficient selection of content and sequencing; to show chemistry and its inter-relationship with other subjects; to show chemistry and its link with industry, everyday life, benefits and hazards; and to provide a course which is complete for students not proceeding to higher education, while it is at the same time a reasonably adequate foundation for a post-secondary chemistry course.

As a result of the importance of chemistry, it was made a compulsory subject for science students at the secondary school level to facilitate its study and related discipline at higher level of education. Despite the importance of chemistry, its study at the senior secondary level of education has been hampered as shown by students' poor performance in external examinations (See Appendix I for students' performance in 2015-2018 WASSCE chemistry). The WAEC Chief Examiner's Reports from 2015 to 2018 in chemistry practical shows that students' average performance has never exceeded 27.0. According to WAEC stanine, which is a grading system using students' percentile and which varies yearly, the benchmark for pass grade is D7 (45-49%), while failure grade is E8 (40-44%), where scores below the failure grade is indicated as F9. Judging by the stanine standard, the overall students' performance in chemistry has remained below failure grade since 2015 to 2018. In the essay part of the examination, the highest raw mean score attained by the students is 47.00 in 2017.

Again, judging by the stanine, students' overall performance in chemistry essay in 2015 and 2016 is just at the failure and pass grade respectively. The worst overall performance ever, was noted in 2018 according to WAEC Chief Examiner's Report, with students having a raw mean score of 29.00. Such abysmal performance has never been obtained in chemistry until 2018 when it was expected that students ought to be improving their achievement given the quality of teachers in schools and innovations in the teaching and learning of chemistry. The major students' weakness identified by the WAEC Chief examiner's report was that students lack basic understanding of simple chemistry concepts. This may be attributed to the conventional lecture method mostly used by chemistry teachers.

The lecture method is the widely used method of teaching in secondary schools in Nigeria. By this method, learners are encouraged to master course content through constant repetition of facts and drills (Anyafulude, 2014). The method ensures that the course outline is completed on schedule, but it also pushes students to memorize and regurgitate knowledge from learning experiences rather than absorbing and assimilating it (Ajaja, 2009). In addition, the lecture method of teaching does not recognize students' alternative conceptions during instruction. The lecture method does not take into cognizance the fact that students construct ideas about natural phenomena (chemistry concepts) before formal instructions in the classroom. Some of these alternative conceptions are different from what is generally accepted in the scientific community. These alternative conceptions when formed from improper understanding of the learning contents may lead to misconceptions.

According to Mondal (2013), a misconception is described as students' incorrect responses to a specific situation, students' ideas that lead to incorrect responses to a specific situation and students' views about the world that vary from those of scientists. There are a variety of factors that can lead to the formation of misconceptions. First, not all experiences result in proper conclusions or allow students to observe all possible outcomes. Secondly, rather than acknowledging that they do not know the answer to a question posed by their children, it is usual for parents or other family members to give an erroneous response. Other sources of misconceptions include resource materials, the media and teachers. The main issue is that the above sources are considered to be ‘trustworthy’, leading to ready acceptance by students of what they are being taught. Research has shown that these misconceptions of students are very strong and deeply rooted and if neglected hinder effective teaching and learning. Therefore, the conceptual change approach that promotes students reconstruction of past experiences (alternative conceptions) in order to accommodate new ideas or conceptions that are acceptable in scientific community could be an alternative teaching method to the lecture method.

Conceptual change is an approach that encourages students to progress from misconceptions to scientific concepts based Piaget’s assimilation, accommodation and homeostasis principles (Wang & Andre, 1991). This approach claimed that learners cannot learn the scientific concepts satisfactorily without correcting the misconceptions that they themselves have created or that are taught to them in that way. To replace a misconception that has taken root in a learner's mental construct with the correct one, it is important to demonstrate both the misconception's incorrectness and its ineffectiveness in problem-solving.

According to the four conditions namely: dissatisfaction, intelligibility, plausibility and fruitfulness, conceptual change approach as developed by Posner, Strike, Hewson and Gertzog (1982) is a process addressed in two stages. During the first step, students are required to discover that their prior knowledge is insufficient while solving a new problem. When old conceptions are found to be inadequate, the student will encounter a conflict between his or her past knowledge and new knowledge, resulting in a mental conflict, and the student will be ready for conceptual change. In the second stage, student should find the new knowledge understandable, logical and efficient. Atasoy, Akkus and Kadayifci (2009) explained the four conditions of conceptual change approach as follows: students must become dissatisfied with their existing conceptions; the new conception must be intelligible for the student; the new concept must be logical and acceptable for the student; and the new conception must have a potential for explanations in fields (experimentally). The conceptual change strategy proposed by Posner, Strike, Hewson and Gertzog (1982)to help students overcome their misunderstandings (misconceptions) includes instructional techniques such as conceptual change texts, concept maps, analogy and use of models. However, this study only focused on conceptual change texts and concept mapping instructional approaches.

Conceptual change texts specify misconceptions of students, clarify why they are wrong and explain why they are wrong using concrete examples. Conceptual change texts, according to Ozkan and Selcuk (2013), always begin with a question to trigger the misperception in the student's mind. The most widely held misconceptions about that topic are then provided, together with evidence to persuade pupils that they are incorrect. Here, the purpose is to enable students to question the concepts and see the inadequacy of what they think they know. When they are able to do this, they are provided with new information, with examples that will replace the misconception in their minds with the correct concept. Furthermore, according to Ozkan and Selcuk (2013), conceptual change texts are such an excellent teaching approach that it can be employed throughout the teaching-learning process due to its practical benefits.

Cayci (2018) stated that conceptual change texts comprise explanations, case studies, examples, visuals such as images and/or photos, and scientific explanations that show what important misconceptions are and why they occur. Therefore, it can be stated that conceptual change texts have the characteristics of conceptual change approach principles. Several studies have demonstrated that conceptual change texts are among the most effective conceptual change approach in eradicating misconceptions and constructing scientific concepts meaningfully, permanently and functionally. However, the comparative effectiveness of conceptual change texts and concept maps in remediating students' misconception in chemistry among secondary school students in Delta State is yet to be established based on the available literature at the researcher disposal. Therefore, one rationale for this study is to determine if conceptual change texts are more effective than concept mapping in eradicating students' misconceptions and achievement in chemistry in Delta State.

Concept mapping is a graphic depiction of the relationships between concepts using connecting terms in a hierarchical way. Concept mapping is one of the most commonly used techniques in teaching concepts and identifying and eliminating the misconceptions in the field of education (Wang, Wu, Kirschner & Spector, 2018). The concept mapping technique is endorsed by Ausubel (1963) meaningful learning theory. According to meaningful learning theory, learners must integrate new concepts with reference to past knowledge by linking them into a systematic structure in order to learn meaningfully. Concept maps are important tools to help recognise students' biases (misconceptions) as well as understand conceptual change and restructure the understanding of the students.

A concept map works on the notion of providing a visual representation of links and interconnections among a hierarchy of concepts ranging from the very concrete to the abstract (Ajaja, 2013). The author further noted that concept maps help in understanding ideas by showing the connections with other ideas and that since the introduction of concept map, it has become a very useful tool in teaching and learning. Studies have shown that concept mapping improve students’ academic achievement as well (Ajaja, 2013; Bii, 2019).

Academic achievement is the status of a student’s learning. Academic achievement refers to the information and abilities acquired and developed during a student's academic career, as measured by school officials using teacher-created or standardized assessments. Sheoran and Sethi (2016) defined academic achievement as the sum total of information gained after completing a course of instruction (partially or fully) in a particular grade obtained on an achievement test. It is a numerical representation of a student's performance in a specific content area. Academic achievement is used to determine a student's success or failure. Students' attitudes toward a subject area may have an impact on their academic performance.

Attitude can be defined as a pre-disposition to respond in a favourable or unfavourable manner with respect to a given object (Oskamp & Schultz, 2005). Attitude towards chemistry denotes interests or feelings towards studying chemistry. When students’ attitude towards a subject is positive, it will enhance their motivation to learn the course and reverse is the case when students’ attitude is negative. Although, empirical studies have shown that conceptual change texts and concept mapping aid students development of positive attitude but the superiority of one over the other in enhancing students’ attitude towards chemistry in Delta State is yet to be determined. This is another rationale for this study.

Another factor that has been identified to affect students’ academic achievement is students’ sex. Sex according to Prince (2005) referred to the biological and psychological characteristics that define men and women and that male and female are sex categories. Sex simply refers to a state of being male and female chemistry students in this study. Studies have shown mixed findings on sex differences on the effects of conceptual change texts and concept mapping approaches on students' achievement and attitude. Therefore, another rationale for this study is to ascertain if conceptual change texts and concept mapping approaches will enhance male and female students' achievement and attitude towards Chemistry differently. However, sex in this study is a moderator variable. It is against this background, this study examined the effects of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards chemistry.

Statement of the Problem

A review of WAEC Chief Examiner's reports from 2015-2018 (See Appendix I) have shown that students' performance in chemistry has remained poor. The worst overall performance ever, was noted in 2018 according to the WAEC Chief Examiner's Report, with students having a raw mean score of 29.00. The WAEC Chief Examiner's report explicitly stated that students' lack of conceptual understanding of basic chemistry concepts is the major students' weakness in chemistry in the 2018 WASSCE. It is believed that one factor responsible for the poor achievement in chemistry is the fact that students may not have properly understood chemistry concept and often go to examinations with misconception. Such lack of conceptual understanding of basic chemistry concepts may be attributed to the lecture method of teaching often adopted by chemistry teachers. This is because lecture method promotes memorisation and regurgitation of learnt concept as a result of students' passive involvement during instruction and does not take into cognizance students' alternative conceptions. For meaningful learning to take place, there is the need for total eradication of students' misconceptions about chemistry concepts during instruction. Therefore, conceptual change approaches such as conceptual change texts and concept mapping that promotes students reconstruction of past experiences (alternative conceptions) in order to accommodate new ideas or conceptions that are acceptable in the scientific community could be an alternative teaching method to the lecture method. The problem which this study sought to solve is: will conceptual change texts and concept mapping approaches enhance male and female students' reduction of misconception, achievement and attitude towards chemistry?

Research Questions

The following research questions guided this study:

1. What is the effect of conceptual change texts, concept maps and lecture method on students' misconception in chemistry?
2. What is the difference in the mean misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture method?
3. What is the difference in the mean misconception scores between male and female students taught chemistry using conceptual change texts and concept maps?
4. What is the effect of conceptual change texts, concept maps and lecture method on students' achievement in chemistry?
5. What is the difference in the mean achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture method?
6. What is the difference in the mean achievement scores between male and female students taught chemistry using conceptual change texts and concept maps?

7. What is the effect of conceptual change texts, concept maps and lecture method on students' attitude towards chemistry?
8. What is the difference in the mean attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture method?
9. What is the difference in the mean attitude scores between male and female students taught chemistry using conceptual change texts and concept maps?
10. What is the effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' misconception in chemistry?
11. What is the effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' achievement in chemistry?
12. What is the effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' attitude towards chemistry?

Hypotheses

The following formulated hypotheses guided the study:

Ho_1 There is no significant effect of conceptual change texts, concept maps and lecture method on students' misconception in chemistry.

Ho_2 There is no significant difference in the mean misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture method.

Ho_3 There is no significant difference in the mean misconception scores between male and female students taught chemistry using conceptual change texts and concept maps.

Ho_4 There is no significant effect of conceptual change texts, concept maps and lecture method on students' achievement in chemistry.

Ho_5 There is no significant difference in the mean achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture method.

Ho_6 There is no significant difference in the mean achievement scores between male and female students taught chemistry using conceptual change texts and concept maps.

Ho_7 There is no significant effect of conceptual change texts, concept maps and lecture method on students' attitude towards chemistry.

Ho_8 There is no significant difference in the mean attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture method.

Ho_9 There is no significant difference in the mean attitude scores between male and female students taught chemistry using conceptual change texts and concept maps.

Ho_{10} There is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' misconception in chemistry.

Ho_{11} There is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' achievement in chemistry.

Ho_{12} There is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' attitude towards chemistry.

Purpose of the Study

The study generally investigated the effects of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards chemistry. Specifically, the study determined:

1. the effect of conceptual change texts, concept maps and lecture method on students' misconception in chemistry;
2. the difference in the mean misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture method;
3. the difference in the mean misconception scores between male and female students taught chemistry using conceptual change texts and concept maps;
4. the effect of conceptual change texts, concept maps and lecture method on students' achievement in chemistry;
5. the difference in the mean achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture method;
6. the difference in the mean achievement scores between male and female students taught chemistry using conceptual change texts and concept maps;
7. the effect of conceptual change texts, concept maps and lecture method on students' attitude towards chemistry;
8. the difference in the mean attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture method;
9. the difference in the mean attitude scores between male and female students taught chemistry using conceptual change texts and concept maps;
10. the effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' misconception in chemistry;

11. the effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' achievement in chemistry; and
12. the effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' attitude towards chemistry.

Significance of the Study

The study may be of significance to students, parents, chemistry teachers, school administrators, chemistry curriculum planners, school counsellors and prospective researchers. The outcome of this study may help students identify their misconceptions about chemistry concepts. This may enable them to gain conceptual understanding of chemistry concepts that are in line with scientific reasoning. This may also help to improve students' attitude towards chemistry concepts since complete understanding of learnt chemistry concepts reduces abstraction to a great extent.

The findings from this study may expose parents to the effects of conceptual change approaches (conceptual change texts and concept map) on students' achievement and attitude towards chemistry. This may create awareness to parents on how their children pre-conceive knowledge affect their performance in actual school subjects. This may prompts parents to adopt necessary modalities to help students' overcome misconception about chemistry concepts since some of these misconceptions are acquired at home. For example, parents may be prompted to verify the source of information (knowledge) they share with their children on certain chemistry concepts to ascertain if they are scientifically acceptable.

The findings of this study may expose chemistry teachers to some of the misconception of students about chemistry. This may enable chemistry teachers to provide more thorough explanation with examples on chemistry concepts to reduce abstraction. This may also guide chemistry teachers in the selection of distracters when constructing multiple choice items to measure students' achievement in chemistry. This may also provide chemistry teachers with useful information on the effects of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards chemistry. This may encourage chemistry teachers to adopt conceptual change texts and concept mapping and other conceptual change approaches in remediating students' misconception, achievement and attitude towards chemistry.

The findings of this study may provide school administrators with useful information on the effects of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards chemistry. The outcome of this study may expose school administrators to various misconceptions students have about chemistry. This may drive school administrators to determine the causes of students' misconceptions and provide remedies that will enable students overcome misconceptions in chemistry. Also, since the chemistry teacher may be a source of students' misconception, the school administrators may provide in-service training to chemistry teachers to ensure their better understanding of chemistry and mastery of the subject.

Information provided by this study may create awareness to chemistry curriculum planners about the various misconceptions held by students toward chemistry. This may guide chemistry curriculum planners in inculcating varieties of models, pictures, group experiments and real life examples on the various chemistry concepts in the school curriculum to ensure that students easily understand learnt concepts. This may also prompt curriculum planners in suggesting some modalities for overcoming students' misconception about chemistry concepts since students' misconception is inevitable. Since this study may expose curriculum planners to the effects of conceptual change texts and concept mapping, this may prompt curriculum planners to carry out more research on the usefulness of other conceptual change approaches in remediating students' misconception in chemistry.

The outcome of this study may be of benefit to school counsellors since it may furnish the school counsellors with useful information on the effects of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards chemistry. This may serve as guide to them in providing counselling services to students in relation to approaches for overcoming students' misconceptions about chemistry concepts.

The outcome of this study may provide important research materials to prospective researchers carrying out similar or related study as it may broaden their understanding on students' misconception about chemistry. The outcome of the study may also guide prospective researcher in creating a gap for their studies as well as in selecting appropriate methodology.

Scope and Delimitation of the Study

The study was limited in scope to the effects of conceptual change texts and concept mapping in remediating students' misconceptions, achievement and attitude towards some selected concepts in chemistry which include; (i) chemical equilibrium, (ii) solubility product constant and (iii) heat content and chemical reactions (exothermic and endothermic). The effects of these two approaches on misconception, achievement and attitude were compared against the lecture method which served as the comparison group in this study. The study also determined if students' sex moderate the effects of conceptual change texts and concept mapping in remediating students' misconceptions, achievement and attitude towards chemistry concepts.

The study was delimited to all public senior secondary school chemistry students in Delta State. Specifically, the study covered only SSII chemistry students from six public coeducational schools in Delta State (two schools each from the three Senatorial Districts in Delta State). The choice of coeducational secondary schools is to enable the researcher determine if there is a difference in the effects of conceptual change texts and concept mapping in remediating male and female students' misconceptions, achievement and attitude towards chemistry.

Limitations to the study

The limitations to this study are:

1. Students' Absenteeism: There was the problem of absenteeism among the students. The fact that some students skipped classes may have influenced their chemistry achievement.
2. Use of Attitude Scale: The researcher used an attitude scale to generate data on students' attitude towards chemistry. The students' response to the attitude scale may be biased.

Operational Definition of Terms

The operational definitions of terms used in this study are as follows:

Conceptual Change Approach: Conceptual change approaches are teaching strategies that promotes students reconstruction of past experiences/alternative conceptions (misconceptions) in order to accommodate new ideas or conceptions that are acceptable in the scientific community. Examples of such teaching strategies are conceptual change texts, analogy, advance organizers and concept maps.

Conceptual Change Text: It is a written passage that includes explanations, case studies, examples, visuals such as images and/or pictures, and scientific explanations that demonstrate what relevant misconceptions are and why they occur.

Concept Mapping: This simply refers to the use of concept maps which are graphical representation of the relationships among learnt concepts using link words and arrows. Concept maps aid students' schema construction by clarifying ambiguities in learnt concepts and at the same time revealing any misconceptions students have about the learnt concepts.

Remediating: It simply means to correct or improve students' misconception reduction, achievement and attitude towards chemistry.

Misconception: In this study, misconception simply refers to students' mistaken answers to chemistry concepts; and students' alternative conceptions which cause mistaken answers about chemistry concepts.

Achievement: This simply refers to students' scores in chemistry standardized tests.

Attitude: This simply refers to students' positive or negative disposition towards studying chemistry.

Sex: Sex as used in this study is a state of being male or female.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter reviewed relevant and related literature on the effects of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards chemistry. The review was discussed under the following sub-headings:

- Theoretical Framework of the Study
- Concept of Conceptual Change
- Concept of Misconception
- Conceptual Change Model as Strategy for Overcoming Misconceptions
- Conceptual Change Texts
- Concept Mapping
- Steps in Constructing a Concept Map
- Kinds of Concept Maps Commonly Used in Chemistry Teaching
- Concept of Academic Achievement
- Concept of Attitude
- Empirical Studies
- Misconceptions Related to Chemistry
- Effect of Conceptual Change Texts on Misconception in Chemistry
- Combined Effects of Conceptual Change Texts on Misconception in Chemistry
- Effect of Conceptual Change Texts on Achievement in Chemistry
- Combined Effects of Conceptual Change Texts and Sex on Achievement in Chemistry
- Effect of Conceptual Change Texts on Attitude towards Chemistry

- Combined Effects of Conceptual Change Texts and Sex on Attitude towards Chemistry
- Effect of Concept Mapping on Misconception in Chemistry
- Combined Effects of Concept Mapping and Sex on Misconception in Chemistry
- Effect of Concept Mapping on Achievement in Chemistry
- Combined Effects of Concept Mapping and Sex on Achievement in Chemistry
- Effect of Concept Mapping on Attitude towards Chemistry
- Combined Effects of Concept Mapping and Sex on Attitude towards Chemistry
- Appraisal of the Reviewed Literature

Theoretical Framework of the Study

The study is anchored on Piaget's Cognitive Development Theory and Miller's Information Processing Theory. Piaget (1962) postulated the theory of cognitive development. The theory states cognitive development is a gradual restructuring of mental processes that occurs as a result of biological maturation and environmental exposure. According to Piaget, children actively sought out information and adapt it to the knowledge and conceptions of the world that they already have. Thus, children construct their understanding of reality from their own experience. Children organize their knowledge into increasingly complex cognitive structures called schemata.

According to Piaget, children possessed many different schemata, and these change as the children develop. In the new-born, the schemata take the form of innate reflexes and reaction patterns, like sucking. As the child grows and gains experience, the schemata shift from motor activities to mental activities called operations. With aging, these operations get more complicated. Piaget proposed that schemata are transformed based on principles of organization and adaptation that function throughout a person's life. The ability to combine simple physical or psychological structures into more complex systems is known as organization. Assimilation, or fitting new experiences into present cognitive schemata, and accommodation, or altering current schemata to accommodate new experiences, are two complementary processes in adaptation. Both processes are used in the majority of encounters.

Assimilation: Assimilation means a process of interpreting actions or events in relation to one's schema. This refers to a means of fitting reality into one's existing structures of knowledge. The term 'schema', for Piaget, refers to a well-defined sequence of physical and mental actions.

Accommodation: This is the modification of existing schemas to fit reality. The organism is capable of learning when it can modify its schema. As the organism continues to accommodate, it continues to learn. Piaget believes that cognition develops from age to age and from level to level. According to Piaget, the driving force for cognitive development is equilibration. By equilibration, Piaget means balancing assimilation and accommodation to adapt to the demands of the environment.

Piaget believed that for people to learn, they must assimilate and accommodate. Piaget opined that at each stage of development, people use a distinctive underlying logic or structure of reasoning to guide their thinking. Piaget identified four stages of cognitive development – sensory-motor, pre-operational, concrete operational and formal operational to explain cognitive development from infancy to adolescence. However, this study was only concerned with the 'formal operational stage'. This stage occurs within the adolescence stage. At this stage, the young individual can start to think more abstractly. This stage of cognitive learning is characterized by ability to manipulate abstract as well as concrete objects, ideas, and events. At formal operational stage, the young individual acquires more ability to deal with abstractions and may engage in hypothetical reasoning based on logic. At the adolescence stage, individuals can easily carry out practical experiments and demonstrations. Formal operational stage offers the ability for the individual to use abstract symbols for representational purposes.

Piaget’s theory of intellectual development holds that cognitive development takes place from active interaction of the child with his environment. This means that the child's aptitude as he interacts with his physical and social environment is the foundation of learning. Piaget believes that in order for a child to learn, he must act on the objects in his surroundings. This implies that he should participate actively rather than passively. The active involvement of the child may be in form of direct manipulation, visual observation or through mental or internal transportation or change. Piaget believed that mental activity, which is involved in cognitive organization, is a process of adaptation, which is divided into two opposing but inseparable processes of assimilation and accommodation. The Piagetian theory placed the child as the principal agent in the teaching/ learning situation. Therefore, the teacher’s job is to provide the individual with situations that encourage experimentation and manipulation of objects and symbols.

Piaget’s Theory of Cognitive Development has direct implication on this study. Piaget sees cognition as a human construct and the child must be active and interact with his environment during the teaching and learning process seeking information for themselves. Conceptual change texts and concept mapping promotes students’ active participation and interaction with the learning material in the teaching and learning process.

Piaget’s Theory of Cognitive Development stressed the attainment of equilibration, a balance between assimilation and accommodation which is a process where individual comfortably makes sense of new information based on his or her past experience. However, conceptual change texts and concept mapping creates a state of disequilibration in students’ which activate students to seek equilibration in order to makes sense of new information based on his or her past experience. Conceptual change texts and concept mapping promotes students reconstruction of past experiences (existing misconceptions) in order to accommodate new ideas. When this process is successful, a state of equilibration is attained.

Information Processing Theory was developed by Miller in 1956. The human mind, according to Miller (1956), absorbs the stimulus, processes it, stores it, locates it, and then responds to it. According to Miller, the human mind can only hold 5 to 9 bits of knowledge at a time. The information processing theory is a method of studying and analyzing the sequence of events that take place in a person's mind as he or she receives new information. Miller made a comparison between human information processing and that of a computer model. He also stated that learning is nothing more than a change in the knowledge stored in the memory. It's an examination of how a person learns something new. In such a setting, there is a definite pattern of events that occurs, and by understanding this pattern, we can help children and adults with particular skills learn new things faster.

According to information processing theory, the human mind is quite comparable to computers in terms of information processing and analysis. It further stated that any new piece of information that enters the brain is first processed and then put through a series of benchmark tests before being stored in various memory vestibules. Since these actions occur at a very fast speed, we are unable to notice them in action. The sensory perceptors of a human being act similarly to the hardware of a computer, and the person's thinking, rules, and strategies for learning are analogous to the software utilized by computers. If these perceptors and rules are changed, a person's information processing system can be improved. Information processing occurs through three stages which are sensory register, short-term memory and long term-memory.

Sensory Register or Sensory Memory: This is the portion of the brain that absorbs and stores all information, either momentarily or permanently. Sensory receptor cells in the human body assist in the conversion of environmental energy into a message for the brain. Short-term memory is created by this energy conversion mechanism. It is vital to pay attention to the information at this stage in order to transfer it to the next. If the stimulus is attractive or activates a well-known pattern, it can elicit an effective reaction. When information is important, exciting, or perceivable, it is better sensed and registered.

Short Term Memory or Working Memory: This is a section of the sensory register where data is briefly kept. The information will either be destroyed or moved to long-term memory once a choice has been reached about it. It is expected to last 15 to 20 seconds. It does, however, exist for up to 20 minutes if recalled.

Long Term Memory: This is where all of the information is saved indefinitely. It can be retrieved at a later time if necessary. Information is encoded in short-term memory by connecting it to previously acquired knowledge. Elaboration and dispersed practice are two strategies that assist information make its way into long-term memory. A piece of information that has been well-planned and arranged can be simply encoded and saved. Imagery, location, numbers, and rhyming words are all examples of elaboration. Declarative, procedural, and/or visual structures arrange information in long-term memory.

Yildirim, Guneri and Sumer (2002) presented several implications of Information Processing Theory to teaching which has direct implication on this study. These implications are: Students need to attend to the knowledge they are supposed to learn. In other words, students need to be very active in the teaching and learning process so as to learn effectively. Conceptual change texts and concept mapping promotes students' active participation during the teaching and learning process.

Secondly, teachers should help students to establish meaningful connections between new information and their experiences. In conceptual change texts and concept mapping, teachers guide students to link their past experiences to a given problem. In so doing, the teacher determines students' misconception about that particular problem which is contrary to the acceptable scientific conceptions. After which, the teacher presents explanations and models that demonstrates the inconsistency between common misconceptions and the scientific conceptions.

Concept of Conceptual Change

The term "conceptual change" has been defined in a variety of ways. From a Piagetian perspective, for example, conceptual transformation entails going through a process of accommodation, in which schemata are adjusted when learners are introduced to new material that contradicts their prior beliefs (Piaget, 1970). It's vital to remember that new schemas do not supersede or supplant earlier schemas in accommodation because people might have several schemas to explain phenomena at the same time (Carey, 1985; Shtulman, 2009). Rather, the new schema has more explanatory power or is more aligned with the observed reality, thus it is more likely to be considered and become the dominant theory used to explain phenomena in a certain scenario or context. Thus, conceptual change is described in ways that imply that schema is transformed (or reorganized), resulting in a change in conceptions, or that new schema formation processes are occurring, but that individuals maintain their past schemas. The study asserts that conceptual change is formed by expanding on an existing idea to generate a new explanation while keeping the original extant conception's explanation. Because people may hold numerous conceptions to explain a specific phenomenon, the result of the alteration becomes the preferred idea, yet the original conception is kept and can still be relied upon to explain phenomena (Nadelson, Heddy, Jones, Taasoobshirazi & Johnson, 2018; Ohlsson, 2009; Shtulman, 2009).

Concept of Misconception

Mondal (2013) sees the word ‘misconception’ as: students’ mistaken answers to a particular situation; students’ ideas which cause mistaken answers about a particular situation; students’ beliefs about the world different than that of the scientists. Preconceived thoughts, non-scientific beliefs, naive theories, muddled conceptions, or conceptual errors are examples of misconceptions (Martin, Sexton, & Gerlovich, 2002). Children, according to Piaget (Eggen & Kauchak, 2004), look for meaning when they engage with the world around them, and utilize these interactions to verify and revise existing schemata conceptual misconceptions..

The creation of misconceptions can come from a variety of places. To begin with, not every experience leads to the correct conclusions or allows pupils to view all possible outcomes. Secondly, rather than acknowledging that they do not know the solution to a question posed by their children, it is usual for parents or other family members to provide an erroneous answer. Other sources of misconceptions include resource materials, the media and teachers. The primary issue is that the aforesaid sources are regarded as "trustworthy," resulting in students' eager acceptance of what they are taught.

Misconceptions can be caused by misinterpreting facts or receiving contradictory information from trusted sources such as parents and instructors (Hanuscin, n.d.). The major concerns are that it is exceedingly difficult to alter a misperception once it has been developed and that having misconceptions can have substantial consequences for learning (Eggen & Kauchak, 2004). Students enter the classroom having pre-requisite knowledge (existing schemas), which are gradually (or sequentially) built upon as they continue through their education. It is vital to guarantee that the present schema is sound in order to effectively teach science. There are numerous ways available to assist teachers in modifying misconceptions, but first and foremost, the teacher must be able to identify the specific misconceptions that a student may have.

Conceptual Change Model as Strategy for Overcoming Misconceptions

This model is a learning model implying that non-scientific conception held by a student would be replaced if the four conditions of the conceptual change model were met (Posner et al., 1982):

- Dissatisfaction with existing knowledge
- Intelligibility of the new conception
- Plausibility
- Fruitfulness

This model is based on constructivist theory in which knowledge acquisition is viewed as a constructive process that involves active generation and testing of alternative propositions (Cobem, 1996). Teaching science focuses on providing students with opportunities in which they have cognitive conflict and they develop different structures based on their experience. Students can achieve conceptual change if they are given the opportunity to be aware of their own ideas, to confront ideas other than their own, and to see the flaws in their thinking. There are various conceptual change approaches. However, this study only focused on conceptual change texts and concept mapping approaches.

Conceptual Change Texts

Conceptual change texts are texts that specifically confront student held misconceptions through presenting readers with common misconceptions and also the correct scientific explanation of a concept (Durmus & Bayraktar, 2010). Unlike standard textbooks, conceptual transformation texts target the reader's specific assumptions and force the reader to address them (Cetingul & Geban, 2011). Conceptual change text styles may vary from author to author but the overall format remains the same (McKenna, 2014). Mckenna (2014) gave the following formats. A query or a prediction regarding a scientific idea is initially posed to the reader. Second, the reader is confronted with frequent misconceptions regarding the notion. When the reader sees similarity in his or her thinking, cognitive dissonance takes place and the need for correction is realized (Durmus & Bayraktar, 2010). Thirdly, the reader is provided with an accurate description of the notion. Finally, the reader is asked to respond to a series of questions designed to consolidate their understanding and demonstrate accurate correction of previous conceptions (Ozkan & Selcuk, 2013). This process of the conceptual change text successfully fulfils Posner’s requirements for conceptual change: creates dissatisfaction with the original misconception and provides the reader with an explanation that is intelligible, plausible, and fruitful (Posner et al., 1982).

Implementation of Conceptual Change Texts

Conceptual change texts can be used in any science classroom from elementary school to college courses (Ozkan & Selcuk, 2013). Students can utilize these texts both at home and in the classroom but it is suggested that they be used in the classroom under the direction of a teacher (Mckenna, 2014). Research suggests that it is most effective to allow students to read each section silently and then to pause for class discussion after each section (Cetingul & Geban, 2011). During discussion students can express their thoughts and clarify their own thinking through social constructivism (Sungur, Tekkaya & Geban, 2001). Another benefit of pausing at each section is that it allows the teacher to provide clarification and summarize key points for struggling readers. Some authors say it is best to hand out the different sections of the conceptual change texts one section at a time. This is because some students go ahead and read explanations prior to formulating their own thoughts about the associated scientific concept (McKenna, 2014). Other authors say it is fine to just remind students not to read ahead. At the end of the text, students are asked to answer a series of questions to indicate if they have developed an accurate understanding of the scientific concept. Teachers should collect and analyze the questions to determine where their students are struggling and adjust instruction accordingly. Conceptual change texts are not meant to replace other forms of instruction such as demonstrations, laboratory activities, computer simulations and so on (Cetingul & Geban, 2011). The conceptual change texts should be used in conjunction with these other practices and are meant to cause students to analyze their scientific thinking for possible errors.

Benefits of Conceptual Change Texts

Conceptual change texts have been found to be effective for correcting student misconceptions across all of the major scientific fields (McKenna, 2014). Several studies have discovered that conceptual change texts are more effective than traditional instruction in addressing misconceptions in science disciplines such as, but not limited to, particles and matter (Beerenwinkel, Parchman & Grasel, 2011, Durmus & Bayraktar, 2010), air pressure (Akbas & Gencturk, 2011), sound (Ozkan & Selcuk, 2013), acids and bases (Cetingul & Geban, 2011), cellular respiration (Al khawaldeh & Al Olaimat, 2010), nature of science (Cepni & Cil, 2010), chemical bonding (Pabuccu & Geban, 2012), human circulatory system (Sungur et al., 2001), solutions (Uzuntiryaki & Geban, 2005), and ecology (Ozkan, Tekkaya, & Geban, 2004). These studies were found to be effective in three main ways. First, the conceptual change texts successfully identified for both the teachers and students what misconceptions existed. This set the stage for students to begin to correct their thinking but also demonstrated to teachers how they needed to adjust their instruction. Secondly, the texts provided students with accurate and plausible explanations that replaced their previous misconceptions. Thirdly, research conducted weeks after the initial studies showed that experimental groups who utilized conceptual change texts exhibited better retention of the scientific concepts (Durmus & Bayraktar, 2010). This finding makes logical sense as previous research on misconceptions shows that most students return to their initial misconceptions about a science topic unless their misconceptions are directly refuted (McKenna, 2014). Conceptual change texts is believed to be an effective approach for remediation of student-held misconceptions.

Concept Mapping

According to Zeilik (1998), concept maps supply the “big picture” of how learners see things and a visual illustration of a learner’s conceptual knowledge. Concept maps, as determined by Sisovic and Bojovic (2000), are used as a teaching aid to show the link between concepts as seen by the constructor. Teo and Gay (2006) described concept mapping as a way of representing knowledge in graph form.

Concept mapping to Asan (2007) and Mistades (2009) is also called systematic mapping and is similar to long-term memory.

Concept maps must consist of an n-dimensional network, where n is the number of dimensions (but has to be greater than two) otherwise we are just working with a Cartesian plain (McAleese, 1998). We can also refer to some of the linkages as three dimensional, where one of the three can go into the page or out of the page (Langford, 2014). Zeilik (1998) and Novak (2008) described concept maps as a two-dimensional diagram where concepts are linked with each other and the learner's knowledge structure of a specific topic is visualised. Mistades (2009) described concept maps as follows: Concept maps consist of nodes (concepts), linkage lines (unidirectional arrow) and linkage phrases (describing the relationship between two nodes). When we combine the two concepts with a linkage word or phrase, the combined structure is called a proposition (Langford, 2014). The linkage line will link two nodes with the linkage phrase.

McAleese (1998) suggested the following guidelines when creating a concept map:

- Choose a main concept. Every other concept will sprout from this concept.
- Choose or use supplied additional concepts. If not given, determine which concepts will apply to the main concept.
- Create relationships between two concepts using a linkage arrow and a linkage phrase. When linking concepts, try to use a sufficient linkage phrase to sprout more potential matches with other concepts.
- Add more concepts to existing concept clusters.
- Delete inappropriate concept clusters.

- Edit existing concept clusters (can be cluster, linkages, linkage phrases or single concepts).

Zeilik (1998) also supplies a more detailed instructional process when creating concept maps, using a simple concept such as plants:

- Introduce a simple example of a concept topic (plants).
- Write down ten more concepts, e.g. flower(s), roots and food.
- Write the more important concept at the top of the paper (plants).
- Explain that the next step is to link one of the concepts with another and then repeat with the rest of the concepts (remember to link the concepts with a directional arrow and using a linkage phrase); (plants --> food = linkage word produce).
- Supply the learners with enough time (20 – 30 minutes). Encourage networking (cross linking).
- Give assistance to all the participating learners. Make sure to tell them that there is more than one correct answer.
- Collect the concept maps, analyse them and then hand them back to the learners.
- A missing step that can be applied is by taking the concept maps, handing them back, but to a different learner. This way no learner has his/her own map and he/she can see different ways of linking concepts.

The main focus of these concept maps is placed on the linkages (the relationships) between concepts and the progression of the structural complexity (Zeilik, 1998). Mistades (2009) added that the structure of the concept map is determined by the orientation of the concepts which then determine if the structure is hierarchical or non-hierarchical. There are five possibilities of structures – linear, circular, hub spokes, tree and network. The following, extrapolated from Mistades' (2009) research, is an example of a linkage between two concepts using a linkage word: "Potential energy (concept or node) consists of (linkage phrase) either gravitational potential energy (concept or node) or elastic potential energy (concept or node)." In the beginning of the instructional period learners will try to memorise the concept maps rather than use them as thinking tools (Zeilik, 1998), but concept maps do not value the learner's memorisation skills within learning, rather his/her understanding of the system of concepts (Sisovic & Bojovic, 2000). Novak (2008) contended that if concept maps are implemented during the instructional period, the learners will form a greater understanding of science. According to Cliff (2010), there are certain advantages when using concept mapping for assessing learners' learning. These advantages include making visible the complex structure of the learner's knowledge (Asan, 2007; Cliff, 2010); uncovering learners' misunderstandings; and revealing learners' conceptual change.

McAleese, Grabinger and Fisher (1999) went further by supplying more concept map attributes. The first one is the recalling of specific concepts and concept labels. It continues with organising concepts into specific categories; creating systematic cognitive structures which include hierarchies and databases; creating multiple routes to a single concept, thereby developing a better understanding of linkages between concepts; creating a neat and comprehensive template by ignoring the complexity of the concepts; revising existing concepts and refining them; debating alternative concepts of a specific topic amongst one another in order to consider the strengths and weaknesses; creating a cognitive flexibility; and gaining more knowledge to solve a wider range of problems.

According to Novak (2008), there are two aspects that are very important in promoting creative thinking in concept mapping. Firstly, the hierarchical structure (important concept or concepts at the top of the page and the less important concepts thereafter), and secondly, the ability to cross-link concepts (this is very important and one of the main characteristics of a concept map). Concept maps are useful in order to show learners the network of links between concepts (Zoller, 1990) and furthermore proving where there are inconsistencies in the learner's alternative concepts (Zoller, 1990; Zeilik, 1998). All of the learners taking part in previous research improved their learning skills and ability to integrate knowledge and concepts.

Zeilik (1998) lists a few disadvantages when working with concept maps. Progression over a period of time can become time consuming when working with large classes or larger groups. You are obliged to use a consistent scoring method during the whole study. Concept maps are a demanding cognitive process and learners tend to struggle with them. To counteract this problem, sufficient information, time and practice need to be supplied to the participating learners.

Zoller's (1990) research showed that concept maps promote the learners' meaningful learning, when they show links between different concepts, while adequately guided through the process by their science teachers. Meaningful learning (Zeilik, 1998) has occurred when a learner changes how he/she experiences the world. The basis of the theory is linking meaningful learning with an existing framework of prior knowledge. Concept mapping is directly linked to Ausubel's Assimilation Theory (Zeilik, 1998), where emphasis is placed on meaningful learning. Concept mapping (Teo & Gay, 2006) is a way to focus the learner's activity for effective learning. Mistades (2009) argued that it uses the learner's cognitive understanding of concepts. From the cognitive understanding teachers can get a glimpse of the learner's qualitative aspect of learning. Zoller (1990) further stated that concept maps are not suitable for abstract, non-intuitive and non-interrelated concepts, but Cullen (1990), who is a chemistry professor, used concept mapping extensively in his science classroom. He also stated that he has no problem using these maps in order to teach abstract, intuitive or indirectly related concepts.

Concept maps are used as remedial tools and research has shown that these remedial tools influence the learner's learning skills (Zoller, 1990). In order for the learner to gain meaningful information, the learning process is highly dependent on the ability to reason and to build relationships between information gained. Novak (2008) argued that the main use of concept mapping is as a tool for organising and visualising information, data and knowledge. Concept maps are seen as a tool to help the learners to "learn how to learn" in chemistry (Cullen, 1990: 1068). Studies were conducted (Asan, 2007) to determine the effect of concept mapping as a tool for the learner's problem solving. The study of concept mapping's effects reached the following conclusions: concept mapping was a helping factor in the learner's selecting, organising and recall operations. The studies further showed that learners could use thinking and learning skills more effectively in certain situations and contexts. Novak (2008) asserted that concept mapping is a very powerful tool. It can be used as a learning tool, but can also be used as an evaluation tool. This will also lead learners to the meaningful side of learning. Concept maps are also used to identify valid and invalid ideas among learners.

Other studies showed an improvement in the learner's problem-solving skills and higher order of thinking. This was measured by chapter quizzes, tests and projects. Green (2003) stated that concept maps are used to identify certain gaps between concepts and if any alternative concepts have been formed. Concept maps are important tool for this study, because they provided a basic understanding of where the learner has developed certain alternative frameworks, alternative ideas and alternative concepts which guided the chemistry teacher in remediating students' misconception with the sole goal of improving students' academic achievement.

Steps in Constructing a Concept Map

Kilic and Cakmak (2013) highlighted the following steps of constructing a concept map which include:

Step 1: To make an idea map, start by defining the context. Constructing a focus question, or a question that clearly identifies the problem or issue that the concept map should help to tackle, is an excellent method to set the context for a concept map. Every idea map has a focus question, and a good focus question can result in a far more detailed concept map. Assume our main concern is "what is an atom?"

Step 2: Identify the important concepts in a paragraph, laboratory exercise, or chapter; or simply consider and list the concepts in a topic area. It is better to write the concept labels on separate cards or small pieces of paper, in order that they can be moved around.

Step3: Sort the thoughts into a hierarchy by placing the widest and most inclusive notion at the top of the map. It may be difficult to determine which concept is the broadest and most encompassing. It should be noted that this ranking order is simply an estimate. It is helpful to have some idea of the situation for which these concepts are arranged.

Step 4: Work down the paper and add more specific concepts and do hierarchical arrangement of concepts.

Step 5: By drawing lines between the concepts, you can connect them. Action or linking words should be used to label the lines. On the idea map, the links between different domains of knowledge might serve to show how these domains are related to one another. You can observe the structure of meaning for a certain subject area when you bring together a large number of linked ideas.

Step 6: Specific examples of concepts can be added below the concept labels. But these are not included in circles or boxes. They are specific events or objects; so they do not represent concepts.

Step 7: A concept map is never finished. After a preliminary map is constructed, it is always necessary to revise this map. Other concepts can be added by student under the guidance of teacher in classroom work. Good maps usually result from several revisions.

The above steps were adopted in constructing the concepts map that was used for remediating students' misconception, achievement and attitude towards chemistry.

Kinds of Concept Maps Commonly Used in Chemistry Teaching

Kilic and Cakmak (2013) discussed five kinds of concept maps commonly used in chemistry teaching with examples as follows:

1. **Spider Concept Map:** A spider concept map is a kind of map that is used to investigate and enumerate various aspects of a single theme or topic. It helps student to organize their thoughts. Outwardly radiating sub-themes surround the center of the map. It looks a bit like a spider's web, as its name suggests.

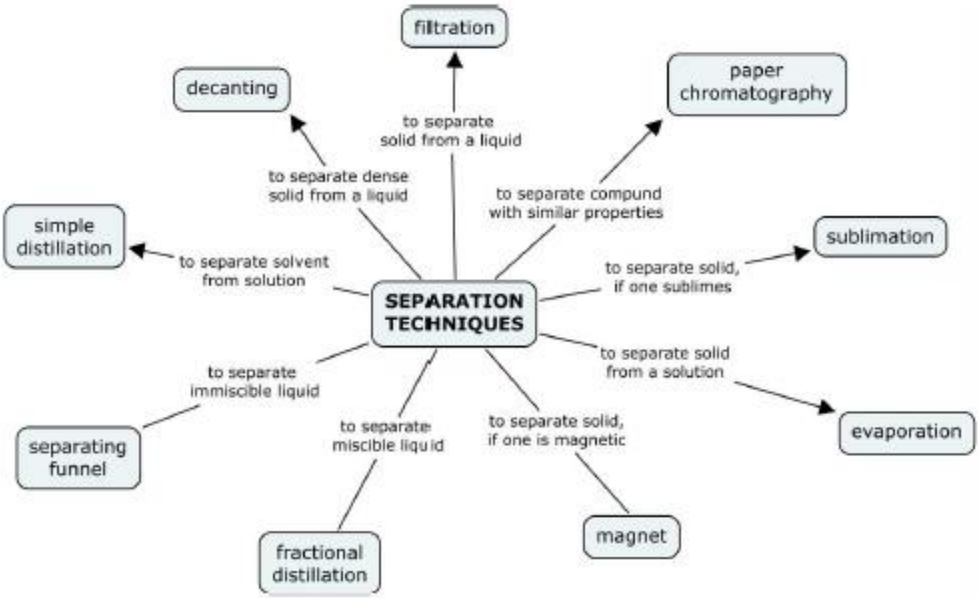

Figure 1: Spider concept map on separation techniques

2. **Hierarchy Concept Map:** It presents information in a descending order of importance. Step by step the student noted down the relevant context in the given boxes/circles. It helps to understand and co-relate the subjects. Figure 2 shows an example to the hierarchy concept map.

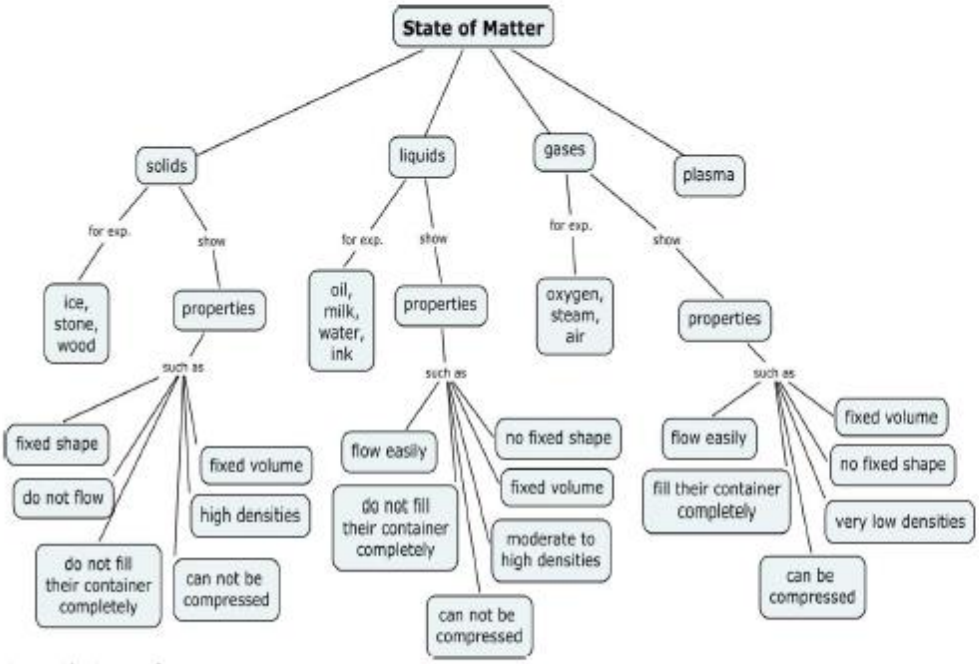

Figure 2: Hierarchy concept map on state of matter

3. **Flowchart Concept Map:** The flowchart concept map organizes information in a linear format as shown in figure 3.

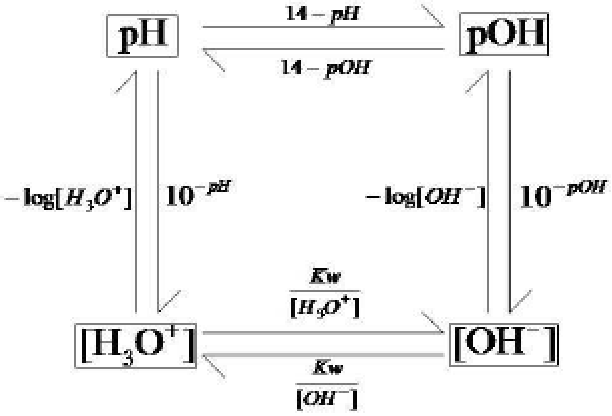

Figure 3: Flowchart concept map on pH and pOH

4. **Systems Concept Map:** The systems concept map organizes information in a systematic format. It includes all data on the map and shows many relationships between the data. It requires critical thinking skills along with problem solving skills.

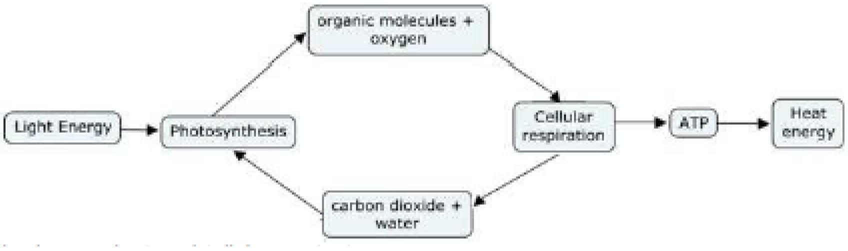

Figure 4: Systems concept map on photosynthesis and cellular respiration

5. **Multi-Dimensional Concept Map:** Multi-dimensional (3D dimensional) concept map describes the flow or state of information or resources which are too complicated for a simple two-dimensional map.

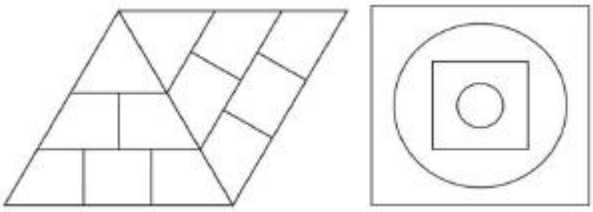

Figure 6a: Multi dimensional (3D dimensional) concept map

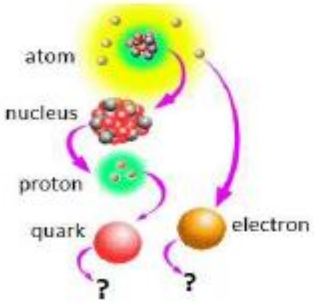

Figure 5: Multi-dimensional concept map on atom

Though various kinds of concept maps exist, this study focused on the effects of hierarchy concept map on students’ misconception, achievement and attitude towards chemistry.

Concept of Academic Achievement

Academic achievement is one part of the wider term of educational growth. It refers to what a student has achieved in different subjects of studies, during the course of academic year. Sheoran and Sethi (2016) defined academic achievement as the sum total of information gained after completing a course of instruction (partially or fully) in a particular grade obtained on an achievement test. Academic achievement, according to Arora (2015), is the degree or level of success or proficiency gained in some academic endeavour. It also pushes students to study hard and learn more, according to the author. Academic achievement refers to the information and abilities gained by a student during their academic career, as measured by school officials using teacher-created or standardized assessments (Emerhiona, 2016).

According to Kan and Nyet (2014), academic achievement is the progress students make towards the goals and objectives of the curriculum. It is the expression of students’ performance in a given content area in numerical form. Academic achievement is used to determine a student's success or failure. Several factors affect students’ academic achievement in chemistry among which is students’ attitude towards chemistry.

Concept of Attitude

Attitude can be defined as a pre-disposition to respond in a favourable or unfavourable manner with respect to a given object (Oskamp & Schultz 2005). The term "attitude toward chemistry" refers to a person's interest in or feelings about chemistry lesson. It is the learners’ disposition towards like or dislikes in a particular field (Ozsoy & Memis, 2009). While attitude in chemistry means scientific approach assumed by an individual for solving problems, assessing ideas and making decisions. Beliefs and attitudes among students have the capacity to help or hinder learning. Many factors could contribute to student’s attitude towards studying chemistry. Attitude to chemistry therefore, is the negative or positive feeling towards learning chemistry.

Attitude is one of the major factors affecting the academic achievement of students (Can & Boz, 2012). However, its influence on achievement may not be widely known because such effects may always be implied. Positive or negative attitude towards the teacher of the subject is known to be associated with academic achievement (Cheung, 2009). Negative attitude may incite students to habour fear for the subject, reduce attention and class attendance or the study of such subject (Kingir & Aydemir, 2012). When students term a subject difficult, such attitude towards the subject or course reduces their motivation to learn the course. Classroom experience and information about course requirement may develop and shape in the students a negative attitude towards the subject. Negative attitudes according to Veloo, Nor &

Khalid (2008) discourage, limit, and even prevent learning, positive change, and growth. But when students develop a favourable attitude, it helps them nurture and enhance their academic achievement (Tytler, 2014).

It was once believed that attitudes were unchangeable and once acquired, students were stuck with them. Now we know this is not true. Psychologists say that we tend to do what we tell our-selves to do. Therefore, if we have negative attitudes, these negative attitudes affect what we expect of ourselves which in turn, affects our actions. Students who believe they cannot do chemistry, for example, are almost certain to have difficulties when attempting chemistry. A pessimistic mindset hinders performance, saps motivation, and prevents learning (Kendura & Cherry, 2013). The more positive one's attitude is, the more opportunities for learning and motivation arise, leading to chemistry success regardless of previous performance (Janssen, Susan, & O'Brien, 2014). By turning a negative mindset into a positive one, the door is opened to the prospect of not only learning but also excelling in chemistry, regardless of previous performance. Positive attitudes can help students overcome frustrations caused by self-imposed constraints on their ability to change via learning, which can lead to academic resilience.

Research has shown that teaching method(s) adopted by the chemistry teacher could also influence students' attitude towards chemistry. Therefore, this study determined the effects of conceptual change texts and concept mapping approaches on students' attitude towards chemistry.

Empirical Studies

Relevant and related empirical studies on the effects of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards were reviewed in this section. The review of empirical studies was done on the following headings:

Misconceptions Related to Chemistry

Bilgin (2003) studied student's misconceptions on the concept of chemical equilibrium by administering a written test to 216 11th grade high school students after their formal class schedule. The original test was developed by Hackling and Garnett (1985) and translated and adopted into Turkish by the authors. The test included 47 multiple choice and true-false items with 0.87 reliability coefficient. An interview was also conducted with 20 students to establish their reasons for misconception with the open-ended questions. Analysis of responses revealed widespread misconceptions among students in the areas related to (1) approaches to chemical equilibrium, (2) characteristics of chemical equilibrium, (3) changing chemical equilibrium conditions, and (4) adding a catalyst.

Sendur, Toprak and Sahin (2010) carried out a study on analyzing students' misconceptions about chemical equilibrium using 151 students who studied in 11th grade at three different high schools in Izmir. Chemical equilibrium misconceptions test (KR20=0.79) was developed to identify students' understanding of chemical equilibrium. The ANCOVA analysis results showed that most of the students had misconceptions in the areas related to approach to equilibrium and changing equilibrium conditions.

Satriana, Yamtinah, Ashadi and Indriyanti (2018) explored student's profile of misconception in chemical equilibrium using six students, two students from high, two from the medium, and two from the low ranked school category. Computerized Two Tier Multiple Choice (CTTMC) was used to identify student's profile misconception. Result revealed that the sub-topic on the concept of chemical equilibrium that most likely causes misconception is interpreting the experimental results in equilibrium state.

Sendur (2012) explored prospective science teachers' misconceptions in organic chemistry (alkenes) with a. sample of 73 prospective science teachers from the Faculty of Education, Dokuz Eylul University, Buca. Alkene Concept Test (ACT) and semi-structured interviews were used as instruments in this study. The study revealed that prospective science teachers have insufficient understanding of nomenclature of alkenes, geometric isomerism, structural isomerism and addition reactions.

Omwirhiren (2016) carried out a study on analysis of misconceptions in organic chemistry among selected senior secondary school students in Zaria Local Government Area of Kaduna State, Nigeria. A total of 120 senior secondary III (SS3) chemistry students was used sample size for the study. Organic Chemistry Misconception test (OCMT) and a structural questionnaire were used as instrument used for data collection. The data were analyzed using frequencies, percentages, mean, standard deviation and t-test statistics at $P<0.05$.The result revealed that students have misconception in organic chemistry and there was no significant difference in the level of misconception between male and female students ($t.cal=0.48<t.crit=1.96$).

The reviewed studies showed that students' have misconception in various concepts in chemistry. However, this study focused on students' misconception in chemical equilibrium, solubility product constant, heat content and chemical reactions.

Effect of Conceptual Change Texts on Misconception in Chemistry

Onder and Geban (2006) studied the effect of conceptual change texts oriented instruction on students' understanding of the solubility equilibrium concept with a sample of 125 high school chemistry students. Data were collected using interviews. The study's findings revealed that instruction based on a conceptual change approach, which included the use of conceptual change texts, was superior to traditional techniques in terms of correcting misconceptions and enhancing students' knowledge of the idea of solubility equilibrium.

Using quasi-experimental design, Ozmen (2011) explored animation enhanced conceptual change texts (CCT–CA) and grade 6 students’ understanding of the particulate nature of matter (PNM) and transformation during the phase changes. 51 students made up the sample size for the study. Particulate Nature of Matter Concept Test (ParNoMaC) and Transformation of Matter Statement Test (ToMaSaT) were used for data collection. Results indicated that the performance of students exposed to animation enhanced conceptual change texts is greater than those expose to the lecture method. Furthermore, animation enhanced conceptual change texts was better in remediating students’ alternative conceptions related to the PNM and transformations during the phase changes than the lecture method.

Dagdelen and Kosterelioglu (2015) explored the effect of conceptual change texts for overcoming misconceptions in people and management unit in Corum using quasi-experimental designed. The study focused on 26 4th graders in a primary school. The People and Management Unit Achievement Test (PMUAT) was used for collection of data. Data analysis pointed to significant differences between the post test scores of students taught using conceptual change text and those taught using the lecture method, in the favour of conceptual change text in the post test scores.

Using Quasi-experimental design, Yumusak, Maras and Sahin (2015) studied the effects of computer-assisted instruction with conceptual change texts on removing the misconceptions of radioactivity in Celal Bayar University. 92 students were used for the study. Two-tier misconception diagnostic instrument was used for data collection. The study revealed that computer-assisted instruction with conceptual change texts was more successful than traditional teaching method in terms of removing misconceptions on radioactivity.

Perdana, Suma and Pujani (2018) determined the effect of conceptual change text structure on concept understanding and misconception reduction of dynamic electricity using a quasi-experimental design. 90 tenth-grade students were sampled for the study. Dynamic Electricity Concept Test (DECT) was used for data collection. MANCOVA analysis indicated that the student taught with conceptual change text showed significantly higher understanding and higher misconceptions reduction compared to the students taught with expository text.

Combined Effects of Conceptual Change Texts and Sex on Misconception in Chemistry

Adopting quasi-experimental design, Azyzodlu (2004) studied conceptual change oriented instruction and students' misconceptions in gases. 100 10th grade students were used for the study. Gases Concept Test, Attitude Scale toward Chemistry, Science Process Skills Test and Learning Style Inventory were used for data collection. The results of ANOVA analysis showed that conceptual change oriented instruction caused significantly better acquisition of the scientific conceptions related to gases than traditional instruction. Insignificant effect of gender difference on students' understanding the concepts about gases and students' attitudes toward chemistry was found.

Cetin (2009) studied the effect of conceptual change oriented instruction on understanding of gases concepts. Quasi experimental design was used in this study. 67 tenth grade students from two intact classes of a chemistry course were used for the study. Gases Concepts Test (GCT), Gases Achievement Test (GAT), and Attitude Scale toward Chemistry (ASTC) were used for data collection. The results of ANCOVA indicated that instruction based on conceptual change approach caused significantly better acquisition of the scientific conceptions, achievement and retention related to gases concepts than traditionally designed chemistry instruction. However no significant effect of gender difference on students' understanding, achievement and attitudes toward chemistry as a school subject was found.

Gokulu and Geban (2014) explored the effects of conceptual change texts oriented instruction accompanied with analogies on 7th grade students' understanding of atom, molecule, ion and matter concepts using quasi-experimental design. In this study, 70 students at seventh grade from two classes participated in the study. Attitude Toward Science and Atom, Molecule, Ion, Matter Test was used for data collection. Collected data were analyzed using ANOVA. The results showed that students in the conceptual change texts oriented instruction accompanied with analogies significantly gain better acquisition of the scientific conceptions related to atom, molecule, ion and matter concepts than the traditional group. No significant gender effect was found.

Using quasi-experimental design, Adzape and Akpoghol (2015) carried out a study to correct students' misconceptions using constructivism and analogy as instructional technique and to evaluate the effect on achievement. 66 SSII chemistry students participated in the study. Chemical Concept Achievement Test (CCAT) was used for the collection of data. The study showed that gender had no significant effect on the understanding of male and female students in the experimental group. It was concluded that teaching by constructivism and analogy was a better way of correcting students' chemical misconceptions. Teachers are therefore, advised to adopt this teaching method. Text writers and curriculum developers are advised to also change their texts and curriculum designs respectively.

Effect of Conceptual Change Texts on Achievement in Chemistry

Aslan and Demircioglu (2014) explored the effect of video-assisted conceptual change texts on 12th grade students' understanding and alternative conceptions concerning the gas concept using the quasi-experimental design. 41 twelfth grade students participated in the study. Students' understanding and alternative conceptions of gas concept was used for data collection. The analysis of the findings revealed statistically significant differences between the -assisted conceptual change texts and tradition instruction groups with respect to conceptual understanding of the gas concept after the treatment, in favour of -assisted conceptual change texts. Finally, it was proposed that Video-Assisted Conceptual Change be used. Textbooks may be an excellent tool to teach the notion of gas, and curriculum designers and textbook writers should keep these strategies in mind when creating new science curriculum. For further work, similar studies can be constructed for other chemistry topics or concepts with larger sample sizes.

Using quasi-experimental design, Ozkan and Selcuk (2015) examined the effect of technology enhanced conceptual change texts on elementary school students' understanding of buoyant force. 40 students participated in this study. Data were collected five open-ended questions concerning buoyancy. When the results of the study were examined as to the conceptual understanding attained, it was found that technology enhanced conceptual change texts group's conceptual understanding was higher than that of traditional instruction group. These writings concerning "buoyant force," an often misunderstood subject in science education, are thought to be particularly beneficial teaching materials that can help students learn more effectively.

Adopting quasi-experimental design, Yuruk and Eroglu (2016) explored the effect of conceptual change texts enriched with meta-conceptual processes on pre-service science teachers' conceptual understanding of heat and temperature. 105 pre-service teachers participated in this research. Heat and Temperature Concept Test (HTCT) was used for data collection. The results show that the conceptual understanding of pre-service teachers who read conceptual change text enriched with meta-conceptual processes was significantly better than that of the other groups and this significantly positive effect did not diminish eight weeks after reading the texts.

Onder (2017) investigated the effectiveness of conceptual change texts supplemented instruction on students' understanding of electrochemistry and their attitudes towards chemistry using quasi-experimental design. A 24-item multiple on electrochemistry and attitude scale toward chemistry were used the for collection of data. As a result, it was obtained that there was no significant difference between groups (conceptual change texts supplemented instruction and traditional instruction) on understanding of electrochemistry concepts and their attitudes towards chemistry as a school subject.

Combined Effects of Conceptual Change Texts and Sex on Achievement in Chemistry

Balci (2006) investigated the effectiveness of conceptual change text oriented instruction accompanied with analogies over traditionally designed chemistry instruction on overcoming 10th grade students' misconceptions, their understanding of rate of reaction concepts and their attitude towards chemistry as a school subject. Quasi-experimental design was employed in this study. 42 tenth grade students were involved in the study. Rate of Reaction Concepts Test and Attitude Scale Towards Chemistry were used for data collection. MANCOVA was used to analyze data. The study found significant difference between post-test mean scores of males and females with respect to their understanding of rate of reaction concepts and their attitudes towards chemistry. No significant effect of interaction of gender and treatment with respect to understanding of rate of reaction concepts and students' attitudes towards chemistry was found.

Using quasi-experimental design, Muhammad (2014) investigated the influence of conceptual instructional method on students' performance in, and attitude towards practical chemistry in Zaria Educational Zone, Kaduna State using quasi-experimental design. The target population for the study was 1401 SS II Science Students. A sample of 100 students was randomly drawn from two co-educational senior secondary schools, within Zaria educational zone. The following instruments were developed and validated for data collection: Chemistry Practical Achievement Test (CPAT) with reliability coefficient of 0.71, Chemistry Practical Performance (CPPT) with reliability coefficient of 0.73 and Chemistry Practical Attitude Inventory (CPAI) with reliability coefficient of 0.79. Six research questions were stated and six null hypotheses were tested. T-test statistics was used to test the hypotheses on achievement, performance and gender difference. Mann-Whitney U-test was used to test the subjects change in attitude towards practical chemistry while Pearson product moment correlation coefficient r- statistic was used to test the relationship between academic achievement and practical performance of subjects in the experimental group. The study revealed there was no significant difference between male and female students academic achievement in the experimental group but there was a significant difference between male and female students practical performance with the male students performing better than their female counterparts. It was also found that, there was a significant relationship between academic achievement and practical performance of subjects in the experimental group. On the basis of the findings outlined above, it was concluded that, conceptual instructional method enhances senior secondary school students' academic achievement, practical performance and attitude towards practical chemistry. A number of recommendations were made some of which are: (1) Chemistry teachers should incorporate conceptual instructional method for teaching at senior secondary school level. (2) Curriculum planners should recommend and ensure conceptual instructional method is used for teaching chemistry at senior secondary school.

Ezechi (2017) determined if conceptual change instructional model, better address students’ alternative conceptions to enhance achievement in biology using quasi-experimental design. 282 students participated in the study. Biology Achievement Test (BAT) was used for data collection. Mean and standard deviation were used to answer the research questions while ANCOVA was used to test the null hypothesis. The study revealed that the conceptual change instructional model was more effective in facilitating students’ achievement in genetics, and that female students achieve better than the males in biology achievement test. As a result, the researcher recommended, among other things, the employment of appropriate novel teaching methodologies such as the conceptual change instructional model, which recognizes students' prior knowledge of biological phenomena prior to science training.

Adopting quasi-experimental design, Nwankwo, Achufusi, Orafu and Aghado (2019) studied the effect of meta-conceptual teaching approach on students’ achievement in Physics in Awka South Local Government Area of Anambra State. 68 SS2 physics students participated in the study. Thermal Physics Achievement Test (T-PAT) was used for data collection. The findings showed no gender influence on students’ achievement in physics when MTA was used as a method of instruction.

Effect of Conceptual Change Texts on Attitude towards Chemistry

Employing quasi-experimental design, Cakir, Geban and Yuruk (2002) examined the effect of conceptual change text-oriented instruction over traditional instruction on students' understanding of cellular respiration concepts and their attitudes toward biology as a school subject. 84 eleventh-grade students participated in the study. Students' Attitude towards Biology scale was used for data collection. The result showed that there was no significant difference between the attitudes of students in the conceptual change text-oriented instruction and traditional instruction groups toward biology as a school subject.

Kaya and Geban (2011) explored the effect of conceptual change based instruction accompanied with demonstrations (CCBIAD) on 11th grade students' attitudes toward chemistry. The study adopted quasi-experimental design. 69 11th grade students in two classes participated in the study. Attitude Scale toward Chemistry was used for data collection. The results of ANOVA showed that there was a significant mean difference between post-test scores of the two groups in favour of the experimental group. As a conclusion, CCBIAD has a key role in forcing students' attitudes toward chemistry.

Cetin, Ertepinar and Geban (2015) investigated the effects of conceptual change text based instruction on 9th grade students' understanding of ecological concepts, and attitudes towards biology and environment in North-Western Turkey. The study employed quasi-experimental design. 82 9th grade students took part in the study. Ecology Concepts Test, Attitude Scale towards Biology and Attitude Scale towards Environment were used for data collection. The study revealed no statistically significant effect of the treatment on the participants' attitudes towards biology and environment.

Cayci (2018) investigated the effects of conceptual change text-based concept teaching on various variables. The instruments for data collection are ‘Concept Achievement Test’ by Calık and Ayas (2003), ‘Attitude Scale toward Conceptual Change Text’ by Yalvac (1998) and ‘Science Teaching Self-Efficacy Belief Instrument’ by Enochs and Riggs (1990). The scales were conducted as pre-test before empirical process and post-test after empirical process. The study group consisted of 112 teacher candidates studying at the 3rd grade of Primary School Teaching Department at a State university. The study was designed and conducted using experimental design. The data analysis revealed that teacher candidates who received conceptual change texts based concept education had significantly higher concept achievements, attitudes toward conceptual change texts, and elementary science teaching self-efficacy beliefs than teacher candidates who received traditional concept education without conceptual change texts.

Combined Effects of Conceptual Change Texts and Sex on Attitude towards Chemistry

Cetin (2003) investigated the effects of conceptual change text oriented instruction accompanied by demonstrations in small groups (CCTI) on ninth grade students’ achievement and understanding levels of ecology, attitudes towards biology, and attitudes towards environment. The Test of Ecological Concepts (TEC), the Attitude Scale towards Biology (ASB), the Attitude Scale towards Environment (ASE), and the Test of Logical Thinking were utilized in this study (TOLT). Data were collected from the public high school in Balıkesir in the Spring Semester of 2001- 2002. 88 students from four classes and two teachers were included in this study. Data related to the TEC, ASB and ASE were analyzed by multivariate analysis of covariance (MANCOVA). The results of the MANCOVA showed there was no significant effect of the treatment on the attitudes towards biology and attitudes towards environment. Results further showed that there was no significant gender effect and interaction effect of gender and treatment on achievement and attitude.

As earlier reviewed, Baser and Geban (2007) evaluated the effects of two types of instructional programs (conceptual change oriented and traditional instructions) as well as gender differences on students' grasp of heat and temperature concepts and attitudes toward science as a discipline. 72 seventh grade students participated in the study. Achievement Test and Attitude Scale was used for data collection. The result revealed no significant difference between the performance of females and that of males in terms of learning heat and temperature concepts and attitudes toward science. However, the interaction of treatment regarding to gender was significant for learning the concepts.

Effect of Concept Mapping on Misconception in Chemistry

Warrick (2002) looked at how concept mapping affected students' perceptions of science concepts. Three eighth-grade students took part in the study. The students constructed two concept maps that were quantitatively examined for comprehension and misconceptions based on the linkages, propositions, and cross-links. A questionnaire was used to assess if the students had any misconceptions about concept mapping and how to help them understand. According to the findings, concept maps made it easier for students to comprehend knowledge. Misconceptions were discovered in the students' concept maps, which were corrected.

Uzuntiryaki and Geban (2005) compared the effects of conceptual change texts and concept mapping training on 64 8th grade students' understanding of solution concepts and attitudes toward science as a school subject to traditional instruction (TI). The study adopted quasi-experimental design. Solution Concept Test was used for data collection. The findings revealed that combining a conceptual change text with concept mapping instruction resulted in significantly better acquisition of scientific conceptions related to solution concepts and significantly higher positive attitudes toward science as a school subject than traditional instruction.

Turkmen, Cardak and Dikmenli (2005) studied the use of concept maps in changing the misconceptions of the first year high school students in biology courses in classification of living things and their diversity. This study was carried out with 92 students using quasi-experimental design. Achievement test and Attitude Scale were used for data collection. After analyzing the data, it is seen that students who learned the classification and diversity of living organisms with the concept maps showed statistically higher achievement than those who learned the same subject with the traditional method ($P<0.05$). As a result, this study showed that teaching and learning concepts with the concept maps in biology courses in high schools changed students' attitudes and achievements positively.

Chiou (2008) examined whether concept mapping can be used to help students to improve their learning achievement and interests in Taiwan. The participants were 124 students. Achievement Test and Interest Scale were used for data collection. When compared to standard expository teaching methods, the results showed that concept mapping can dramatically boost student accomplishment. In addition, the majority of students were pleased with the use of concept mapping in an advanced accounting course. They stated that concept mapping can assist them in better understanding, integrating, and clarifying accounting topics, as well as pique their interest in accounting. They also believed that concept mapping could be valuable in other areas of the curriculum.

Combined Effects of Concept Mapping and Sex on Misconception in Chemistry

Using quasi-experimental design, Yavuz (2005) investigated the effectiveness of conceptual change instruction accompanied with demonstration and computer assisted concept mapping on seventh grade students understanding matter concepts. 75 7th grade students at Özel ENKA Middle School during fall semester of 2003–2004 took part in the study. Matter Concept Test and Attitude Scale toward Science were used for data collection. The findings showed that conceptual change instruction combined with demonstration and computer-assisted concept mapping resulted in greater learning of scientific conceptions about matter concepts and more positive views toward science as a topic than traditional science instruction.

Boujaoude and Attieh (2008) explored the effect of using concept maps as study tools on achievement in chemistry using quasi-experimental design. Sixty tenth-grade students took part in the study. Data were gathered using the Chemistry Achievement Test. Results showed that there were sex-achievement interactions at the knowledge and comprehension level questions favouring females and achievement level – achievement interactions favouring low achievers. Finally, there were significant correlations between students' scores on high level questions and the convergence and total concept map scores.

Gongden (2016) determined if male and female students differ in their problem solving ability when taught the three concepts using analogies, concept maps and lecture method. 96 students were randomly selected, pre-tested and assigned into control, and two experimental groups. The control group was taught using lecture method, while the experimental groups were taught using analogy and concept mapping respectively. Data was collected using the Chemistry Achievement Test (CAT), Mathematical Skill Test (MST), and Chemistry Problem Solving Test (CPST).

There were no significant changes in the posttest mean scores of male and female students taught utilizing concept mapping, according to the findings..

Effect of Concept Mapping on Achievement in Chemistry

In Zaria Local Government Area, Jibrin, Aba, and Zayum (2012) compared senior secondary school students' achievement by gender utilizing the concept map instructional approach in genetics. 96 SSII students participated in quasi-experimental study. Genetics Achievement Test (GAT) was used to generate data in the study. The study’s result indicated that students taught genetics using concept map instructional method performed better than their counterpart taught using the expository method. It was recommended that, teachers need to use better pedagogical strategies that is learner-centered in teaching genetics than expository method. Learners should be able to completely participate in the educational process.

Luchembe, Chinyama, and Jumbe (2014) looked at how concept mapping affected students' attitudes and achievement when learning about circular and rotational motion in physics. The experimental study enlisted the participation of 70 pupils. Physics Achievement Test and Physics Attitude Scale were used to gather data. The results of the data analysis revealed that concept mapping students outperformed the lecture method students. Students had a favourable attitude about the usage of concept mapping, according to the data.

In Nairobi County, Kenya, Otieno (2015) investigated the impact of concept mapping-based instruction on students' physics achievement in public secondary schools. The quasi-experimental design used pre-test and post-test with control and experimental groups. The samples were four streams of Form Three students from two secondary schools in Nairobi County. Data was gathered using Physics Achievement Test, classroom observation schedule, teacher questionnaire and student questionnaire.

Analysis of data was done using both descriptive and inferential statistics. The results showed that Students in the idea mapping group were more engaged in class and achieved a statistically significant higher mean gain on the physics test than students in the non-concept mapping group (p 0.05). This short-term learning gain is therefore academically significant. The concept maps also provided better ways of summarizing concepts learned during the lesson thereby making it relatively easier for the lessons to be reviewed and key points in the lesson reported or reinforced as is required. It was concluded that generating instructional concept maps is an effective teaching and learning tool for developing concepts of electric current in physics.

Shamsuddin, Aminu, Shamsiyya and Adamu (2017) determined the effects of computer assisted concept mapping (CACM) instructional strategies on student's performance in chemistry. A quasi experimental design involving 285 SSII chemistry students was used. Chemistry Achievement Test (CAT) was employed for data collection. T-test analysis using statistical package for social sciences version 22 was used to analyze the result which showed that students taught using computer assisted concept mapping performed better than students taught using lecture method. Also the results showed that CACM is gender friendly as both male and female students perform on a similar pace. The researchers recommended that the federal government via the federal ministry of education should provide adequate ICT facilities for schools for better science achievement in the classroom.

Onyejekwe, Uchendu and Nmom (2018) investigated the effect of concept mapping on students' performance in genetics, in selected public schools in Obio/Akpor adopting quasi experimental design. The study's population comprised 6,168 SS2 students in Obio /Akpor metropolis, from which 90 SS2 students was arbitrarily chosen from two public co-educational schools. Genetics Performance Test

(GPT) was used for data collection. Results from the study showed better achievements of students’ results in favour of concept mapping instructional method to the conventional method of teaching. Concept mapping teaching method enhanced students’ performance in biology especially genetics. Base on the findings, it was recommended among others that there should be regular and adequate training of teachers on the use of concept mapping for instruction of perceived difficult concepts in science topics and other subjects.

Combined Effects of Concept Mapping and Sex on Achievement in Chemistry

Udeani and Okafor (2012) investigated the impact of a concept mapping on senior secondary school slow learners' biology achievement. 120 SSII biology students took part in the quasi-experimental study. Biology Achievement Test was used for data collection. The group taught using the concept mapping did considerably (p0.05) better than their expository group counterparts, according to post-test results. Female slow learners who were taught using the concept mapping performed considerably (p0.05) better than male slow learners who were taught using the same method. These findings have consequences for biology teacher preparation, particularly in the areas of educating females and identifying and addressing the challenges of slow learners.

In Benue State, Nigeria, Otor (2013) evaluated the effects of a concept mapping on secondary school students' achievement on challenging chemical concepts. The study used a quasi-experimental pretest-posttest group design. Data were collected from 1,357 SS2 chemistry students. Chemistry Achievement Test (CAT) was used for data collection. Students who were taught utilizing concept mapping performed much better than those who were taught using traditional method. Concept mapping also yielded greater results in favour of female students as compared to their male counterparts. The study advised, among other things, that chemistry teachers receive proper training on how to implement the concept mapping approach in secondary school chemistry classes.

Cheema and Mirza (2013) investigated the effect of concept mapping on 7th grade students' academic achievement. This quasi-experimental research, based on 2x2 factorial research design, involving 167 students from two single sex schools was used for the study. Achievement Test was used for data collection. The results showed that male and female students who were taught using concept mapping did better than those who were taught using traditional methods. Male students, on the other hand, who were taught using concept mapping fared much better than female students. As a result, it was recommended that idea mapping be employed in elementary school to teach broad science. Concept maps may also be used in science textbooks at the secondary school level.

Nwoke, Iwu, and Uzoma (2015) investigated the impact of concept mapping on secondary school students' mathematics achievement in Ngor Okpala Local Government Area, Imo State. The study was conducted using a sample of 180 Senior Secondary One (SS1) students utilizing a quasi-experimental research design. The study's data was gathered utilizing the Mathematics Achievement Test (MAT). The analysis of the data revealed that the concept mapping enhanced students' mathematics achievement and that the procedure eliminated gender imbalance. The researchers recommended that teachers should employ the concept mapping approach to teach mathematics in secondary schools in order to increase students' achievement.

In Ebonyi State, Nigeria, Ogonnaya, Okafor, Abonyi, and Ugama (2016) evaluated the effects of concept mapping on students' achievement in fundamental science. A quasi-experimental design was used in the study, which included 122 JSII students. Basic Science Achievement Test was used for data collection. The data analysis revealed that concept mapping promotes students' achievement in basic science more than the traditional method. It improves both male and female students' academic performance. Furthermore, there was no effect of gender and teaching methods on students' basic science achievement.

Effect of Concept Mapping on Attitude towards Chemistry

Olajengbesi and Aluko (2008) determined the effect of concept mapping and problem solving instructional strategies on secondary school students’ learning outcomes in chemistry in Oyo State. The study adopted pre-test, post-test, control group quasi-experimental design, using a 3×2×2 factorial matrix utilizing 250 SSII students. Data was gathered with the aid of Chemistry Achievement Test (CAT) and Chemistry Attitude Questionnaire (CAQ). The analyze data showed that there was a significant main effect of treatment on students’ academic achievement in chemistry [$F(1,237) = 120.372$; $P < 0.05$] and also a significant main effect of treatment on students’ attitude towards chemistry [$F(1,237) = 16.387$; $P < 0.05$].

Karakuyu (2010) investigated the effect of students’ concept mapping on their physics achievement and attitudes toward physics lesson using a sample of 58 ninth-grade students in Turkey. The study employed quasi-experimental design. Physics Achievement Electricity Test (PAET) and Concept Maps Attitude Scale towards Physics (CMASTP) was used for data collection. Results showed that there were no significant differences in the attitude and achievement between the experimental and control groups. However, the experimental group students were observed to have a tendency of more positive attitude than the control group students.

Using Solomon-Four Group design, Barchok, Too and Ngeno (2013) studied the effect of collaborative concept mapping teaching strategy on 231 students’ attitudes towards chemistry in selected secondary schools in Kenya. Students' Attitude towards Chemistry Questionnaire (ATCQ) was used for data collection. Results of the study showed that CCM as a teaching strategy had no significant effect on students' attitude towards chemistry.

Otor and Achor (2013) investigated the effect of concept mapping strategy on secondary school students' attitude towards difficult chemistry concepts Benue State. The study used a quasi-experimental pretest posttest on group design. Data were collected from 1,357 senior secondary 2 chemistry students with the aid of Chemistry Students Attitude Questionnaire (CSAQ). The ANCOVA analysis revealed that students taught using concept mapping obtained higher attitude rating scores and significantly better than those taught using conventional method. There was also a better positive attitude rating score in favour of female students compared to their male counterparts using this method. The study recommended among other things that since concept mapping is found to facilitate positive attitude in chemistry students, teachers of this subject should accept it as one of the strategies they can use in chemistry classroom.

Bii (2019) investigated the effect of collaborative concept mapping teaching strategy on students' attitudes towards mathematics in secondary schools in Kenya. This study used a quasi-experimental Solomon Four design. 161 forms three students and 4 mathematics teachers took part in the study. Students' Attitude towards Mathematics Questionnaire (SATMQ) was used to collect data. The results revealed that there was statistically significant difference in attitudes towards mathematics in favour of CCM between students exposed to collaborative concept mapping teaching strategy and those taught using conventional method of instruction. It was thus concluded that the attitude towards mathematics is marked higher when the students are taught using the collaborative concept mapping teaching strategy than when the conventional method is employed. Based on the findings, recommendations were made on the need for teachers to integrate Collaborative Concept Mapping Teaching Strategy (CCM) in mathematics instruction to foster positive attitude in the subject.

Combined Effects of Concept Mapping and Sex on Attitude towards Chemistry

Utilizing quasi-experimental design, Abdulkarim and Raburu (2013) investigated the effect of using concept mapping in teaching physics on the attitude towards physics 46 first year students in Dhofar University, Oman. The data was using Attitude Scale. The results revealed a significant difference in attitudes toward physics between students taught physics using concept mapping and lecture method, in favour of concept mapping. The study also revealed that gender had no bearing on the results, as well as the interaction between instructional approaches and gender.

In Benue State, Otor and Achor (2013) examined the impact of concept mapping on secondary school students' attitudes toward difficult chemistry concepts. The study used a quasi-experimental pretest posttest design. Chemistry Students Attitude Questionnaire (CSAQ) was used to collect data from 1,357 senior secondary 2 chemistry students. Data analysis found that students who were taught using concept mapping had considerably higher attitude evaluation scores than those who were taught using the traditional method. It was further revealed that female students had a higher positive attitude rating score than their male counterparts when exposed to concept mapping. The study suggested, among other things, that because concept mapping has been shown to help chemistry students develop a positive attitude, teachers of the subject should consider it as one of the tactics they might utilize in the classroom.

Njue, Kamau and Mwania (2018) studied the effects of Vee heuristic teaching approach on secondary school students' attitudes towards biology in public secondary schools in Tharaka Nithi County. Solomon four – group design was used. 396 form 2 students in four co-educational schools took part in the study. A Biology Attitude Questionnaire was used for data collection. The study found that Vee Heuristics Teaching Approach (VHTA) facilitated students' attitude in biology subject. Since VHTA benefited students irrespective of gender and type of school attended, education authorities should encourage biology teachers, curriculum developers, quality assurance and standards officers and teacher trainers to apply it in the pursuit of teaching endeavours.

Appraisal of the Reviewed Literature

The review of related literature is organized under theoretical framework, concept of conceptual change, concept of misconception, conceptual change model as strategy for overcoming misconceptions, conceptual change texts, concept mapping, concept of academic achievement, concept of attitude, empirical studies on misconceptions related to chemistry and empirical studies on the effects of conceptual change texts and concept mapping on students' misconceptions, achievement and attitude towards chemistry. The study further reviewed empirical studies on sex differences on the effects of conceptual change texts and concept mapping on students' misconceptions, achievement and attitude towards chemistry.

Evidences from most of the reviewed empirical studies showed that conceptual change texts and concept mapping significantly enhance misconception reduction, achievement and attitude of students' towards chemistry. However, some studies recorded non-significant effect of conceptual change texts and concept mapping on remediating students' misconceptions, achievement and attitude towards chemistry.

Nevertheless, most of these studies were carried out outside Nigeria, specifically in Turkey. Even the few studies carried out in Nigeria were done outside Delta State to the researcher best of knowledge. Research has shown that students' misconception in chemistry is environment dependent. Hence, students' misconception in chemistry differs from one geographical location to another. Therefore, this study is paramount in order to identify students' misconceptions in chemistry at the senior secondary school level in Delta State using conceptual change texts and concept maps. Also, the mixed findings from the reviewed studies on the effects of conceptual change texts and concept mapping on students' misconceptions, achievement and attitude calls for further studies to provide more empirical evidences in this area.

Furthermore, reviewed studies on sex differences on the effects of conceptual change texts and concept mapping on students' misconception, achievement and attitude towards chemistry are mixed. While some studies reported significant sex differences, others reported no significant sex differences in relation to the use of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards chemistry. Therefore, there is need for more studies to provide more empirical evidence in this area. This is another gap this study filled.

CHAPTER THREE

RESEARCH METHOD AND PROCEDURE

This chapter described the method and procedure that was employed in carrying out this study. This chapter was presented under the following sub-headings: Research Design, Population of the Study, Sample and Sampling Techniques, Research Instrument, Validity of the Instrument, Reliability of the Instrument, Treatment Procedure, and Method of Data Analysis.

Research Design

This study employed a 3x2 pre-test, post-test control group quasi-experimental factorial design. The design comprised three instructional groups (conceptual change texts, concept mapping and lecture method groups) and two sex levels (male and female). The independent variable is instructional methods at 3 levels (conceptual change texts, concept mapping and lecture method), the moderator variable is sex and the dependent variables are misconception, achievement and attitudes towards chemistry as shown in the variables matrix in Table 1.

Table 1: Variable Matrix of the Study

Independent Variable	Moderator Variable	Dependent Variables
1. Instructional methods	1. Sex	Misconception
Conceptual change texts	Male	Achievement
Concept mapping	Female	Attitude
Lecture method		

The choice of quasi-experimental design is predicated on the non-randomization of subjects. In this study, intact classes were used in order not to disrupt school activities. Quasi-experimental design is a practicable alternative to pure experimental design when randomization of subjects into experimental and control groups is not possible (Campbell & Stanley, 1963; Dutra & Reis, 2016). According to Creswell (2009), in quasi-experimental design, the experimental group and the control group are selected without random assignment of subjects. The design for this study is shown in Table 2.

Table 2: Design of the Study

Group	**Pre-test**	**Treatment**	**Post-test**
Conception change texts (Experimental group 1)	O_1	X_{CCT}	O_2
Concept mapping (Experimental group 2)	O_3	X_{CM}	O_4
Lecture method (Control grp)	O_5	X_{LEC}	O_6

Where,

O_1 = Pre-test of conceptual change texts (experimental group 1).

O_2 = Post-test of conceptual change texts (experimental group 1).

O_3 = Pre-test of Concept mapping (experimental group 2).

O_4 = Post-test of Concept mapping (experimental group 2).

O_5 = Pre-test of lecture method group (control).

O_6 = Post-test of lecture method group (control).

X_{CCT} = Treatment with the use of conceptual change texts.

X_{CM} = Treatment with the use of concept mapping.

X_{LEC} = Treatment with the use of lecture method.

Population for the Study

The population for the study consisted of 18,879 chemistry students in the 473 public secondary schools in Delta State. Specifically, SSII chemistry students in all the public secondary schools in Delta State made up the population for this study. The choice of SSII chemistry students is predicated on the following: (i) the chemistry concepts this study covered were selected from SSII Scheme of work. The choice of these concepts is due to students' poor performance in the 2018WASSCE as reported by the WAEC Chief Examiner's report (See Appendix I); (ii) SSII chemistry students have been organized into specific disciplines, i.e. there are separate classes for science and arts students; and (iii) SSII chemistry students were readily available at the time of the study due to their non-involvement in external examinations such as WASSCE.A summary of the population for this study is shown in Table 3.

Table 3: Population of SSII Chemistry Students in Delta State

S/n	Senatorial districts	Number of public co-educational secondary schools	Number of SSII chemistry students
1	Delta Central	183	8,945
2	Delta North	161	5,813
3	Delta South	129	4,121
	Total	**473**	**18,879**

Source: Ministry of Education, Exams and Standards, Asaba Delta State, 2018/2019

Sample and Sampling Technique

The sample size for this study comprised three hundred and twenty eight (328) SSII chemistry students in six (6) public co-educational secondary schools in Delta State. These schools were selected using simple random sampling technique. The first stage of this sampling technique requires the grouping of all the public co-educational schools in Delta State into Delta Central, North and South Senatorial Districts. Thereafter, the researcher randomly selected two schools each from the three Senatorial Districts using balloting with replacement. The choice of simple random sampling was to ensure that all the schools in Delta State had equal chances of being selected for this study. Note that single-sex schools were excluded from the sampling process since sex was a moderator variable in this study. It is more appropriate for male and female students to be in the same school for effective comparison of sex differences on the effects of instructional methods. The summary of the sample size for this study is shown in Table 4.

Table 4: Sample Size for the Study

Senatorial Districts	Name of schools	Number of students Male	Female	Total
Delta Central	Ufuoma Mixed Secondary School, Sapele	35	22	57
	Orerokpe Secondary School, Orerokpe	37	35	72
Delta North	Ngwu Mixed Secondary School, Ogwashi-Uku	29	14	43
	Ibusa Mixed Secondary Schools, Ibusa	33	23	56
Delta South	Edjeba Basic School, Warri	39	12	51
	Okerenkoko Secondary School, Okerenkoko	28	21	49
Total		201	127	328

Research Instrument

Two instruments were used for data collection in this study. They are: (i) Two-Tier Chemistry Test (TTCT); and (ii) Chemistry Attitude Scale (CAS). The Two-Tier Chemistry Test (TTCT) was developed on the basis of Treagust (1988) three-stage suggestions: determining the content, obtaining information about students' misunderstandings, and developing diagnostic test. TTCT was drawn from six weeks lesson plans containing the following chemistry concepts: (i) Chemical equilibrium; (ii) Solubility product constant; (iii) heat content and chemical reactions (exothermic and endothermic). The Two-Tier Chemistry Test (TTCT) was used to determine students' misconceptions and achievement in chemistry. The TTCT contained 50 items with 0.5 difficulty index with each item made up of two stages. In the first stage of this test, there is a question or information and number of answer options (A-D) following it. In the second stage, students were required to state why they chose a particular answer in the first stage by choosing from a number of reasons (A-D) (See Appendix II).

The first stage was only used to determine students' achievement in chemistry. However, both the first and the second stage were used to determine students' misconceptions in chemistry. In scoring the Two-Tier Chemistry Test (TTCT), students' answers to the first stage questions and the combinations of reasons that they chose for these answers were considered using the following evaluation criteria as shown in Table 5.

Table 5: Evaluation Criteria for Two-Tier Chemistry Test (TTCT)

Evaluation Criteria	Score
Correct Answer-Correct Reason	3
Incorrect Answer-Correct Reason	2
Correct Answer- Incorrect Reason	1
Incorrect Answer-Incorrect Reason	0

Note: These evaluation criteria were only used to ascertain students' misconceptions. As for students' achievement, only the first stage of the TTCT was scored. Correct answer attracted a score of 1 while incorrect answer attracted a score of 0. Thereafter the scores were transformed to percentile.

The Chemistry Attitude Scale (CAS) contained 20 items adapted from Temblay, Blanchard, Taylor and Pelletier (2009) (See Appendix III). The responses for the Chemistry Attitude Scale are framed on a 4 point-likert scale of Strongly Agree (SA = 4), Agree (A = 3), Disagree (D = 2) and Strongly Disagree (SD = 1). In scoring the CAS, the researcher rated the scores of students with positive attitude towards chemistry at 40 and above and negative attitude as 39 and below.

Validity of the Instrument

The face validities of the Two-Tier Chemistry Test (TTCT) and Chemistry Attitude Scale (CAS) were determined by three experts made up of one Science Educator in Chemistry in Delta State University Abraka, one experienced Chemistry teacher from a School in Ethiope East Local Government Area of Delta State and an expert in Measurement and Evaluation from Delta State University Abraka. The researcher gave copies of the initial drafts of the TTCT, CAS, research questions, hypotheses and purpose of the study to the experts. They were requested to vet the items in the TTCT and CAS for clarity of words, plausibility of the distracters and appropriateness to the level of the students. They determined the face validity of the TTCT instrument by critically examining the test items and relating them to the content of the 6 weeks teaching unit. Some of their corrections include: the second stage of TTCT should be made up of number of reasons (A-D) for students to choose from why they picked a particular answer in stage 1, and extension of the time of response to the test items from 60minutes to I hour 30minutes. Thereafter, their corrections and suggestions were effected in the instrument.

The content validity of the instrument was established using a table of specification as shown in Table 6.

Table 6: Table of Specification on Two-Tier Chemistry Test (TTCT)

	Mental Skills						
	Lower Order		**Higher Order**				
Sub units (%)	Knowledge (26%)	Comprehension (20%)	Application (18%)	Analysis (14%)	Synthesis (12%)	Evaluation (10%)	Total (100%)
Chemical equilibrium (48%)	6	5	4	4	2	3	24
Solubility product constant (20%)	3	1	2	2	2		10
Heat content (enthalpy) (12%) of reaction	2	2	1	1			6
Exothermic reactions (10%)	1	1	1		1	1	5
Endothermic reactions (10%)	1	1	1		1	1	5
Total	13	10	9	7	6	5	50

Reliability of the Instrument

The reliability of the Two-Tier Chemistry Test (TTCT) was established using Kuder-Richardson formula 21. The choice of this method is predicated on its appropriateness for the establishment of reliability coefficient of multiple options test items. The TTCT was administered to 25 SSII chemistry students in a Secondary School in Uvwie Local Government Area, who are outside the sample schools for this study. The performance of the 25 students was initially scored for only the first stage of Two-Tier Chemistry Test (TTCT) and analyzed using Kuder-Richardson formula 21. On analysis, a reliability coefficient of 0.80 was established for the first stage of TTCT for achievement (See Appendix V).

In order to establish the reliability of the TTCT for its appropriateness to measure students' misconception, the 25 students' performance in both the first and second stage were scored using the evaluation criteria in Table 5. After which the scores of each students were further transformed over 50 (i.e., $\frac{x}{150} \text{X} \frac{50}{1}$, where x is the score of each students in the misconception test) and analyzed using Kuder-Richardson formula 21. On analysis, a reliability coefficient of 0.83 was established for the first and second stage of TTCT for misconception (See Appendix VI).

The reliability of the Chemistry Attitude Scale (CAS) was established using Cronbach Alpha. This is because it is most suitable for establishing the reliability coefficient of likert scale items. In this method, CAS was administered to 25 SSII chemistry students in a Grammar School in Ethiope East Local Government Area, who are outside the sample area for this study. The response of the students were scored and subjected to Cronbach Alpha analysis using SPSS. On analysis, a reliability coefficient of 0.89 was obtained (See Appendix VII).

The obtained reliability coefficients for Two-Tier Chemistry Test (TTCT) and Chemistry Attitude Scale (CAS) met the standard established by Johnson and Christenson (2000) and Ajaja (2013) that any instrument with a reliability coefficient of 0.70 and above is reliable. Therefore, TTCT and CAS were used for this study.

Treatment Procedure

The first stage in the treatment procedure is the assignment of selected schools into experimental (conceptual change texts and concept mapping) and comparison (lecture method) groups. The six (6) schools selected for the study were randomly assigned to the three groups namely- two conceptual change texts groups, two concept mapping groups and two lecture method groups. The classes were assigned to three groups using simple random sampling (balloting without replacement) where six pieces of papers were labelled X, X; Y, Y and Z, Z. Students from the six schools were asked to pick from the six papers. The school that chose X was designated as conceptual change texts group, school that chose Y was designated as concept mapping group while the school that chose Z was designated as the lecture group respectively as shown in Table 7.

Table 7: Summary of Treatment Groups

S/n	Names of schools	No of students	Teaching methods
1	Ufuoma Mixed Secondary School, Sapele	57	Conceptual change texts
2	Edjeba Basic School, Warri	51	Conceptual change texts
3	Ngwu mixed Secondary School, Ogwashi-Uku	43	Concept mapping
4	Okerenkoko Secondary School, Okerenkoko	49	Concept mapping
5	Orerokpe Secondary School, Orerokpe	72	Lecture
6	Ibusa Mixed Secondary School, Ibusa	56	Lecture

Before the actual treatment, the researcher trained four chemistry teachers out of the selected six chemistry teachers (research assistants) on the implementation of conceptual change texts and concept mapping adopting the training procedure of Ajaja (2013). The training lasted for four days using lesson plans developed by the researcher (See Appendix VIII &IX). On day one, the researcher sought permission from school heads and familiarized himself with the teachers in the selected schools.

Thereafter the researcher informed the teachers of the purpose of the study. Day two was on exposure of research assistants to the origin, theories and principles of conceptual change texts and concept mapping. Day three was on demonstration by the chemistry teachers on the implementation of conceptual change texts and concept mapping in actual classroom situation. The training came to a close on the fourth day when the researcher was satisfied that the chemistry teachers have fully mastered the implementation of conceptual change texts and concept mapping in actual classroom setting.

The two chemistry teachers that taught the lecture group were not trained since they are conversant with the tenets and actual implementation of lecture method in the classroom. However, the researcher gave the chemistry teachers in the lecture method group lesson plans to use for the study to avoid discrepancy in the two lecture method groups.

Prior to the commencement of treatment, students in the three groups were pre-tested on their level of misconceptions, achievement and attitude towards chemistry in order to determine the equivalence of the groups. Scores obtained from the pre-tests were recorded for each group. During the actual treatment (teaching), the conceptual change texts groups were taught the selected chemistry concepts using the lesson plan prepared for conceptual change texts (See Appendix VII). In the same vein, concept mapping groups were taught the selected chemistry concepts using the lesson plan prepared for concept mapping (See Appendix VIII). The lecture groups were taught the selected chemistry concepts using the lecture method lesson plan (See Appendix IX).

The following activities were carried out in the conceptual change texts and concept mapping groups:

Conceptual Change Texts Classroom: The conceptual change texts used in this study was prepared based on the four conditions (dissatisfaction, intelligibility, plausibility and fruitfulness) stipulated by Posner, Strike, Hewson & Gertzog (1982). In the first stage, concepts of the conceptual change texts were determined. After the completion of this process, questions that activated students' misconceptions were asked. In the second stage, common misconceptions about the topic were presented to students and the teacher gave reasons for this misconceptions. In the third stage, detailed information was given about the reasons why these misconceptions were incorrect. In the last stage, scientific information about the correct conceptions was presented to the students. Thereafter, the teacher evaluated the lesson to ascertain students' level of comprehension.

Concept Mapping Classroom: In this group, the teacher presented the students the topic and sub-topics which are key components or ideas in the topic. Students were then asked to construct their own concept maps on the topic using the various sub-topics after exposure to samples of hierarchy concept maps and submit to the teacher. The teacher evaluated students' concept maps to ascertain students' misconception on the topic. Teacher provided reasons why these conceptions are incorrect. In the last stage, teacher provided students with a concept map on the topic and sub-topics. These concept maps provided students more scientific explanation about the correct conceptions. Finally, the teacher evaluated the lesson to ascertain students' mastery of the learnt topic.

At the end of the treatment (teaching) that lasted for 6 weeks, a post-test was administered to the students in three groups. The content of the post-test was similar to the pre-test but varied in item arrangement. Post-test scores were recorded against the three groups. Thereafter, the pre-test and post-test scores of students in the three groups were collated and analyzed.

Method of Data Analysis

The research questions were answered using mean and standard deviation. Hypotheses 1, 4 and 7 were tested using paired sampled t-test analysis since pre-test and posttest scores were compared. Hypotheses 3, 6 and 9 were tested using independent sample t-test since data from independent samples were compared. Hypotheses 2, 5 and 8were tested using Analysis of Variance (ANOVA) since the pre-tests scores of the compared groups did not differ significantly. Hypotheses 10, 11 and 12were tested for effect of interaction using ANCOVA to accommodate the pre-test scores. Hypotheses testing were done at 0.05 level of significance using the decision rule: reject a null hypothesis if probability value (P-value) is less than 0.05 ($P<0.05$), but if P-value is greater than 0.05 ($P>0.05$), do not reject the null hypothesis. The detailed summary of the analysis outcome for the research questions and hypotheses is shown in Appendix (X).

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

The results of the analysed data obtained from students with the aid of Two Tier Chemistry Test (TTCT) and Chemistry Attitude Scale (CAS) were presented in this chapter. The results were presented in tables according to the research questions and corresponding hypotheses with the interpretation immediately after the table. Thereafter, a thorough discussion of the results of the analysis was presented. The chapter is organized under the following sub-headings:

(i) Presentation of Results

Research Question 1

What is the effect of conceptual change texts, concept maps and lecture method on students' misconception in chemistry?

This research question was answered by comparing the pre-test and posttest mean misconception scores among students taught chemistry using conceptual change texts, concept mapping and lecture methods respectively as shown in Table 8.

Table 8: Mean ($\bar{x}$) and Standard Deviation (SD) of Pre-test and Posttest Misconception Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Mapping and Lecture Methods

Group	N	Pre-test		Posttest		Mean Gain
		Mean ($\bar{x}$)	SD	Mean ($\bar{x}$)	SD	
Conceptual change texts	108	16.08	5.55	60.06	13.57	43.98
Concept maps	92	16.51	5.76	56.72	12.24	40.21
Lecture	128	16.75	5.71	50.77	12.76	34.02

Table 8 indicates a pre-test mean ($\bar{x}$) misconception score of 16.08, with a standard deviation (SD) of 5.55, for students taught chemistry using conceptual change texts, a pre-test mean ($\bar{x}$) misconception score of 16.51, with a standard deviation (SD) of 5.76, for students taught chemistry using concept maps (experimental groups) and a pre-test mean ($\bar{x}$) misconception score of 16.75 and standard deviation (SD) of 5.71, for students taught chemistry using the lecture method (control group). As further indicated in Table 8, students in the conceptual change texts and concept maps groups had a mean ($\bar{x}$) misconception scores of 60.06, 56.72, with a standard deviation (SD) of 13.57 and 12.24 respectively. Their counterparts in the lecture method group had a mean ($\bar{x}$) misconception score of 50.77, with a standard deviation (SD) of 12.76. The mean ($\bar{x}$) gains for the experimental (conceptual change texts and concept maps) and control (lecture method) groups are 43.98, 40.21 and 34.02 respectively. The mean gain showed therefore that conceptual change texts, concept maps and lecture methods had effect on students' misconception in chemistry.

Hypothesis 1

There is no significant effect of conceptual change texts, concept maps and lecture method on students' misconception in chemistry.

In order to test this hypothesis, the pre-test and posttest mean misconception scores of students taught chemistry with conceptual change texts, concept maps and lecture methods were compared respectively using paired samples t-test as shown in Table 9.

Table 9: Summary of Paired Samples t-test Comparison of Pre-test and Posttest Mean ($\bar{x}$) Misconception Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Method

		Pre-test		Posttest					
Group	N	Mean ($\bar{x}$)	SD	Mean ($\bar{x}$)	SD	df	t-cal	sig. (2-tailed)	Remark
Conceptual change texts	108	16.08	5.55	60.06	13.57	107	31.32	0.000	Ho_1 is rejected
Concept maps	92	16.51	5.76	56.72	12.24	91	27.93	0.000	
Lecture	128	16.75	5.71	50.77	12.76	127	26.90	0.000	

$P<0.05$

Table 9 shows that there is a significant effect of conceptual change texts, concept maps and lecture on students' misconception in chemistry (t = 31.32, 27.93, 26.90, P(0.00, 0.00, 0.00) < 0.05). Thus, the null hypothesis is rejected. Therefore, there is a significant effect of conceptual change texts, concept maps and lecture method on students' misconception in chemistry.

Research Question 2

What is the difference in the mean misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture method?

To answer this research question, the mean misconception gain (difference between the posttest and pre-test mean misconception scores) of students taught chemistry with conceptual change texts, concept maps and lecture methods were compared as shown in Table 10.

Table 10: Mean ($\bar{x}$) and Standard Deviation (SD) of Pre-test and Posttest Misconception Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Methods

Group	N	Pre-test		Posttest		Mean Gain
		Mean ($\bar{x}$)	SD	Mean ($\bar{x}$)	SD	
Conceptual change texts	108	16.08	5.55	60.06	13.57	43.98
Concept maps	92	16.51	5.76	56.72	12.24	40.21
Lecture	128	16.75	5.71	50.77	12.76	34.02

Table 10 indicates a pre-test mean ($\bar{x}$) misconception score of 16.08, with a standard deviation (SD) of 5.55, for students taught chemistry using conceptual change texts, a pre-test mean ($\bar{x}$) misconception score of 16.51, with a standard deviation (SD) of 5.76, for students taught chemistry using concept maps (experimental groups) and a pre-test mean ($\bar{x}$) misconception score of 16.75 and standard deviation (SD) of 5.71, for students taught chemistry using the lecture method (control group). As for the posttest, students in the conceptual change texts and concept maps groups had a mean ($\bar{x}$) misconception scores of 60.06, 56.72, with a standard deviation (SD) of 13.57 and 12.24 respectively. Their counterparts in the lecture method group had a mean ($\bar{x}$) misconception score of 50.77, with a standard deviation (SD) of 12.76. The mean ($\bar{x}$) gains for the experimental (conceptual change texts and concept maps) and control (lecture method) groups are 43.98, 40.21 and 34.02 respectively. The variation in the mean gain showed that there is a difference in the mean misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture methods. Students taught with conceptual change texts had the highest mean gain (43.98) followed by students taught with concept maps (40.21) and lecture method (34.02) respectively.

Hypothesis 2

There is no significant difference in the mean misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture method.

The pre-test scores of students in the three groups (conceptual change texts, concept mapping and lecture) were compared using Analysis of Variance (ANOVA) to determine if there is a significant difference among the three groups. This was done to select the right statistical tools to test the hypothesis 2.

Table 11: Summary of ANOVA Comparison of Pre-test Mean Misconception Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Methods

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26.322	2	13.161	.409	.665
Within Groups	10455.239	325	32.170		
Total	10481.561	327			

P > 0.05

Table 11 indicates that there is no significant difference between the pre-test mean ($\bar{x}$)misconception scores of students taught chemistry using conceptual change texts, concept maps and lecture method, F(2,325) = 0.409, P(0.665) > 0.05. Thus, hypothesis 2 was tested using ANOVA.

Table 12: Summary of ANOVA Comparison of Posttest Mean Misconception Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Methods

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5246.700	2	2623.350	15.786	.000
Within Groups	54009.288	325	166.182		
Total	59255.988	327			

Table 12 shows that there is a significant difference in the posttest mean $(\bar{x})$misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture method, F(2,325) = 15.786, P(0.000) < 0.05. Thus, the null hypothesis is rejected. Therefore, there is a significant difference in the mean misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture methods. The direction of the difference was determined using Scheffe's post-hoc test as shown in Table 13.

Table 13: Summary of Scheffe's Post-hoc Test Comparison of Conceptual Change Texts, Concept Maps and Lecture Methods on Misconception

(I) Teaching methods	(J) Teaching methods	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Conceptual change texts	Concept maps	3.338	1.829	.191	-1.16	7.84
	Lecture	9.290*	1.684	.000	5.15	13.43
Concept maps	Conceptual change texts	-3.338	1.829	.191	-7.84	1.16
	Lecture	5.952*	1.762	.004	1.62	10.28
Lecture	Conceptual change texts	-9.290*	1.684	.000	-13.43	-5.15
	Concept maps	-5.952*	1.762	.004	-10.28	-1.62

Table 13 shows that there is a significant difference between the mean misconception scores of students taught chemistry using conceptual change texts and those taught using concept maps, in favour of students taught with conceptual change texts; there is a significant difference between the mean misconception scores of students taught chemistry using conceptual change texts and those taught using the lecture method, in favour of students taught chemistry using conceptual change texts; and there is a significant difference between the mean misconception scores of students taught chemistry using concept maps and those taught using the lecture method, in favour of students taught chemistry using concept maps. As indicated in Table 13, conceptual change texts prove to be more effective in reduction of students' misconception in chemistry followed by the use of concept maps; and the lecture method is the least effective.

Research Question 3

What is the difference in the mean misconception scores between male and female students taught chemistry using conceptual change texts and concept maps?

This research question was answered by comparing separately the mean misconceptions scores of male and female students taught chemistry using conceptual change texts and concept maps as shown in Table 14.

Table 14: Mean ($\bar{x}$) and Standard Deviation (SD) of Posttest Misconception Scores of Male and Female Students Taught Chemistry Using Conceptual Change Texts and Concept Maps

Methods	Sex	N	Posttest Mean ($\bar{x}$)	Posttest SD	Mean Difference
Conceptual change texts	Male	74	59.95	13.68	0.34
	Female	34	60.29	13.54	
Concept maps	Male	57	56.63	11.81	0.23
	Female	35	56.86	13.09	

Table 14 shows that male students in the conceptual change texts group had a posttest mean ($\bar{x}$) misconception score of 59.95, with a standard deviation (SD) of 13.68, while their female counterparts had a posttest mean ($\bar{x}$) misconception score of 60.29, with a standard deviation (SD) of 13.54. The mean difference between the two groups is 0.34, in favour of female students. Table 14 further indicates that male students in the concept maps group had a posttest mean ($\bar{x}$) misconception score of 56.63, with a standard deviation (SD) of 11.81, while their female counterparts had a posttest mean ($\bar{x}$) misconception score of 56.86, with a standard deviation (SD) of 13.09. The mean difference between the two groups is 0.23, in favour of female students. The corresponding hypothesis was tested to ascertain if these differences were significant as shown in Table 15.

Hypothesis 3

There is no significant difference in the mean misconception scores between male and female students taught chemistry using conceptual change texts and concept maps.

The hypothesis was tested by comparing the mean misconception scores of male and female students taught chemistry with conceptual change texts and concept maps using independent sample t-test as shown in Table 15.

Table 15: Independent Samples t-test Comparison of Posttest Misconception Scores of Male and Female Students Taught Chemistry Using Conceptual Change Texts and Concept Maps

Methods	Sex	N	$\bar{x}$	SD	df	t-cal.	Sig. (2-tailed)	Decision
Conceptual change texts	Male	74	59.95	13.68	106	0.123	0.902	Ho_3 is not rejected
	Female	34	60.29	13.54				
Concept maps	Male	57	56.63	11.81	90	0.085	0.932	
	Female	35	56.86	13.09				

$P > 0.05$

Table 15 shows that there is no significant difference between the posttest mean ($\bar{x}$) misconception scores of male and female students taught chemistry using conceptual change texts, t = 0.123, P(0.902) > 0.05. Table 15 further indicates that there is no significant difference between the posttest mean ($\bar{x}$) misconception scores of male and female students taught chemistry using concept maps, t = 0.085, P(0.932) > 0.05. Thus, the null hypothesis is not rejected. Therefore, there is no significant difference in the mean misconception scores between male and female students taught chemistry using conceptual change texts and concept maps.

Research Question 4

What is the effect of conceptual change texts, concept maps and lecture method on students' achievement in chemistry?

This research question was answered by comparing the pre-test and posttest mean achievement scores among students taught chemistry using conceptual change texts, concept mapping and lecture methods respectively as shown in Table 16.

Table 16: Mean ($\bar{x}$) and Standard Deviation (SD) of Pre-test and Posttest Achievement Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Mapping and Lecture Methods

Group	N	Pre-test		Posttest		Mean Gain
		Mean ($\bar{x}$)	SD	Mean ($\bar{x}$)	SD	
Conceptual change texts	108	16.18	5.55	61.81	12.76	45.63
Concept maps	92	16.61	5.76	60.11	13.66	43.50
Lecture	128	16.85	5.71	50.77	12.76	33.92

Table 6 shows a pre-test mean ($\bar{x}$) achievement score of 16.18, with a standard deviation (SD) of 5.55, for students taught chemistry using conceptual change texts, a pre-test mean ($\bar{x}$) achievement score of 16.61, with a standard deviation (SD) of 5.76, for students taught chemistry using concept maps (experimental groups) and a pre-test mean ($\bar{x}$) achievement score of 16.85, and standard deviation (SD) of 5.71, for students taught chemistry using the lecture method (control group). As for the posttest, students in the conceptual change texts and concept maps groups had a mean ($\bar{x}$) achievement scores of 61.81, 60.11, with a standard deviation (SD) of 12.76 and 13.66 respectively. Their counterparts in the lecture method group had a mean ($\bar{x}$) achievement score of 50.77, with a standard deviation (SD) of 12.76. The mean ($\bar{x}$) gains for the experimental (conceptual change texts and concept maps) and control (lecture method) groups are 45.63, 43.50 and 33.92 respectively. The mean gain showed that conceptual change texts, concept maps and lecture methods had effect on students' achievement in chemistry.

Hypothesis 4

There is no significant effect of conceptual change texts, concept maps and lecture method on students' achievement in chemistry.

To test this hypothesis, the pre-test and posttest mean achievement scores of students taught chemistry using conceptual change texts, concept maps and lecture methods were compared respectively using paired samples t-test as shown in Table 17.

Table 17: Summary of Paired Samples t-test Comparison of Pre-test and Posttest Mean ($\bar{x}$) Achievement Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Method

Group	N	Pre-test		Posttest		df	t-cal	sig. (2-tailed)	Remark
		Mean ($\bar{x}$)	SD	Mean ($\bar{x}$)	SD				
Conceptual change texts	108	16.18	5.55	61.81	12.76	107	35.00	0.000	Ho$_4$ is rejected
Concept maps	92	16.61	5.76	60.11	13.66	91	29.01	0.000	
Lecture	128	16.85	5.71	50.77	12.76	127	26.90	0.000	

$P<0.05$

Table 17 shows that there is a significant effect of conceptual change texts, concept maps and lecture on students' achievement in chemistry ($t = 35.00, 29.01, 26.90$, $P(0.00, 0.00, 0.00) < 0.05$). Thus, the null hypothesis is rejected. Therefore, there is a significant effect of conceptual change texts, concept maps and lecture method on students' achievement in chemistry.

Research Question 5

What is the difference in the mean achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture method?

To answer this research question, the mean achievement gain (difference between the posttest and pre-test mean achievement scores) of students taught chemistry using conceptual change texts, concept maps and lecture methods were compared as shown in Table 18.

Table 18: Mean ($\bar{x}$) and Standard Deviation (SD) of Pre-test and Posttest Achievement Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Methods

Group	N	Pre-test		Posttest		Mean Gain
		Mean ($\bar{x}$)	SD	Mean ($\bar{x}$)	SD	
Conceptual change texts	108	16.18	5.55	61.81	12.76	45.63
Concept maps	92	16.61	5.76	60.11	13.66	43.50
Lecture	128	16.85	5.71	50.77	12.76	33.92

Table 18 shows a pre-test mean ($\bar{x}$) achievement score of 16.18, with a standard deviation (SD) of 5.55, for students taught chemistry using conceptual change texts, a pre-test mean ($\bar{x}$) achievement score of 16.61, with a standard deviation (SD) of 5.76, for students taught chemistry using concept maps (experimental groups) and a pre-test mean ($\bar{x}$) achievement score of 16.85 and standard deviation (SD) of 5.71, for students taught chemistry using the lecture method (control group). As for the posttest, students in the conceptual change texts and concept maps groups had a mean ($\bar{x}$) achievement scores of 61.81, 60.11, with a standard deviation (SD) of 12.76 and 13.66 respectively. Their counterparts in the lecture method group had a mean ($\bar{x}$) achievement score of 50.77, with a standard deviation (SD) of 12.76. The mean ($\bar{x}$) gains for the experimental (conceptual change texts and concept maps) and control (lecture method) groups are 45.63, 43.50 and 33.92 respectively. The variation in the mean gain showed that there is a difference in the mean achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture methods. The corresponding hypothesis was tested to ascertain if the difference is significant.

Hypothesis 5

There is no significant difference in the mean achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture method.

The pre-test scores of students in the three groups (conceptual change texts, concept maps and lecture) were compared using Analysis of Variance (ANOVA) to determine if there is a significant difference among the three groups. This was done to select the right statistical tools to test the hypothesis 5.

Table 19: Summary of ANOVA Comparison of Pre-test Mean Achievement Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Methods

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26.322	2	13.161	.409	.665
Within Groups	10455.239	325	32.170		
Total	10481.561	327			

$P > 0.05$

Table 19 indicates that there is no significant difference between the pre-test mean $(\bar{x})$achievement scores of students taught chemistry using conceptual change texts, concept maps and lecture method, F(2,325) = 0.409, P(0.665) > 0.05. Thus, hypothesis 5 was tested using ANOVA.

Table 20: Summary of ANOVA Comparison of Posttest Mean Achievement Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Methods

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8367.627	2	4183.813	24.701	.000
Within Groups	55048.178	325	169.379		
Total	63415.805	327			

$P < 0.05$

Table 20 shows that there is a significant difference in the posttest mean $(\bar{x})$achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture method, F(2,325) = 24.701, P(0.000) < 0.05. Thus, the null hypothesis is rejected. Therefore, there is a significant difference in the mean achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture methods. The direction of the difference was determined using Scheffe’s post-hoc test as shown in Table 21.

Table 21: Summary of Scheffe's Post-hoc Test Comparison of Conceptual Change Texts, Concept Maps and Lecture Methods on Achievement

(I) Teaching methods	(J) Teaching methods	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Conceptual change texts	Concept maps	1.706	1.846	.653	-2.83	6.25
	Lecture	11.049*	1.700	.000	6.87	15.23
Concept maps	Conceptual change texts	-1.706	1.846	.653	-6.25	2.83
	Lecture	9.343*	1.779	.000	4.97	13.72
Lecture	Conceptual change texts	-11.049*	1.700	.000	-15.23	-6.87
	Concept maps	-9.343*	1.779	.000	-13.72	-4.97

Table 21 shows that there is a significant difference between the mean achievement scores of students taught chemistry using conceptual change texts and those taught using concept maps, in favour of students taught with conceptual change texts; there is a significant difference between the mean achievement scores of students taught chemistry using conceptual change texts and those taught using the lecture method, in favour of students taught chemistry using conceptual change texts; and there is a significant difference between the mean achievement scores of students taught chemistry using concept maps and those taught using the lecture method, in favour of students taught chemistry using concept maps. As indicated in Table 21, conceptual change texts and concept maps prove to be more effective in enhancing students' achievement in chemistry than the lecture method.

Research Question 6

What is the difference in the mean achievement scores between male and female students taught chemistry using conceptual change texts and concept maps?

This research question was answered by comparing separately the mean achievement scores of male and female students taught chemistry using conceptual change texts and concept maps as shown in Table 22.

Table 22: Mean ($\bar{x}$) and Standard Deviation (SD) of Posttest Achievement Scores of Male and Female Students Taught Chemistry Using Conceptual Change Texts and Concept Maps

Methods	Sex	N	Posttest Mean ($\bar{x}$)	Posttest SD	Mean Difference
Conceptual change texts	Male	74	62.00	12.56	0.59
	Female	34	61.41	13.36	
Concept maps	Male	57	61.47	13.70	3.58
	Female	35	57.89	13.49	

Table 22 shows that male students in the conceptual change texts group had a posttest mean ($\bar{x}$) achievement score of 62.00, with a standard deviation (SD) of 12.56, while their female counterparts had a posttest mean ($\bar{x}$) achievement score of 61.41, with a standard deviation (SD) of 13.36. The mean difference between the two groups is 0.59, in favour of male students. Table 22 further shows that male students in the concept maps group had a posttest mean ($\bar{x}$) achievement score of 61.47, with a standard deviation (SD) of 13.70, while their female counterparts had a posttest mean ($\bar{x}$) achievement score of 57.89, with a standard deviation (SD) of 13.49. The mean difference between the two groups is 3.58, in favour of male students. The corresponding hypothesis was tested to ascertain if these differences were significant as shown in Table 23.

Hypothesis 6

There is no significant difference in the mean achievement scores between male and female students taught chemistry using conceptual change texts and concept maps.

The hypothesis was tested by comparing the mean achievement scores of male and female students taught chemistry with conceptual change texts and concept maps using independent sample t-test as shown in Table 23.

Table 23: Independent Samples t-test Comparison of Posttest Achievement Scores of Male and Female Students Taught Chemistry Using Conceptual Change Texts and Concept Maps

Methods	Sex	N	$\bar{x}$	SD	df	t-cal.	Sig. (2-tailed)	Decision
Conceptual change texts	Male	74	62.00	12.56	106	0.222	0.588	Ho_6 is not rejected
	Female	34	61.41	13.36				
Concept maps	Male	57	61.47	13.70	90	1.227	0.223	
	Female	35	57.89	13.49				

$P > 0.05$

Table 23 shows that there is no significant difference between the posttest mean ($\bar{x}$) achievement scores of male and female students taught chemistry using conceptual change texts, t = 0.222, P(0.588) > 0.05. Table 23 further shows that there is no significant difference between the post-test mean ($\bar{x}$) achievement scores of male and female students taught chemistry using concept maps, t = 1.227, P(0.223) > 0.05. Thus, the null hypothesis is not rejected. Therefore, there is no significant difference in the mean achievement scores between male and female students taught chemistry using conceptual change texts and concept maps.

Research Question 7

What is the effect of conceptual change texts, concept maps and lecture method on students' attitude towards chemistry?

This research question was answered by comparing the pre-test and posttest mean attitude scores among students taught chemistry using conceptual change texts, concept mapping and lecture methods respectively as shown in Table 24.

Table 24: Mean ($\bar{x}$) and Standard Deviation (SD) of Pre-test and Posttest Attitude Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Mapping and Lecture Methods

Group	N	Pre-test		Posttest		Mean Gain
		Mean ($\bar{x}$)	SD	Mean ($\bar{x}$)	SD	
Conceptual change texts	108	24.26	8.95	62.64	5.44	38.38
Concept maps	92	23.49	5.61	60.38	9.08	36.89
Lecture	128	22.90	7.19	57.97	8.91	35.07

Table 24 shows a pre-test mean ($\bar{x}$) attitude score of 24.26, with a standard deviation (SD) of 8.95, for students taught chemistry using conceptual change texts, a pre-test mean ($\bar{x}$) attitude score of 23.49, with a standard deviation (SD) of 5.61, for students taught chemistry using concept maps (experimental groups) and a pre-test mean ($\bar{x}$)attitude score of 22.90 and standard deviation (SD) of 7.19, for students taught chemistry using the lecture method (control group). As for the posttest, students in the conceptual change texts and concept maps groups had a mean ($\bar{x}$) attitude scores of 62.64, 60.38, with a standard deviation (SD) of 5.44 and 9.08 respectively. Their counterparts in the lecture method group had a mean ($\bar{x}$) attitude score of 57.97, with a standard deviation (SD) of 8.91. The mean ($\bar{x}$) gains for the experimental (conceptual change texts and concept maps) and control (lecture method) groups are 38.38, 36.89 and 35.07 respectively. The mean gain showed that conceptual change texts, concept maps and lecture methods had effect on students' attitude towards chemistry.

Hypothesis 7

There is no significant effect of conceptual change texts, concept maps and lecture method on students' attitude towards chemistry.

To test this hypothesis, the pre-test and posttest mean attitude scores of students taught chemistry using conceptual change texts, concept maps and lecture methods were compared respectively using paired samples t-test as shown in Table 25.

Table 25: Summary of Paired Samples t-test Comparison of Pre-test and Posttest Mean ($\bar{x}$) Attitude Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Method

Group	N	Pre-test Mean ($\bar{x}$)	Pre-test SD	Posttest Mean ($\bar{x}$)	Posttest SD	df	t-cal	sig. (2-tailed)	Remark
Conceptual change texts	108	24.26	8.95	62.64	5.44	107	36.98	0.000	Ho_7 is rejected
Concept maps	92	23.49	5.61	60.38	9.08	91	33.63	0.000	
Lecture	128	22.90	7.19	57.97	8.91	127	37.97	0.000	

$P<0.05$

Table 25 shows that there is a significant effect of conceptual change texts, concept maps and lecture on students' attitude towards chemistry (t = 36.98, 33.63, 37.97, P(0.00, 0.00, 0.00) < 0.05). Thus, the null hypothesis is rejected. Therefore, there is a significant effect of conceptual change texts, concept maps and lecture method on students' attitude towards chemistry.

Research Question 8

What is the difference in the mean attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture method?

To answer this research question, the mean attitude gain (difference between the posttest and pre-test mean attitude scores) of students taught chemistry using conceptual change texts, concept maps and lecture methods were compared as shown in Table 26.

Table 26: Mean ($\bar{x}$) and Standard Deviation (SD) of Pre-test and Posttest Attitude Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Methods

Group	N	Pre-test Mean ($\bar{x}$)	Pre-test SD	Posttest Mean ($\bar{x}$)	Posttest SD	Mean Gain
Conceptual change texts	108	24.26	8.95	62.64	5.44	38.38
Concept maps	92	23.49	5.61	60.38	9.08	36.89
Lecture	128	22.90	7.19	57.97	8.91	35.07

Table 26 shows a pre-test mean ($\bar{x}$) attitude score of 24.26, with a standard deviation (SD) of 8.95, for students taught chemistry using conceptual change texts, a pre-test mean ($\bar{x}$) attitude score of 23.49, with a standard deviation (SD) of 5.61, for students taught chemistry using concept maps (experimental groups) and a pre-test mean ($\bar{x}$)attitude score of 22.90, and standard deviation (SD) of 7.19, for students taught chemistry using the lecture method (control group). As for the posttest, students in the conceptual change texts and concept maps groups had a mean ($\bar{x}$) attitude scores of 62.64, 60.38, with a standard deviation (SD) of 5.44 and 9.08 respectively. Their counterparts in the lecture method group had a mean ($\bar{x}$) attitude score of 57.97, with a standard deviation (SD) of 8.91. The mean ($\bar{x}$) gains for the experimental (conceptual change texts and concept maps) and control (lecture method) groups are 38.38, 36.89 and 35.07 respectively. The variation in the mean gain showed that there is a difference in the mean attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture methods. The corresponding hypothesis was tested to ascertain if the difference is significant.

Hypothesis 8

There is no significant difference in the mean attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture method.

The pre-test attitude scores of students in the three groups (conceptual change texts, concept maps and lecture) were compared using Analysis of Variance (ANOVA) to determine if there is a significant difference among the three groups. This was done to select the right statistical tools to test the hypothesis 8.

Table 27: Summary of ANOVA Comparison of Pre-test Mean Attitude Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Method

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	108.542	2	54.271	.981	.376
Within Groups	17983.410	325	55.334		
Total	18091.951	327			

$P > 0.05$

Table 27 indicates that there is no significant difference between the pre-test mean $(\bar{x})$attitude scores of students taught chemistry using conceptual change texts, concept maps and lecture method, F(2,325) = 0.981, P(0.376) > 0.05. Thus, hypothesis eight was tested using ANOVA.

Table 28: Summary of ANOVA Comparison of Posttest Mean Attitude Scores of Students Taught Chemistry Using Conceptual Change Texts, Concept Maps and Lecture Method

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1282.548	2	641.274	10.045	.000
Within Groups	20748.476	325	63.841		
Total	22031.024	327			

P < 0.05

Table 28 shows that there is a significant difference in the posttest mean $(\bar{x})$attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture method, F(2,325) = 10.045, P(0.000) < 0.05. Thus, the null hypothesis is rejected. Therefore, there is a significant difference in the mean attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture methods. The direction of the difference was determined using Scheffe's post-hoc test as shown in Table 29.

Table 29: Summary of Scheffe's Post-hoc Test Comparison of Conceptual Change Texts, Concept Maps and Lecture Methods on Attitude

(I) Teaching methods	(J) Teaching methods	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Conceptual change texts	Concept maps	2.258	1.134	.139	-.53	5.05
	Lecture	4.670*	1.044	.000	2.10	7.24
Concept maps	Conceptual change texts	-2.258	1.134	.139	-5.05	.53
	Lecture	2.412	1.092	.049	-.27	5.10
Lecture	Conceptual change texts	-4.670*	1.044	.000	-7.24	-2.10
	Concept maps	-2.412	1.092	.049	-5.10	.27

Table 29 shows that there is a significant difference between the mean attitude scores of students taught chemistry using conceptual change texts and those taught using concept maps, in favour of students taught with conceptual change texts; there is a significant difference between the mean attitude scores of students taught chemistry using conceptual change texts and those taught using the lecture method, in favour of students taught chemistry using conceptual change texts; and there is a significant difference between the mean attitude scores of students taught chemistry using concept maps and those taught using the lecture method, in favour of students taught chemistry using concept maps. As indicated in Table 29, conceptual change texts and concept maps prove to be more effective in enhancing students' attitude towards chemistry than the lecture method.

Research Question 9

What is the difference in the mean attitude scores between male and female students taught chemistry using conceptual change texts and concept maps?

This research question was answered by comparing separately the mean attitude scores of male and female students taught chemistry using conceptual change texts and concept maps as shown in Table 30.

Table 30: Mean ($\bar{x}$) and Standard Deviation (SD) of Posttest Attitude Scores of Male and Female Students Taught Chemistry Using Conceptual Change Texts and Concept Maps

Methods	Sex	N	Posttest		Mean Difference
			Mean ($\bar{x}$)	SD	
Conceptual change texts	Male	74	62.30	5.63	1.08
	Female	34	63.38	5.01	
Concept maps	Male	57	59.93	9.24	1.18
	Female	35	61.11	8.90	

Table 30 shows that male students in the conceptual change texts group had a posttest mean ($\bar{x}$) attitude score of 62.30, with a standard deviation (SD) of 5.63, while their female counterparts had a posttest mean ($\bar{x}$) attitude score of 63.38, with a standard deviation (SD) of 5.01. The mean difference between the two groups is 1.08, in favour of female students. Table 30 further shows that male students in the concept maps group had a posttest mean ($\bar{x}$) attitude score of 59.93, with a standard deviation (SD) of 9.24, while their female counterparts had a post-test mean ($\bar{x}$) attitude score of 61.11, with a standard deviation (SD) of 8.90. The mean difference between the two groups is 1.18, in favour of female students. The corresponding hypothesis was tested to ascertain if these differences were significant as shown in Table 31.

Hypothesis 9

There is no significant difference in the mean attitude scores between male and female students taught chemistry using conceptual change texts and concept maps.

The hypothesis was tested by comparing the mean attitude scores of male and female students taught chemistry with conceptual change texts and concept maps using independent sample t-test as shown in Table 31.

Table 31: Independent Samples t-test Comparison of Posttest Attitude Scores of Male and Female Students Taught Chemistry Using Conceptual Change Texts and Concept Maps

Methods	Sex	N	$\bar{x}$	SD	df	t-cal.	Sig. (2-tailed)	Decision
Conceptual change texts	Male	74	62.30	5.63	106	0.963	0.338	Ho_9 is not rejected
	Female	34	63.38	5.01				
Concept maps	Male	57	59.93	9.24	90	0.605	0.547	
	Female	35	61.11	8.90				

$P > 0.05$

Table 31 shows that there is no significant difference between the posttest mean ($\bar{x}$) attitude scores of male and female students taught chemistry using conceptual change texts, t = 0.963, P(0.338) > 0.05. Table 31 further shows that there isno significant difference between the posttest mean ($\bar{x}$) attitude scores of male and female students taught chemistry using concept maps, t = 0.605, P(0.547) > 0.05. Thus the null hypothesis is not rejected. Therefore, there is no significant difference in the mean attitude scores between male and female students taught chemistry using conceptual change texts and concept maps.

Research Question 10

What is the effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' misconception in chemistry?

To answer this research question, the pre-test and posttest mean misconception scores of students taught chemistry using conceptual change texts, concept maps and lecture method were compared as shown in Table 32.

Table 32: Mean and Standard Deviation on Interaction Effect of Teaching Methods and Sex on Students' Achievement

Methods		**Conceptual change texts**			**Concept maps**			**Lecture**	
	N	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Pretest									
Male	74	15.78	5.47	57	16.89	5.82	70	16.94	5.63
Female	34	16.74	5.55	35	15.89	5.68	58	16.52	5.85
Differences		**0.96**	**0.08**		**1.00**	**0.14**		**0.42**	**0.22**
Posttest									
Male	74	59.95	13.68	57	56.63	11.81	70	49.89	13.84
Female	34	60.29	13.54	35	56.86	13.09	58	51.83	11.33
Differences		**0.34**	**0.14**		**0.23**	**1.28**		**1.94**	**2.51**

Table 32 shows a mean misconception score of 59.95 and 60.29, for male and female students who were taught chemistry using conceptual change texts, while male and female students taught using concept maps had a mean misconception score of 56.63 and 56.83 respectively (experimental groups). Male students who were taught with lecture method had a mean misconception score of 49.89, while their female counterparts had a mean misconception score of 51.83. The results do not suggest effect of interaction between teaching methods and sex on students' misconception in chemistry. This was because at all the levels of sex, the mean misconception scores were higher for students in the experimental groups.

Hypothesis 10

There is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' misconception in chemistry.

This hypothesis was tested by comparing the pre-test and posttest mean misconception scores of male and female students taught chemistry using conceptual change texts, concept maps and lecture method using ANCOVA as shown in Table 33.

Table 33: Summary of ANCOVA on Effect of Interaction of Teaching Methods and Sex on Students' Misconception

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5433.327^a	6	905.555	5.401	.000
Intercept	111302.811	1	111302.811	663.813	.000
Pretest	63.092	1	63.092	.376	.540
Methods	4805.386	2	2402.693	14.330	.000
Sex	50.920	1	50.920	.304	.582
Methods * Sex	49.615	2	24.807	.148	.863
Error	53822.661	321	167.672		
Total	1069356.000	328			
Corrected Total	59255.988	327			

Table 33 indicates that there is no significant effect of interaction of teaching methods and sex on students' misconception in chemistry, F(2, 321) = 0.148, P(0.863) > 0.05. Therefore, the null hypothesis is not rejected. Thus, there is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' misconception in chemistry.

Research Question 11

What is the effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' achievement in chemistry?

To answer this research question, the pre-test and posttest mean achievement scores of students taught chemistry using conceptual change texts, concept maps and lecture method were compared as shown in Table 34.

Table 34: Mean and Standard Deviation on Interaction Effect of Teaching Methods and Sex on Students' Achievement

Methods		**Conceptual change texts**			**Concept maps**			**Lecture**	
	N	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Pretest									
Male	74	15.78	5.47	57	16.89	5.82	70	16.94	5.63
Female	34	16.74	5.77	35	15.89	5.68	58	16.52	5.85
Differences		**0.96**	**0.30**		**1.00**	**0.14**		**0.42**	**0.22**
Posttest									
Male	74	62.00	13.56	57	61.47	13.70	70	49.89	13.84
Female	34	61.41	13.36	35	57.89	13.49	58	51.83	11.33
Differences		**0.59**	**0.20**		**3.58**	**0.21**		**1.94**	**2.51**

Table 34 shows a mean achievement scores of 62.00 and 61.41, for male and female students who were taught chemistry using conceptual change texts, while male and female students taught using concept maps had a mean achievement score of 61.47 and 57.89 respectively (experimental groups). Male students who were taught with lecture method had a mean achievement score of 49.89, while their female counterparts had a mean misconception score of 51.83. The results do not suggest effect of interaction between teaching methods and sex on students' achievement in chemistry. This was because at all the levels of sex, the mean achievement scores were higher for students in the experimental groups.

Hypothesis 11

There is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' achievement in chemistry.

This hypothesis was tested by comparing the pre-test and posttest mean achievement scores of male and female students taught chemistry using conceptual change texts, concept maps and lecture method using ANCOVA as shown in Table 35.

Table 35: Summary of ANCOVA on Effect of Interaction Teaching Methods and Sex on Students' Achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8789.357[a]	6	1464.893	8.608	.000
Intercept	109761.019	1	109761.019	644.986	.000
Pretest	14.903	1	14.903	.088	.767
Methods	7450.718	2	3725.359	21.891	.000
Sex	40.724	1	40.724	.239	.625
Methods * Sex	392.547	2	196.273	1.153	.317
Error	54626.447	321	170.176		
Total	1130000.000	328			
Corrected Total	63415.805	327			

Table 35 indicates that there is no significant effect of interaction of teaching methods and sex on students' achievement in chemistry, F(2, 321) = 1.153, P(0.317) > 0.05. Therefore, the null hypothesis is not rejected. Thus, there is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' achievement in chemistry.

Research Question 12

What is the effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' attitude towards chemistry?

To answer this research question, the pre-test and posttest mean attitude scores of students taught chemistry using conceptual change texts, concept maps and lecture method were compared as shown in Table 36.

Table 36: Mean and Standard Deviation on Interaction Effect of Teaching Methods and Sex on Students' Attitude

Methods		Conceptual change texts			Concept maps			Lecture	
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Pretest									
Male	74	24.19	8.75	57	23.05	5.84	70	23.53	7.02
Female	34	24.41	9.49	35	24.26	5.22	58	22.14	7.37
Differences		**0.22**	**0.74**		**1.21**	**0.62**		**1.39**	**0.35**
Posttest									
Male	74	62.30	5.63	57	59.93	9.24	70	60.43	10.48
Female	34	63.38	5.01	35	61.11	8.90	58	55.00	5.23
Differences		**1.08**	**0.62**		**1.18**	**0.34**		**5.43**	**5.25**

Table 36 shows a mean attitude scores of 62.30 and 63.38, for male and female students who were taught chemistry using conceptual change texts, while male and female students taught using concept maps had a mean attitude score of 59.93 and 61.11, respectively. Male students who were taught with lecture method had a mean attitude score of 60.43, while their female counterparts had a mean attitude score of 55.00. The results suggest effect of interaction between teaching methods and sex on students' achievement in chemistry. This was because at all the levels of sex, the mean achievement scores were not higher for students in the experimental groups.

Hypothesis 12

There is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' attitude towards chemistry.

This hypothesis was tested by comparing the pre-test and posttest mean attitude scores of male and female students taught chemistry using conceptual change texts, concept maps and lecture method using ANCOVA as shown in Table 37.

Table 37: Summary of ANCOVA on Effect of Interaction of Teaching Methods and Sex on Students' Attitude

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2319.803[a]	6	386.634	6.296	.000
Intercept	101685.635	1	101685.635	1655.965	.000
Pretest	44.673	1	44.673	.728	.394
Methods	1386.836	2	693.418	11.292	.000
Sex	82.718	1	82.718	1.347	.247
Methods * Sex	772.569	2	386.284	2.291	.062
Error	19711.221	321	61.406		
Total	1210042.000	328			
Corrected Total	22031.024	327			

Table 37 indicates that there is no significant effect of interaction of teaching methods and sex on students' attitude towards chemistry, F(2, 321) = 2.291, P(0.062) > 0.05. Therefore, the null hypothesis is not rejected. Thus, there is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' attitude towards chemistry.

(ii) Discussion

The findings of this study were discussed follows:

Effect of Conceptual Change Texts and Concept Mapping on Students' Misconception, Achievement and Attitude in Chemistry

The first finding of this study revealed that there is a significant effect of conceptual change texts, concept maps and lecture method on students' misconception in chemistry. This is evident in the significant increase in the posttest misconception scores compared to the pre-test scores of all the students taught chemistry using conceptual change texts, concept maps and lecture method. As indicated in Table 8, students in the conceptual change texts, concept mapping and lecture method groups had mean pre-text misconception scores of 16.08, 16.51 and 16.75 before treatment. However, after treatment students taught chemistry using conceptual change texts, concept maps and lecture had mean posttest misconception scores of 60.06, 56.72 and

50.77, resulting to a mean gain of 43.98, 40.21 and 34.02, for students in the conceptual change texts, concept mapping and lecture groups respectively. This significant increase in the posttest scores of students taught using the three methods is ascribable to treatment, that is, teaching of students using conceptual change texts, concept maps and lecture method. Therefore, conceptual change texts, concept mapping and lecture method had significant effect on students' misconception in chemistry. Nevertheless, the effect of conceptual change texts, concept mapping and lecture method on students' misconception in chemistry varies judging by the variation in the mean gain (positive difference between posttest and pre-test mean scores) of students taught using these methods.

Another finding of this study revealed that there is a significant effect of conceptual change texts, concept maps and lecture method on students' achievement in chemistry. This is predicated on the fact that the posttest achievement scores compared to the pre-test scores of all the students taught chemistry using conceptual change texts, concept maps and lecture method increased significantly after treatment. As indicated in Table 16, students in the conceptual change texts, concept mapping and lecture method groups had mean pre-test achievement scores of 16.18, 16.61 and 16.85 before treatment. However, after treatment students taught chemistry using conceptual change texts, concept maps and lecture had mean posttest achievement scores of 61.81, 60.11 and 50.77, resulting to a mean gain of 45.63, 43.50 and 33.92, for students in the conceptual change texts, concept mapping and lecture groups respectively. This significant increase in the posttest achievement scores of students taught chemistry using the three methods is as a result of treatment, that is, teaching students' chemistry using conceptual change texts, concept maps and lecture method. Therefore, conceptual change texts, concept mapping and lecture method had significant effect on students’ achievement in chemistry. Nevertheless, the effect of conceptual change texts, concept mapping and lecture method on students’ achievement in chemistry also varies judging by the variation in the mean gain of students taught using the three methods.

This study also revealed that there is a significant effect of conceptual change texts, concept maps and lecture method on students’ attitude towards chemistry. This is due to the fact that the posttest attitude scores of all the students taught chemistry using conceptual change texts, concept maps and lecture method increased significantly after treatment compared to the pre-test attitude scores. As indicated in Table 24, students in the conceptual change texts, concept mapping and lecture method groups had mean pre-text attitude scores of 24.26, 23.49 and 22.90, before treatment. However, after treatment students taught chemistry using conceptual change texts, concept maps and lecture had mean posttest attitude scores of 62.64, 60.38 and 57.97, resulting to a mean gain of 38.38, 36.89 and 35.07, for students in the conceptual change texts, concept mapping and lecture groups respectively. This significant increase in the posttest attitude scores of students taught chemistry using the three methods is as a result of treatment, that is, teaching students’ chemistry using conceptual change texts, concept maps and lecture method. Therefore, conceptual change texts, concept mapping and lecture method had significant effect on students’ attitude towards chemistry. Nevertheless, the effect of conceptual change texts, concept mapping and lecture method on students’ achievement in chemistry also varies judging by the variation in the mean gain of students taught chemistry using the three methods. These findings concur with the view of Ajaja (2013) who stated that the difference noticed in an experimental research must be as a result of treatment and not by chance.

Difference in the Effect of Conceptual Change Texts and Concept Mapping on Students' Misconception, Achievement and Attitude towards Chemistry

The result from this study revealed that there is a significant difference in the mean misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture methods. The Scheffe's post-hoc test revealed that conceptual change texts prove to be more effective in reduction of students' misconception in chemistry followed by the use of concept maps and the lecture method is the least effective. The statistically significant higher misconception scores of students taught chemistry using conceptual change texts over those taught using concept mapping may be due to the practical nature of conceptual change texts. In the conceptual change texts classroom, meaningful explanation, demonstration coupled with practical experiments were carried out in the course of teaching in order to identify and remedy students' misconception in chemistry. However, in the concept mapping classroom, only meaningful explanation and demonstration were carried out. This may have accounted for the lower misconception scores of students taught using concept maps.

As indicated in Table 13, the post-hoc test showed that students taught chemistry using conceptual change texts and concept maps had higher misconception posttest scores than their counterparts taught chemistry using the lecture method. This observation may be ascribable to the level of students' participation and interaction with the learning materials offered by conceptual change texts, concept mapping and lecture method. Students taught chemistry using conceptual change texts and concept mapping may have been more involve during the learning process than their counterparts taught using the lecture method. Conceptual change texts and concept mapping ensured that students' misconception are identified and remedied during instruction thereby enhancing students understanding of basic chemistry concepts.

This is not the case for the lecture method where information about chemistry concept is passed to students without paying attention to students' misconception. This may have accounted for the significant higher misconception score of students taught chemistry using conceptual change texts and concept maps over the lecture method. This finding confirms that of Yumusak, Maras and Sahin (2015) who examined the effects of computer assisted instruction with conceptual change texts on removing the misconceptions of radioactivity. Yumusak, Maras and Sahin (2015) reported that the method used on experimental group (conceptual change texts) was more successful than the traditional lecture method in terms of removing misconception in radioactivity. This finding further agrees with views of Turkmen, Cardak and Dikmenli (2005) who reported that the use of concept maps remedied the misconception of high school students in biology courses than the traditional lecture method.

Another finding from the result of this study revealed that there is a significant difference in the mean achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture methods, in favour of students taught using conceptual change texts, followed by students taught using concept maps and lecture method respectively. The Scheffe's post-hoc test revealed a significant difference between the mean achievement scores of students taught chemistry using conceptual change texts and concept maps, in favour of conceptual change texts. The statistically significant higher achievement scores of students taught chemistry using conceptual change texts over those taught using concept mapping may be due to the practical nature of conceptual change texts. In the conceptual change texts classroom, meaningful explanation, demonstration coupled with practical experiments were carried out in the course of teaching in order to identify and remedy students' misconception with the sole aim of enhancing students' achievement in chemistry. However, in the concept mapping classroom, only meaningful explanation and demonstration were carried out. Therefore, the practical nature of conceptual change texts facilitated students' understanding of chemistry concepts more than the use of concept maps. This may have accounted for the higher achievement scores of students taught chemistry using conceptual change texts over their counterparts taught using concept maps.

The Scheffe's post-hoc test revealed that conceptual change texts and concept mapping proves to be more effective in enhancing students' achievement in chemistry than the lecture method. The post-hoc test showed that students taught chemistry using conceptual change texts and concept maps had higher statistically significant achievement posttest scores than their counterparts taught chemistry using the lecture method. This observation may be as a result of students' active involvement during instruction. Students taught chemistry using conceptual change texts and concept mapping may have been more active during the learning process than their counterparts taught using the lecture method. Conceptual change texts and concept mapping ensured students' active participation and interaction with the learning materials during instruction. This is not the case for the lecture method where final information about chemistry concept is passed to students rendering the students passive during instruction. This may have accounted for the significant higher achievement score of students taught chemistry using conceptual change texts and concept maps over the lecture method. This finding confirm that of Aslan and Demircioglu (2014) who studied the effect of video-assisted conceptual change texts on 12th grade students' understanding and alternative conceptions concerning the gas concept. Aslan and Demircioglu (2014) reported statistically significant differences between the experimental (video-assisted conceptual change texts) and comparison (lecture method) groups with respect to conceptual understanding of the gas concept after the treatment, in favour of the experimental group. This finding also lends credence to that of Onyejekwe, Uchendu and Nmom (2018) who examined the effect of concept mapping on students' performance in genetics in selected secondary schools in Obio/Akpor metropolis. The authors reported better achievements of students' results in favour of concept mapping instructional method to the conventional lecture method of teaching.

Another finding of the study revealed that there is a significant difference in the mean attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture methods. The Scheffe's post-hoc test revealed that there is a significant difference between the mean attitude scores of students taught chemistry using conceptual change texts and concept maps, in favour of conceptual change texts. The higher attitude scores of students taught chemistry using conceptual change texts over those taught using concept mapping may also be due to the practical nature of conceptual change texts. In the conceptual change texts classroom, meaningful explanation, demonstration coupled with practical experiments were carried out in the course of teaching in order to identify and remedy students' misconception. This singular act to a great extent made the lesson very real thereby reducing students' abstraction in chemistry. However, in the concept mapping classroom, only meaningful explanation and demonstration were carried out. Therefore, the practical nature of conceptual change texts reduced students' abstraction in chemistry concepts more than the use of concept maps. This may have accounted for the higher attitude scores of students taught chemistry using conceptual change texts over their counterparts taught using concept maps.

Further indicated by the Scheffe's post hoc text, conceptual change texts and concept maps prove to be more effective in enhancing students' attitude towards chemistry than the lecture method. The possible explanation for this observation may be predicated on the fact that conceptual change texts and concept mapping arouse, stimulate and sustain students' interest in chemistry since the students are practically active during the teaching and learning process. This may have accounted for the higher attitude scores of students taught chemistry using conceptual change texts and concept mapping over those taught using lecture method that were passive during the teaching and learning process. This finding agrees with that of Kaya and Geban (2011) who studied the effect of conceptual change based instruction on students' attitudes towards chemistry. The authors reported that there was a significant mean difference between posttest scores of students taught chemistry using conceptual change based instruction and those taught chemistry using the traditionally designed instruction, in favour of students taught using conceptual based instruction. This finding lend credence to that of Otor and Achor (2013) who in a study "effect of concept mapping strategy on secondary school students' attitude towards difficult chemistry concepts" reported that students taught chemistry using concept mapping strategy obtained higher attitude rating scores and significantly better than those taught using conventional lecture method.

Conceptual Change Texts, Concept mapping and Sex on Students' Misconception, Achievement and Attitude towards Chemistry

The finding of this study revealed that there is no significant difference in the mean misconception scores between male and female students taught chemistry using conceptual change texts. In addition, it was also revealed that there is no significant difference in the mean misconception scores between male and female students taught chemistry using concept maps. This is predicated on the fact that the use of conceptual change texts and concept mapping ensured students' active participation during the teaching and learning process irrespective of students' sex. Thus, the fact that male and female students were active in the conceptual change texts and concept mapping classroom may have accounted for the non-significant difference between the mean misconception scores of male and female students taught chemistry using conceptual change texts and concept mapping. This finding confirms that of Cetin (2009) who found no significant effect of gender difference on students' understanding, achievement and attitudes toward chemistry. This finding further concurs with the view of Yavuz (2005) who found no significant effect of gender difference on students' understanding of concepts of matter and their attitudes towards chemistry when taught using conceptual change instruction accompanied with demonstration and computer assisted concept mapping.

Another finding from the result of this study revealed that there is no significant difference in the mean achievement scores between male and female students taught chemistry using conceptual change texts and concept maps. In other words, male and female students taught chemistry using conceptual change texts and concept mapping performed equally. This is equally predicated on the fact that the use of conceptual change texts and concept mapping ensured students' active participation during the teaching and learning process irrespective of students' sex. This finding confirms that of Muhammad (2014) who investigated the influence of conceptual instructional method on students' performance and attitude towards practical chemistry. Muhammad (2014) reported with reference to gender, no significant difference between male and female students academic achievement in chemistry when taught using conceptual instructional method. This finding also conforms to that of Nwoke, Iwu and Uzoma (2015) who reported that concept mapping strategy removed gender inequality in relation to students' achievement in mathematics.

The result of this study further revealed that there is no significant difference in the mean attitude scores between male and female students taught chemistry using conceptual change texts and concept maps. This implies that conceptual change texts and concept maps differentiate between sexes relation to students' attitude towards chemistry. This may be predicated on the fact that conceptual change texts and concept mapping equally arouse, stimulate and sustain male and female students' interest during instruction. This finding is in agreement with that of Gokulu and Geban (2014) who investigated the effects of conceptual change texts oriented instruction accompanied with analogies on seven grade students' understanding of atom, molecule, ion and matter concepts. Gokulu and Geban (2014) found no significant effect of gender difference on understanding of atom, molecule, ion and matter concepts and students' attitudes toward chemistry as a school subject. This finding is in line with that of Abdulkarim and Raburu (2013) who determined the attitude of undergraduate students towards physics through concept mapping. The authors reported that no significant difference attributed to gender and the interaction between teaching methods and gender.

Effect of Interaction of Teaching Methods and Sex on Students' Misconception, Achievement and Attitude towards Chemistry

The study revealed that there is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' misconception in chemistry. This implies that the effect of conceptual change texts and concept mapping on students' misconception is not moderated by students' sex. In other words, conceptual change texts and concept mapping did not combine with students' sex to influence their misconception in chemistry. This finding is in line with that of Adzape and Akpoghol (2015) who found no significant effect of interaction of conceptual change strategies and gender on students' misconception in chemical equilibrium. This finding corroborates with that of Yavuz (2005) who found no significant effect of interaction of teaching methods and sex on students' misconception in various subjects.

The eleventh finding of the study revealed that there is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' achievement in chemistry. This implies that conceptual change texts and concept mapping did not interact with students' in relation to students' achievement in chemistry. In other words, the use of conceptual change texts and concept mapping did not enhance the achievement of male students than their female counterparts. This finding is in agreement with the views of Adzape and Akpoghol (2015) who found no significant effect of interaction of conceptual change strategies and gender on students' achievement in chemical equilibrium. This finding also concurs with that of Ogonnaya, Okafor, Abonyi and Ugama (2016) who found no significant interaction effect of concept mapping and gender on students' achievement in basic science.

The study finally revealed that there is no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' attitude towards chemistry. This implies that conceptual change texts and concept mapping did not combine with students' sex to influence their attitude towards chemistry. This finding agrees with that of Abdulkarim and Raburu (2013) who found no significant interaction between teaching method (concept mapping) and gender in relation to students' attitude towards physics. This finding contradicts that of Baser and Geban (2007) who found no significant difference between the performance of females and that of males in terms of learning heat and temperature concepts and attitudes toward science, but the interaction of treatment regarding gender was significant for learning the concepts when taught using conceptual change instruction.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

The summary of the research, conclusion, recommendations, contributions to knowledge and suggestions for further research were presented in this chapter.

Summary of the Research

The effects of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards chemistry in Delta State were examined in this study. Twelve research questions and twelve hypotheses guided this study. The study adopted a 3x2 pre-test, posttest control group quasi-experimental factorial design. The population for the study consisted of18,879 chemistry students in public secondary schools in Delta State. 328 SSII chemistry students in six public co-educational secondary schools intact classes made up the sample of the study. The six intact classes were selected using simple random sampling technique. Two-Tier Chemistry Test (TTCT) and Chemistry Attitude Scale (CAS) were the instruments used for data collection in the study. Two-Tier Chemistry Test (TTCT) and Chemistry Attitude Scale (CAS) were face-validated by three experts made up of one Science Educator in Chemistry in Delta State University Abraka, one experienced Chemistry teacher from Abraka Grammar School in Ethiope East Local Government Area of Delta State and an expert in Measurement and Evaluation from Delta State University Abraka. The reliability of the Two-Tier Chemistry Test (TTCT) was established using Kuder-Richardson formula 21 approach. The TTCT was administered to 25 SSII Chemistry students in a Secondary School in Uvwie Local Government Area, who were outside the sampled schools for the study. The performance of the 25 students was initially scored for only the first stage (for achievement) and later for the first and second stage (for misconception) of Two-Tier Chemistry Test (TTCT) and analyzed using Kuder-Richardson formula 21. On analysis, a reliability coefficient of 0.80 was established for the first stage of TTCT for achievement and 0.83 for the first and second stage of TTCT for misconception. The reliability of the Chemistry Attitude Scale (CAS) was established using Cronbach Alpha. The CAS was administered to 25 SSII chemistry students in a Grammar School in Ethiope East Local Government Area, which was outside the sample area for this study. The response of the students was scored and on analysis, a reliability coefficient of 0.89 was obtained.

The treatment in this study involved instructing students on some selected concepts in chemistry using conceptual change texts and concept mapping (experimental group), and the students in the comparison group using the lecture method. Pre-test and posttest were administered before and after treatment with the aid of TTCT and CAS. Mean, standard deviation, t-test, Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA) were used to analyse the students' scores obtained from pre- and post-tests.

Findings

The analysis revealed the following:

1. There was a significant effect of conceptual change texts, concept maps and lecture method on students' misconception in chemistry.
2. There was a significant difference in the mean misconception scores among students taught chemistry using conceptual change texts, concept maps and lecture method. The Scheffe's post-hoc test revealed that conceptual change texts and concept maps were statistically more superior in remediating students' misconception in chemistry than the lecture method. In addition, the Scheffe's post-hoc test showed that conceptual change texts is more effective in remediating students' misconception in chemistry than concept maps.

3. There was no significant difference in the mean misconception scores between male and female students taught chemistry using conceptual change texts and concept maps.
4. There was a significant effect of conceptual change texts, concept maps and lecture method on students' achievement in chemistry.
5. There was a significant difference in the mean achievement scores among students taught chemistry using conceptual change texts, concept maps and lecture method. The Scheffe's post-hoc texts revealed that conceptual change texts was more effective in enhancing students' achievement in chemistry than concept maps and lecture method. However, concept mapping was more effective in boosting students' achievement in chemistry than the lecture method.
6. There was no significant difference in the mean achievement scores between male and female students taught chemistry using conceptual change texts and concept maps.
7. There was a significant effect of conceptual change texts, concept maps and lecture method on students' attitude towards chemistry.
8. There was a significant difference in the mean attitude scores among students taught chemistry using conceptual change texts, concept maps and lecture method, in favour of conceptual change texts followed by concept mapping and the lecture method came last.
9. There was no significant difference in the mean attitude scores between male and female students taught chemistry using conceptual change texts and concept maps.

10. There was no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' misconception in chemistry.
11. There was no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' achievement in chemistry.
12. There was no significant effect of interaction of teaching methods (conceptual change texts, concept maps and lecture method) and sex on students' attitude towards chemistry.

Conclusion

The conclusion drawn based on the findings of the study is that conceptual change texts and concept mapping are effective instructional strategies for remediating students' misconceptions in chemistry. The use of conceptual change texts has a relative advantage and bears more beneficial boost than concept mapping in changing students' misconception. The study concludes that both conceptual change texts and concept maps have the potential for ensuring that students' misconception in chemistry can be uniformly remedied for both male and female students.

The study also concluded that conceptual change texts and concept mapping facilitate students' active role in the learning process in a way that results in improved achievement. Conceptual change texts, more than concept mapping, however, enables students to have a proper conceptualization of the contents taught leading to better achievement. It is concluded that both methods are not sex-biased.

The study further concluded that conceptual change texts and concept mapping approaches encourages students to learn. Their positive disposition to learn leads to more positive attitude towards chemistry. Conceptual change texts is comparably more effective in helping students, irrespective of sex, to develop a more favourable attitude towards chemistry than concept mapping.

Recommendations

Based on the conclusion drawn from this study, the researcher recommended the following:

1. The adoption of conceptual change texts and concept mapping by chemistry teachers in teaching chemistry concepts at the secondary school level.
2. Chemistry teachers should strive to pay keen attention to students' misconceptions during chemistry instruction to facilitate students' comprehension of chemistry concept concepts.
3. Government and other stakeholders in education should provide in-service training to chemistry teachers on known common misconception in chemistry. This will expose chemistry teachers to the various misconceptions in chemistry and strategies to remedy them.
4. Government and other educational stakeholders should train chemistry teachers on the implementation of conceptual change instruction in actual classroom teaching.
5. In addition, government should provide adequate learning resources to secondary schools to facilitate the implementation of conceptual change instructions.

Contributions to Knowledge

The following are the contributions of this study to knowledge:

1. The study established that conceptual change texts is a superior teaching approach than concept mapping in remediating students' misconception and promoting students' achievement in chemistry. The study established that

conceptual change texts is a more effective approach than concept mapping in boosting students' attitude towards chemistry.

2. The study re-affirmed that conceptual change texts and concept mapping did not affect male and female students differently in relation to students' reduction of misconception and achievement in chemistry. The study again re-affirmed that conceptual change texts and concept mapping did not differentiate between sexes with reference to students' attitude towards chemistry.
3. The study showed that conceptual change texts and concept mapping did not combine with students' sex to influence students' misconception and achievement in chemistry. The study further established that conceptual change texts and concept mapping approaches did not interact with students' sex to influence students' attitude towards chemistry.

Suggestions for Further Research

The following areas are suggested for further study:

1. Effects of conceptual change texts and concept mapping in remediating students' misconception, achievement and attitude towards chemistry in other states should be studied.
2. A research should be carried out on the effect of conceptual change texts accompanied by the use of concept maps in remediating students' misconception, achievement and attitude towards chemistry.
3. A study should be carried out on the effects of animated enhanced conceptual change texts and video-assisted concept mapping on students' achievement, retention and attitude towards chemistry.

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APPENDIX I

Students' Performance in WASSCE Chemistry (2015-2018)

Year	Population of Students	Paper 2 (practical)		Paper 3 (Essay)	
		Raw Mean Score	SD	Raw Mean Score	SD
2015	691, 407	27.00	8.83	36.00	15.62
2016	667, 412	25.00	7.81	43.00	15.36
2017	704, 494	26.00	8.37	47.00	16.00
2018	728, 988	24.00	9.95	29.00	13.78

Source:https://www.waeconline.org.ng/e-learning/Chemistry/chemmain.html

APPENDIX II

Two-Tier Chemistry Test (TTCT)

Name of School: ____
Name of Student: ____
Duration: 1hour

Instructions: Items 1-50 consists of two-tier multiple choice questions. Each question comprised two segments with four options labelled A, B, C and D. For each question, choose the **CORRECT** answer in the first segment and choose the **CORRECT** reason in the second segment from the given options. Circle the appropriate letters on your answers sheets.

1. The following hypothetical reaction reaches equilibrium at 25^0C: $A_{(g)} + B_{(g)} \rightleftharpoons C_{(g)} + D_{(g).}$ Once equilibrium has been reached, the concentration of C is increased by the addition of more C. Assume that the temperature remains constant, which of the following can be said about the value of the equilibrium constant, Kc? It will:

A. Decrease
B. Increase
C. Remain the same
D. Highly increased

Reason: ....

A. The value of Kc will increase with addition of more C
B. The value of Kc will decrease with addition of more C
C. The value of Kc will change only when temperature changes
D. The value of Kc will increase since the temperature is constant

2. Limestone decomposes to form quicklime and carbon dioxide as follows: $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$. Which reaction will be favoured after removing some solid $CaCO_3$ from the equilibrium mixture?

A. Forward reaction
B. Reverse reaction
C. None of them is favoured
D. Both forward and reverse reactions

Reason: ....

A. Reverse reaction will be favoured since the removal of some $CaCO_3$ particles reduces it concentration.
B. Forward reaction will be favoured because quicklime will dissociates to neutralize the removal of limestone
C. Concentration of pure solid is constant, therefore equilibrium will not be disturbed
D. Equilibrium will shift to the left to annul the removal of limestone.

3. Consider the following reversible reaction that is in a state of equilibrium in a blue solution: $\underset{\text{Pink}}{[Co(H_2O)_6]^{2+}_{(aq)}} + 4Cl^-_{(aq)} \rightleftharpoons \underset{\text{blue}}{CoCl_4{}^{2-}_{(aq)}} + 6H_2O_{(l)}$

what will be observed if water is added to this system?

A. The solution turns pink
B. The solution becomes more blue
C. The solution remains unchanged
D. The solution becomes colourless

Reason: ....

A. Equilibrium position will shift to the right to produce more $CoCl_4{}^{2-}$ ion
B. Equilibrium position will shift to the left to produce more $[Co(H2O)]^{2+}$ ions

C. Equilibrium position will shift to the right to produce more water molecules
D. Equilibrium position will shift to the left to produce more Cl^- ions

4. In the first step of the Ostwald process for the synthesis of nitric acid, ammonia is oxidized to nitric oxide by the reaction: $4NH_{3(g)} + 5O_{2(g)} \rightleftharpoons 4NO_{(g)} + 6H_2O_{(g)}$; ΔH = -905.6 KL/mol. How does the equilibrium constant vary with an INCREASE in temperature?

A. Decreases
B. Increases
C. Remains unchanged
D. Highly decreases

Reason: ……………………………………………………………………………………

A. The reverse reaction will be favoured and the concentration of reactants will increase, Kc is inversely proportional to reactant concentration
B. The foward reaction will be favoured and the concentration of products will increase, Kc is directly proportional to product concentration
C. The reverse reaction will be favoured and the concentration of reactants will increase, Kc is directly proportional to reactant concentration
D. The foward reaction will be favoured and the concentration of products will increase, Kc is directly proportional to product concentration.

5. Sulphur dioxide and oxygen react to form sulphur trioxide in the following reaction: **$2SO_2$ (g) + O_2 (g) $\rightleftharpoons$ $2SO_3$ (g); ΔH = - 197, 78 kJ/mol.** What can we say about the forward reaction rate compared with the reverse reaction rate if a **catalyst** is added to system?

A. Higher
B. Lower
C. The same
D. Extremely higher

Reason: ……………………………………………………………………………………

A. Catalyst increases the rate of the forward reaction only
B. Catalyst decreases the rate of the reverse reaction only
C. Catalyst decreases the rate the rate of both forward and reverse reaction only
D. Catalyst increases the rate of both forward and reverse reaction to the same extent, therefore the net effect is zero

6. Suppose that **0.30mol PCI_5**is placed in a reaction vessel of volume **1dm3** and allowed to reach equilibrium with its decomposition products: phosphorus trichloride and chlorine at **250°C**, when **Kc = 1.8** for
PCI_5 (g) $\rightleftharpoons$ PCI_3 (g) + CI_2 (g).
What can we say about the concentration of the **PCI_3**gas and **CI_2**gas at equilibrium?

A. Higher than $0.30mol/dm^{-3}$
B. Lower than $0.30mol/dm^{-3}$
C. Equal to $0.30mol/dm^{-3}$
D. Equal to $0.15mol/dm^{-3}$

Reason: ……………………………………………………………………………………

A. In a sealed vessel, the decomposition of PCl_5 is less than 100% because as reactants decompose, products form back the reactants until equilibrium is established
B. In a sealed vessel, the decomposition of PCl_5 is more than 100% because as reactants decompose quicker than the formation of products form back the reactants until equilibrium is established

C. In a sealed vessel, the decomposition of PCl_5 is 100% because as reactants decompose, products form back the reactants until equilibrium is established

D. In a sealed vessel, the decomposition of PCl_5 is 50% because as reactants decompose, products form back the reactants until equilibrium is established

7. Calcium carbonate decomposes to form calcium oxide and carbon dioxide according to the equation: **$CaCO_3(s)$ + heat $\rightleftarrows$ $CaO(s) + CO_2(g)$.** After the system reaches equilibrium in a closed container, extra **solid** $CaCO_3$ is added to the equilibrium mixture. What will happen to the concentration of carbon dioxide after addition?

A. Increase
B. Decrease
C. Remains unchanged
D. Decrease extremely

Reason: ....

A. Reverse reaction will be favoured since the addition of some $CaCO_3$ particles increases it concentration.
B. Forward reaction will be favoured because more quicklime will be formed to neutralize the addition of limestone
C. Concentration of pure solid is constant, therefore equilibrium will not be disturbed
D. Equilibrium will shift to the right to annul the addition of limestone.

8. Carbon monoxide reacts with oxygen to form carbon dioxide in accordance with following reaction.

$2CO(g) + O_2(g) \rightleftarrows 2CO_2(g)$; $\Delta H = - 566$ kJ/mol. Suppose that you have a reaction vessel containing an equilibrium mixture of **[CO]= 0.30mol/dm-3**, **[O_2]= 0.20mol/dm-3 and [CO_2] = 0.25mol/dm-3**. What will happen to the concentration of CO_2 if a **catalyst** is added while the system is at equilibrium?

A. Will be higher than 0.25
B. Will be lower than 0.25
C. Will be equal to 0.25
D. Will be equal to 0.50

Reason: ....

A. Catalyst decreases the rate of the reverse reaction only
B. Catalyst decreases the rate the rate of both forward and reverse reaction only
C. Catalyst increases the rate of both forward and reverse reaction to the same extent, therefore the net effect is zero
D. Catalyst increases the rate of the forward reaction only

9. Consider the gaseous reaction of hydrogen with iodine;

$H_2(g) + I_2(g) \rightleftarrows 2HI(g)$. Suppose that we have a mixture of **$H_2(g)$** and **$I_2(g)$** at 700°C with the initial concentrations **[H_2] = 0.1 mol/dm-3** and **[I_2] = 0.2mol/dm-3**. When the system reaches equilibrium, the numerical value of equilibrium constant equals, **Kc = 57.0.** If the initial concentration is changed to **0.3mol/dm-3 H_2**and **0.3 mol/dm-3 I_2,** what would you say about the value of Kc when the system reaches equilibrium at the same temperature?

A. Increases
B. Decreases
C. Remain the same
D. Remain unchanged

Reason: ....

A. The value of Kc will change only when temperature changes

B. The value of Kc will increase with addition of more C
C. The value of Kc will decrease with addition of more C
D. The value of Kc will increase since the temperature is constant

10. If you have a **0.5mol/dm-3** solution of sodium dichromate **$(Na_2Cr_2O_7)$** in which the following equilibrium is established

$2CrO_4^{2-}$ (aq) + $2H^+$ (aq) $\rightleftharpoons$ Cr_2O_7 2-(aq) + H_2O(l)
yellow orange

and you add **10cm3 of 0.5mol/dm-3** solution of sodium dichromate to the original solution, what would you observe?

A. The solution becomes yellow
B. The solution becomes deeper orange
C. The solution remains unchanged
D. The solution becomes pale yellow

Reason: ....

A. The concentration of dichromate ions will not change therefore equilibrium will not be disturbed
B. The concentration of dichromate ions change but equilibrium will not be disturbed
C. The concentration of dichromate ions change but equilibrium will be extremely disturbed

11. The concentration of dichromate ions change but equilibrium will be disturbed
Consider the following reversible reaction that is in a state of equilibrium.

$N_2(g)+3H_2(g) \rightleftharpoons 2NH_3\ (g)$; $\Delta H = -\ 92,4$ kJ/mol.

If the temperature of the system is increased, which reaction will be favoured?

A. Reverse
B. Forward
C. None of them is favoured
D. Favoured both forward and reverse reactions

Reason: ....

A. Increase in temperature favour the forward reaction since it has higher number of moles
B. Increase in temperature favours endothermic reaction which in this case is the reverse reaction
C. Increase in temperature favours exothermic reaction which in this case is the forward reaction
D. Increase in temperature equally favours both forward and reversible reaction

12. The Haber process represented by the balanced equation below reaches equilibrium at **300^0C**.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; ΔH <0

What will happen to the mass of **NH_3**if the temperature is **INCREASED** to **500^0C**?

A. Increase
B. Decrease
C. Remain the same
D. Change slightly

Reason: ....

A. Increase in temperature favour the forward reaction since it has higher number of moles
B. Increase in temperature favours endothermic reaction which in this case is the reverse reaction

C. Increase in temperature favours exothermic reaction which in this case is the forward reaction
D. Increase in temperature equally favours both forward and reversible reaction

13. The equation below represents a chemical reaction at equilibrium in a closed container. $\mathbf{H_2(g) + I_2(g) \rightleftharpoons 2HI(g)\ ;\ H < 0}$. Which ONE of the following changes will increase the mass of **HI(g)** in the above reaction?

A. Add a catalyst
B. Decrease the temperature
C. Increase the temperature
D. Increase the concentration

Reason: ....

A. Increase in temperature favour the forward reaction since it has higher number of moles
B. Increase in temperature favours endothermic reaction which in this case is the reverse reaction
C. Decrease in temperature favours exothermic reaction which in this case is the forward reaction
D. Increase in temperature equally favours both forward and reversible reaction

14. Consider the following hypothetical reaction that reached equilibrium in a closed container at **450°C**: $\mathbf{XY(s) \rightleftharpoons X(g) + Y(s)\ ;\ \Delta H > 0}$

Which **ONE** of the following changes will **NOT** affect the equilibrium position?

A. Increase in the amount of $Y_{(s)}$
B. Decrease in pressure at constant volume
C. Increase in the volume of the container
D. Decrease the pressure

Reason: ....

A. Reverse reaction will be favoured since the addition of some $CaCO_3$ particles increases it concentration.
B. Forward reaction will be favoured because more quicklime will be formed to neutralize the addition of limestone
C. Concentration of pure solid is constant, therefore equilibrium will not be disturbed
D. Equilibrium will shift to the right to annul the addition of limestone.

15. H_2, which is thought as fuel in the future, is obtained through the decomposition of H_2O at a high temperature. The reaction reaches equilibrium as shown in the equation the below:

$\mathbf{2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g)}$, ($K_c = 5.31 \times 10^{-10}$, at 2000K)

How will the mass of $\mathbf{H_2}$be affected when helium, an inert gas is added to the equilibrium mixture at constant volume?

A. Addition of an inert gas has no effect on this equilibrium system
B. Increase in pressure will shift the equilibrium to the side with less number of moles
C. Partial pressure of H_2O will increase and the equilibrium to the right
D. Addition of an inert gas has effect on this equilibrium system

Reason: ....

A. Adding an inert gas at constant volume increases total pressure but does not affect the concentration of substances so no disturbance of equilibrium occurs
B. Adding an inert gas at constant volume increases total pressure thereby causing a disturbance on equilibrium

C. Adding an inert gas at constant volume increases the concentration of substances which alters the equilibrium position
D. None of the above

16. The decomposition of dinitrogen tetraoxide (**N_2O_4**) reaches equilibrium in a transparent sealed vessel as shown below:

$N_2O_4(g) \rightleftharpoons 2NO_2(g)$.
Colourless Brown

How will the colour of the system change immediately after the total pressure is increased while keeping the temperature constant?

A. Dark brown
B. Colourless
C. Remain the same
D. Light brown

Reason: ....

A. Since the temperature is constant, the system colour will remain constant
B. Increase pressure causes increase in volume and a decreases in concentration making the system colourless
C. Increase in pressure causes a decrease in volume and an increase in concentration making the brown colour more conspicuous
D. Since the temperature is not constant, the system colour will remain constant

17. Ammonium bromide decomposes to ammonia and hydrogen bromide in a sealed vessel. The reaction reaches equilibrium as shown:

$NH_4Br(s) \rightleftharpoons NH_3(g) + HBr(g)$.

How will the mass of **HBr(g)** change after adding some **$NH_3(g)$** while keeping the volume and temperature constant?

A. Increase
B. Decrease
C. Remain the same
D. Extremely decrease

Reason: ....

A. The reverse reaction will be favoured, therefore some of the HBr will be used alongside with NH3 to form the reactants
B. The forward reaction will be favoured, therefore some of the NH_4Br will be used to produce more HBr
C. The forward reaction will be favoured, therefore some of the NH_4Br will be used to produce more NH_3
D. The reverse reaction will be favoured, therefore none of the HBr will be used alongside with NH3 to form the reactants

18. Cobalt (II) chloride crystals are dissolved in a water/ alcohol mixture to form a blue solution. As represented by the following equilibrium equation

$CoCl_4^{2-}(aq) + 6H_2O(l) \rightleftharpoons [Co(H_2O)_6]^{2+}(aq) + 4Cl^-(aq)$
Blue Pink

A few drops of concentrated sulphuric acid are added to the above solution. What colour change is observed?

A. No change in colour
B. Pink
C. Deep blue
D. Light blue

Reason: ....

A. H_2SO_4 is a weak dehydrating agent

B. H_2SO_4 is a strong dehydrating agent
C. H_2SO_4 is a strong reducing agent
D. H_2SO_4 is a strong oxidizing agent

19. In a closed system, the following equilibrium can be established: **C_2H_6 (g) ⇌C_2H_4 (g) + H_2(g).** Initially **8mol of C_2H_6**are present, at this time C_2H_4 and H_2 have not been yet been formed. At equilibrium, **3mol $C_2H_4$and H_2** are present. How many mol of C_2H_6 and H_2 exist at equilibrium?

A. 2mol C_2H_6 and 3mol H_2
B. 3mol C_2H_6 and 3mol H_2
C. 5mol C_2H_6 and 3mol H_2
D. 7mol C_2H_6 and 3mol H_2

Reason: ....

A. Equilibrium moles of C_2H_6: 8-3 = 5, C_2H_4: 5-3 = 2
B. Equilibrium moles ofC_2H_6: 8-3 = 5, H_2: 5-3 = 2
C. Equilibrium moles of H_2: 0+3 = 3, C_2H_4: 5-3 = 2
D. Equilibrium moles of C_2H_6: 8-3 = 5, H_2: 0+3 = 3

20. The following equilibrium can be found between the compounds NO_2 and N_2O_4: **$2NO_2$(g) ⇌N_2O_4(g).** Initially**7mol NO_2**were placed in a closed vessel. At equilibrium, **2mol N_2O_4**are formed. How many mol of NO_2 exist at equilibrium?

A. 2 mol NO_2
B. 3 mol NO_2
C. 6 mol NO_2
D. 8 mol NO_2

Reason: ....

A. Equilibrium moles of NO_2: 7-2(2) = 3
B. Equilibrium moles of NO_2: 7-2 = 5
C. Equilibrium moles of NO_2: 7-2(1) = 5
D. Equilibrium moles of NO_2: 7-2(3) = 1

21. In a closed vessel, the following equilibrium is established between hydrogen (H_2), iodine (I_2) and hydrogen iodide (HI): **2HI(g) ⇌H_2(g) + I_2(g).** Initially **6mol HI** are present. At this time H_2 and I_2 have not yet been formed. At equilibrium, **I mol of H_2**exist. How much HI and I_2 exist at equilibrium?

A. 1 mol HI and 1 mol I_2
B. 2 mol HI and 1 mol I_2
C. 4 mol HI and 1 mol I_2
D. 6 mol HI and 1 mol I_2

Reason: ....

A. Equilibrium moles of HI: 6-1=5, I_2: 1(1) = 1
B. Equilibrium moles of HI: 6-2(1)=4, I_2: 1(1) = 1
C. Equilibrium moles of HI: 6-2(1)=4, I_2: 4-1 = 3
D. Equilibrium moles of HI: 6-2(2)=2, I_2: 4-1 = 3

22. The following hypothetical reaction reaches equilibrium at 25ºC: A(g) + B(g) ⇌C(g) + D(g) . Once equilibrium has been reached, the concentration of C is increased by the addition of more C. Assume that the temperature remains constant. Which of the following can be said about the numerical value of the equilibrium constant?

A. Decreases

B. Increases
C. Remains unchanged
D. Decreases extremely

Reason: ....

A. The ratio between products' concentrations and reactants' concentrations increases at constant temperature
B. The ratio between products' concentrations and reactants' concentrations decreases at constant temperature
C. The ratio between products' concentrations and reactants' concentrations is constant at constant temperature
D. The ratio between products' concentrations and reactants' concentrations is constant when the temperature increases

23. Limestone decomposes to form quicklime and carbon dioxide as follow: $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$. What can we say about any equilibrium shift after removing some solid $CaCO_3$ from the equilibrium mixture?

A. Shift to the reactants' side
B. Will not shift the equilibrium
C. Will not be predictable
D. Shift to the products' side

Reason: ....

A. $CaCO_3$ is solid, removing it does not affect the equilibrium
B. $CaCO_3$ is liquid, removing it does not affect the equilibrium
C. $CaCO_3$ is gaseous, removing it does not affect the equilibrium
D. $CaCO_3$ is aqueous, removing it does not affect the equilibrium

24. Carbon monoxide and hydrogen react according to the following equation. $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$. When 0.02**M** CO and 0.03**M** H_2 are introduced into a vessel at 800K and allowed to come to equilibrium, what can we say about the rate of reverse and forward reactions at equilibrium?

A. The rates are equal
B. Forward reaction rate is greater than the reverse one
C. Reverse reaction rate is greater than the forward one
D. The rates are not equal

Reason: ....

A. The rates of the forward and reverse reactions are equal when the system reaches equilibrium
B. The rates of the forward reaction is slightly higher than the reverse reaction when the system reaches equilibrium
C. The rates of the forward reaction is slightly smaller than the reverse reaction when the system reaches equilibrium
D. The rates of the forward and reverse reactions are never equal when the system reaches equilibrium

25. Consider the following reversible reaction that is in a state of equilibrium in a blue solution. $Co(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq) + 6H_2O(l)$

Pink **blue**

What will be observed if water is added to this system?

A. The solution turns pink
B. The solution becomes more blue
C. The solution remains unchanged
D. The solution becomes light blue

Reason: ....

A. Equilibrium position will shift to the right to produce more $CoCl_4^{2-}$ ion
B. Equilibrium position will shift to the left to produce more $[Co(H2O)]^{2+}$ ions
C. Equilibrium position will shift to the right to produce more water molecules
D. Equilibrium position will shift to the left to produce more Cl^- ions

26. In the first step of the Ostwald process for the synthesis of nitric acid, ammonia is oxidized to nitric oxide by the reaction: $4NH_3$ (g) + $5O_2$ (g) ⇌ 4NO (g) + $6H_2O$ (g), ΔH = -905.6 kJ/mole. How does the equilibrium constant vary with an increase in temperature?
A. Increases
B. Decreases
C. Remains the same
D. Remains unchanged
Reason: ....
A. The equilibrium will remain unchanged
B. The equilibrium will shift to the right with an increase in temperature
C. The equilibrium will shift to the left with a decrease in temperature
D. The equilibrium will shift to the left with an increase in temperature

27. Sulphur dioxide and oxygen react to form sulphur trioxide in the following reaction: $2SO_2$(g) + O_2(g) ⇌ $2SO_3$ (g). ΔH = - 197.78 kJ/mole. What can we say about the forward reaction rate compared with the reverse reaction rate if a catalyst is added to system?
A. Higher
B. Lower
C. The same
D. Unequal
Reason: ....
A. A catalyst lowers the activation energy for the forward and reverse reactions by exactly the same amount
B. A catalyst lowers the activation energy for the forward reaction more than the reverse reaction
C. A catalyst increases the activation energy for the forward reaction than the reverse reaction
D. A catalyst increases the activation energy for the reverse reaction than the forward reaction

28. The equilibrium between sulphur dioxide gas, oxygen gas and sulphur trioxide gas is as follows: $2SO_2$ (g) + O_2 (g)⇌ $2SO_3$ (g). If the reaction starts with the concentration of 0.02M SO_2, 0.01M O_2 and 0.00M SO_3, and reaches equilibrium at a constant temperature, what can we say about the equilibrium concentrations of SO_2 gas and O_2 gas?
A. Decrease
B. Become zero
C. Remain unchanged
D. Increase
Reason: ....
A. As time passes, SO_2 and O_2 reactants are consumed, decreasing their concentrations
B. As time passes, SO_2 and O_2 reactants are used up, increasing their concentrations
C. As time passes, SO_2 reactants is consumed, decreasing its concentrations

D. As time passes, O_2 reactants is consumed, decreasing its concentrations

29. Suppose that 0.30 mol PCI_5 is placed in a reaction vessel of volume 1000 mL and allowed to reach equilibrium with its decomposition products: phosphorus trichloride and chlorine at 250ºC, when K eq= 1.8 for PCI_5 (g) ⇌ PCI3(g) + CI_2(g) . What can we say about the concentration of the PCI_3 gas and CI_2 gas at equilibrium?

A. Higher than 0.30M
B. Lower than 0.30M
C. Equals to 0.30M
D. Equals to 0.60M

Reason: ....

A. Phosphorus pentachloride decomposes to an extent more than 100% to produce phosphorus trichloride and chlorine.
B. Phosphorus pentachloride decomposes at 100% to produce phosphorus trichloride and chlorine.
C. Phosphorus pentachloride decomposes to an extent less than 100% to produce phosphorus trichloride and chlorine.
D. Phosphorus pentachloride decomposes to an extent less than 100% to produce phosphorus trichloride only

30. Calcium carbonate decomposes to form calcium oxide and carbon dioxide according to the equation: $CaCO_3$(s) + heat ⇌CaO(s) + CO_2(g). After the system reaches equilibrium in a closed container, extra solid $CaCO_3$ is added to the equilibrium mixture. What will happen to the concentration of carbon dioxide after addition?

A. Increases
B. Decreases
C. Remains unchanged
D. Remains the same

Reason: ....

A. Addition of extra limestone increases the concentration of CO_2.
B. Addition of extra limestone decreases the concentration of CO_2
C. Concentration of pure solid is constant, therefore concentration of CO_2 is constant
D. Concentration of pure solid is not constant, therefore concentration of CO_2 is constant.

31. Carbon monoxide reacts with oxygen to form carbon dioxide in accordance with following reaction. $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$, ΔH = -566 kJ/mole. Suppose that you have a reaction vessel containing an equilibrium mixture of [CO] = 0.30M, [O_2] = 0.20M and [CO_2] = 0.25M. What will happen to the concentration of CO_2 if a catalyst is added to the equilibrium mixture?

A. Will be higher than 0.25
B. Will be lower than 0.25
C. Will be equal to 0.25
D. Will be equal to 0.50

Reason: ....

A. A catalyst has no effect on the equilibrium composition of a reaction mixture
B. A catalyst increases the concentration of a gas
C. A catalyst decreases the concentration of a gas
D. A catalyst increases and decreases the concentration of gas simultaneously

32. Consider the gaseous reaction of hydrogen with iodine; $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$. Suppose that we have a mixture of H_2 (g) and I_2 (g) at 700 K with the initial concentrations $[H_2]$ = 0.1M and $[I_2]$ = 0.2M. When the system reaches equilibrium, the numerical value of equilibrium constant equals, K eq = 57.0. If the initial concentration is 0.3 M H_2 and 0. 3 M I_2, what would say the numerical value of Keq when the system reaches equilibrium?

A. Increases
B. Decreases
C. Remains the same
D. Static

Reason: ....

A. The numerical value of Keq solely depend on the initial concentrations of the reactants
B. The numerical value of Keq slightly depend on the initial concentrations of the reactants
C. The numerical value of Keq does not depend on the initial concentrations of the products
D. The numerical value of Keq does not depend on the initial concentrations of the reactants

33. If you have a 0.5 M solution of sodium dichromate ($Na_2Cr_2O_7$) in which the following equilibrium is established

$2CrO_4^{2-}$ (aq) + $2H^+$ (aq)$\rightleftharpoons$ $Cr_2O_7^{2-}$ (aq) + H_2O(l)
yellow orange

and you add 10mL of 0.5M solution of sodium dichromate to the original solution what would you observe?

A. The solution becomes yellow
B. The solution becomes deeper orange
C. The solution remains unchanged
D. The solution becomes slightly yellow

Reason: ....

A. There is no change in the concentration of any species
B. The solution becomes obviously yellow since more sodium dichromate was added
C. The solution becomes obviously orange since more sodium dichromate was added
D. The concentration increases

34. Consider the following reversible reaction that is in a state of equilibrium.

$N_2(g)+3H_2(g) \rightleftharpoons 2NH_3(g)$, $\Delta H = -92.4$ kJ/mole

If the temperature of the system is increased, the equilibrium position will

A. Shift to the left
B. Shift to the right
C. Remain unchanged
D. Shift to left and then to right

Reason: ....

A. If the temperature is increased, more products are formed
B. If the temperature is increased, more reactants are formed
C. If the temperature is increased, no reactants are formed
D. If the temperature is increased, equal reactants and products are formed

35. In exothermic reactions, the final energy content of products ---

A. Is lower than the energy contents of the reactants

B. Is higher than the energy contents of the reactants
C. Does not depend upon the energy content of the reactants
D. Does depend upon the energy content of the reactants

Reason: ....

A. In exothermic reaction, heat is gain from to the surrounding
B. In exothermic reaction, heat is lost to the surrounding
C. In exothermic reaction, heat is neither lost nor gain
D. In exothermic reaction, water is absolved from the surrounding

36. On heating, sodium nitrate, $NaNO_{3(s)}$ gets converted into

A. Sodium oxide and nitrogen(IV) oxide
B. Nitric acid
C. Nitrogen I oxide
D. Nitrogen II oxide

Reason: ....

A. On heating sodium nitrate gets converted into sodium oxide and nitrogen(IV) oxide only
B. Because sodium nitrate gets converted into nitric acid and nitrogen(IV) oxide
C. Because sodium nitrate gets converted into sodium oxide only
D. Because sodium nitrate gets converted into nitrogen(IV) oxide only

37. On burning, hydrogen is changed into

A. Hydroxides
B. Water vapours
C. Dilute acids
D. Hydrogen chloride

Reason: ....

A. Combustion of hydrogen yield hydroxides
B. Combustion of hydrogen yield dilute acids
C. Combustion of hydrogen yield dilute base
D. Because burning in air (combustion) simply involve reaction with oxygen

38. Incorrect statement is: An exothermic reaction,

A. Forms a compound which gives out heat while being formed
B. Contains products that are very stable
C. Resulting in overall enthalpy change zero
D. Resulting in overall positive enthalpy change

Reason: ....

A. Exothermic reaction results to lost of heat to the surrounding, the products formed have less heat compared to the reactants which do not confers stability on the products formed
B. Since exothermic reaction results to loss of heat to the surrounding, the products formed have less heat compared to the reactants which confers stability on the products formed
C. Since exothermic reaction results to gain of heat to the surrounding, the products formed have less heat compared to the reactants which confers stability on the products formed
D. Since exothermic reaction results to loss of heat to the surrounding, the products formed have negligible heat compared to the reactants which confers stability on the products formed

39. Exothermic reactions take place when

A. Energy given out in making bonds is less than the energy taken in for breaking bonds

B. Energy given out in making bonds is more than the energy taken in for breaking bonds
C. Energy given out in making bonds is equal to the energy taken in for breaking bonds
D. Energy given out in making bonds is equivalent to the energy taken in for breaking bonds

Reason: ....

A. Because heat flows from region of higher concentration to that of lower concentration
B. Because heat flows from region of lower concentration to that of lower concentration
C. Because there is no heat flow during a chemical reaction
D. Because there is small heat flow during a chemical reaction

40. A reaction that has oxygen as a reactant and usually has carbon dioxide and water as products is a ---- reaction.
A. Combustion
B. Combination
C. Double replacement
D. Double decomposition

Reason: ....

A. A combustion reaction always have oxygen as one of the reactants and carbon dioxide and water as the only products
B. Because oxygen is combining with another reactant made it a combination reaction
C. Double replacement reaction lead to formation of carbon dioxide and water as products
D. Combustion reaction involving oxygen only yield carbon dioxide

41. $AB \longrightarrow A + B$ is a ----- reaction
A. Combustion
B. Combination
C. Decomposition
D. Addition

Reason: ....

A. Combination reaction since A and B combined to form AB
B. Combustion reaction since AB reacted with air to A and B
C. Decomposition reaction since AB was decompose into A and B
D. Photolytic reaction since the reaction occurs under the presence of light

42. If the value of ΔH for a reaction is negative, it means that the reaction is
A. Endothermic reaction
B. Exothermic reaction
C. Irreversible
D. Reversible reaction

Reason: ....

A. It means that the heat content of the products is higher than the heat content of reactants
B. It means that the heat content of the products is less than the heat content of reactants
C. It means that the heat content of the products equals the heat content of reactants

D. It means that the heat content of the products approximately equals the heat content of reactants

43. Which of the following is true of an endothermic reaction?

A. Heat energy is absorbed
B. A catalyst is required
C. It occurs reversibly
D. It occurs irreversibly

Reason: ....

A. In endothermic reactions, heat is absorbed from the surroundings
B. In endothermic reactions, heat is lost to the surroundings
C. A catalyst is always require in an endothermic reaction
D. A catalyst causes heat to neither lost nor gained during endothermic reaction

44. Reactions are generally faster at higher temperature because the

A. Activation energy increases
B. Energy of the products is lowered
C. Number of effective collisions increases
D. Number of effective collisions decreases

Reason: ....

A. As kinetic energy increases, temperature increases causing reacting particles to collide more often
B. Increase in temperature increases activation energy
C. Increases in activation energy led to more collisions
D. As kinetic energy increases, temperature decreases causing reacting particles not to collide more often

45. To determine the solubility of a solute in water, a solution must be prepared that is------:

A. Saturated
B. Unsaturated
C. Supersaturated
D. Symmetrical

Reason: ....

A. Solubility of solute can only be determined in a supersaturated solution
B. Solubility of solute can only be determined in a saturated solution
C. Solubility of solute can only be determined in an unsaturated solution
D. Solubility of solute can only be determined only in a supersaturated and unsaturated solution

46. Number of grams of compound needed to saturate 100g of water is defined for

A. Solubility
B. Volatility
C. Polarity
D. Purity

Reason: ....

A. Solubility is amount of solvent that can be dissolved in 100g of water
B. Solubility is amount of solute that can be dissolved in 100g of water
C. Solubility is amount of solution that can be dissolved in 100g of water
D. None of the above

47. A saturated solution of lead(II) contains 0.99g per 100g of water. Therefore it is regarded as

A. Saturated solution
B. Unsaturated solution

C. Insoluble
D. Supersaturated solution

Reason: ....

A. Lead is insoluble in water
B. Lead is soluble in water
C. Lead is sparingly soluble in water
D. Lead is covalent in nature

48. Solubility product constant is represented symbolically as ---

A. Ksp
B. Kc
C. Kp
D. Ks

Reason: ....

A. Because equilibrium constant is denoted as K, Kc or Kp, while solubility product constant is denoted as Ksp
B. Ksp is always equal to K
C. Ksp is always equal to Kc
D. Ksp is always equal to Kp

49. Consider the following reversible reaction $Cr_2O_7^{2-}(aq) + H_2O(l) \rightleftharpoons 2CrO_4^{2-}(aq) + 2H^+(aq)$. What will happen to the position of the position of equilibrium and the value of Kc when more H^+ ions are added at constant temperature?

	Position of equilibrium	Value of Kc
A	Shifts to the left	Decreases
B	Shifts to the right	Increases
C	Shifts to the left	Does not change
D	Shifts to the right	Does not change

Reason: ....

A. Kc value changes at constant temperature
B. Kc value does not change at constant temperature
C. Kc value increases at constant temperature
D. Kc value decreases at constant temperature

50. Consider this equilibrium reaction in a sealed container: $H_2O(g) \rightleftharpoons H_2O(l)$. What will be the effect on the equilibrium of increasing the temperature from 20^0C to 30^0C?

A. More of the water will be in the gaseous state at equilibrium
B. More of the water will be in the liquid state at equilibrium
C. At equilibrium the rate of condensation will be greater than the rate of evaporation
D. At equilibrium the rate of evaporation will be greater than the rate of condensation

Reason: ....

A. Increase in temperature will cause a correspondent increase in the reactants particles
B. Increase in temperature will cause a correspondent increase in the products particles
C. Increase in temperature will cause a correspondent increase in both the reactants and products particles

D. Increase in temperature will cause a more increase in the products particles than the reactants particles

Appendix III
TTCT Marking Guide

S/n	Answers	Reasons
1	C	(C) The value of Kc will change only when temperatures changes
2	C	(C) Concentration of pure solid is constant, therefore equilibrium will not be disturbed
3	A	(B) Equilibrium position will shift to the left to produce more [Co(H2O)] 2+ ions
4	C	(A) The reverse reaction will be favoured and the concentration of reactants will increase, Kc is inversely proportional to reactant concentration
5	C	(D) Catalyst increases the rate of both forward and reverse reaction to the same extent, therefore the net effect is zero
6	B	(A) In a sealed vessel, the decomposition of PCl_5 is less than 100% because as reactants decompose, products form back the reactants until equilibrium is established
7	C	(C) Concentration of pure solid is constant, therefore equilibrium will not be disturbed
8	C	(C) Catalyst increases the rate of both forward and reverse reaction to the same extent, therefore the net effect is zero
9	C	(A)The value of Kc will change only when temperature changes
10	C	(A) The concentration of dichromate ions will not change therefore equilibrium will not be disturbed
11	A	(B) Increase in temperature favours endothermic reaction which in this case is the reverse reaction
12	B	(B) Increase in temperature favours endothermic reaction which in this case is the reverse reaction
13	B	(C) Decrease in temperature favours the exothermic reaction which in this case is the forward reactions
14	A	(C) Concentration of a pure solid is constant therefore adding a pure solid will not disturb equilibrium position
15	A	(A) Adding an inert gas at constant volume increases total pressure but does not affect the concentration of substances so no disturbance of equilibrium occurs
16	A	(C) Increase in pressure causes a decrease in volume and an increase in concentration making the brown colour more conspicuous
17	B	(A) The reverse reaction will be favoured, therefore some of the HBr will be used alongside with NH_3 to form the reactants
18	C	(B) H2SO4 is a strong dehydrating agent, it will decrease the concentration of water by forming H3O+. This favours the reverse reaction which produces more $CoCl_4^{2-}$ ions
19	D	(D) Equilibrium moles of C_2H_6: 8-3 = 5 Equilibrium mole of C_2H_4: 0+3 = 3 Equilibrium moles of H_2: 0+3 = 3
20	B	(A) Equilibrium moles of NO_2: 7-2(2) = 3
21	D	(B) Equilibrium moles of HI: 6-2(1) = 4□ Equilibrium moles of I2: 1(1) = 1
22	C	(C) The ratio between products' concentrations and reactants' concentrations is constant at constant temperature

23	B	(A) Because $CaCO_3$ is solid, removing it does not affect the equilibrium
24	A	(A) The rates of the forward and reverse reactions are equal when the system reaches equilibrium
25	A	(B) Equilibrium position will shift to the left to produce more $[Co(H_2O)]^{2+}$ ions
26	B	(D) The equilibrium will shift to the left with an increase in temperature
27	C	(A) A catalyst lowers the activation energy for the forward and reverse reactions by exactly the same amount.
28	A	(A) As time passes, SO_2 and O_2 reactants are consumed, decreasing their concentrations.
29	B	(C) Phosphorus pentachloride decomposes to an extent less than 100% to produce phosphorus trichloride and chlorine.
30	C	(A) The concentrations of pure solids, that is, the quantities in a given volume or densities, are constant.
31	C	(A) A catalyst has no effect on the equilibrium composition of a reaction mixture
32	C	(D) The numerical value of Keq does not depend on the initial concentrations of the reactants
33	C	(A) There is no change in the concentration of any species
34	A	(C) If the temperature is increased, more reactants are formed
35	A	(B) In exothermic reaction, heat is lost to the surrounding
36	D	(A) Because sodium nitrate gets converted into sodium oxide and nitrogen(IV) oxide
37	B	(D) Because burning in air (combustion) simply involve reaction with oxygen, $H_{2(g)} + 1/2O_2 \rightleftharpoons H_2O(l)$
38	B	(B) Since exothermic reaction results to loss of heat to the surrounding, the products formed have less heat compared to the reactants. This less heat confers stability on the products formed.
39	B	(A) Because heat flows from region of higher concentration to that of lower concentration
40	A	(A) A combustion reaction always have oxygen as one of the reactants and carbon dioxide and water as the only products
41	C	(D) Because AB was decompose to form A and B.
42	B	(B) It means that the heat content of the products is less than the heat content of reactants. This occurs when heat is lost to the surrounding
43	A	(A) In endothermic reactions, heat is absorbed from the surroundings
44	D	(A) Kinetic energy increases as temperature increases causing reacting particles to collide more often.
45	A	(B) Solubility is only concerned with saturated solutions
46	A	(B) Solubility is amount of solute that can be dissolved in 100g of water
47	C	(A) Lead is insoluble in water
48	A	(A) Because equilibrium constant is denoted as K, Kc or Kp, while solubility product constant is denoted as Ksp
49	D	(B) Increase in concentration causes the equilibrium position to shift to the left. Kc value does not change at constant temperature.

50	A	(A) Increase in temperature will cause a correspondent increase in the reactants particles.

Appendix IV

Chemistry Attitude Scale (CAS)

Section A
Name of School---
Sex: Male { } Female { }
Section B:

Instructions: Please read the following statements carefully and indicate your level of agreement on the scale provided.

KEY
SA: Strongly Agreed
A: Agreed
D: Disagreed
SD: Strongly Disagreed

S/N	Statement	SA	A	D	SD
1	I like chemistry				
2	Chemistry is very interesting				
3	Chemistry is fascinating and fun				
4	I feel good when I solve chemistry questions				
5	I like chemistry more than any other subject				
6	I feel very happy when studying chemistry				
7	I am willing to spend more time reading chemistry books				
8	Chemistry is stimulating				
9	Chemistry is useful for solving everyday problem				
10	Chemistry is a subject that I like studying				
11	I usually find inner peace whenever I resolve chemistry problems				
12	I never give up with my chemistry assignment				
13	I am very active during chemistry classes				
14	I prefer at the front sit during chemistry instruction				
15	I don’t find it difficult to understand chemistry				
16	The chemistry concept, theories, formulas, calculations and practices are very easy to understand compared to other science subjects.				
17	Chemistry questions are very easy				
18	Chemistry is my favourite subject				
19	Chemistry makes me feel uncomfortable and impatient				
20	Chemistry makes me feel as though I was in a jungle of formulae or equation and can’t find my way				

Appendix V

Reliability Coefficient of TTCT for Achievement

Scores of 25 SSII chemistry students on pilot testing are shown below

17	19	30	25	22
32	21	30	19	41
31	23	25	25	30
12	29	21	27	31
41	24	16	17	12

$$\mathrm{r} = \frac{\mathrm{Kd}^2 - \overline{\mathrm{X}}(\mathrm{K} - \overline{\mathrm{X}})}{\mathrm{d}^2(\mathrm{K} - 1)}$$

Where,

K = number of items = 50

$\overline{\mathrm{X}}$= mean score = 24.80

d = standard deviation = 7.62

$$\boldsymbol{r} = \frac{50(7.62)^2 - 24.80\ (50 - 24.80)}{7.62^2(50 - 1)}$$

$$\mathrm{r} = \frac{2278.26}{2845.1556} = 0.80$$

Appendix VI

Reliability Coefficient of TTCT for Misconception

Scores of 25 SSII chemistry students on pilot testing are shown below

27	22	17	30	23
23	41	32	30	19
19	30	31	25	10
23	31	12	21	26
30	12	41	16	19

$$r = \frac{Kd^2 - \overline{X}(K - \overline{X})}{d^2(K-1)}$$

Where,

K = number of items = 50

$\overline{X}$= mean score = 24.40

d = standard deviation = 8.12

$$\boldsymbol{r} = \frac{50(8.12)^2 - 24.40\ (50 - 24.40)}{8.12^2(50-1)}$$

$$r = \frac{2672.08}{3230.7856} = 0.83$$

Appendix VII

Reliability Coefficient of CAS

Scale: ALL VARIABLES

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.894	.895	20

Appendix VIII

Conceptual Change Texts Lesson Plan

Week 1

Period 1

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 45 minutes

Topic : Chemical Equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Explain chemical equilibrium.
2. Explain Le Chateler's principle

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, conceptual change texts on chemical equilibrium.

Entry behaviour: Students can differentiate between endothermic and exothermic reaction.

Content Development

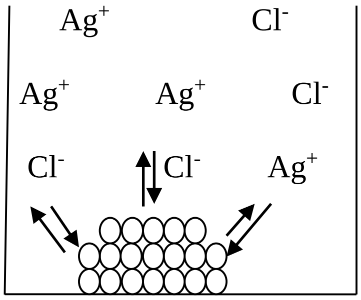
Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: In Figure 1 we see the saturated AgCl solution in equilibrium with solid.



$$AgCl_{(k)} \rightleftharpoons Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Figure: 1

What can we say about AgCl solid, Cl^- and Ag^+ ions formation in Figure 1 showing the saturated AgCl solution?

Before reading what is written on the next page, write down your answer and reason……………………………………………………………………………………

…………………………………………………………………………………………

…………….

Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students believe that in equilibrium, dissolution and precipitation have stopped or ended, and therefore, when we look at Figure 1, they think that more AgCl (k) does not dissolve in equilibrium with solution solids and again AgCl (k) does not occur. Students who think this way usually have this idea in books, while the balance is described in the pictures, as if the solution is shown as if the solution reaches equilibrium or everything is stopped. Another reason is that some students compare the balance to the equations they observe in daily life. For example, seesaw or scales. When the two sides balance each other, they believe that equality and therefore balance are achieved. Is WELL the same when the solutions are in equilibrium with their solids? So everything stops when you're in balance?

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

In fact, while saturated solutions are in equilibrium (we cannot mention equilibrium in unsaturated solutions), dissolution and precipitation continue. Referring to Figure 1, AgCl (k) continues to dissolve in equilibrium and thus the formation of Ag^+ and Cl^- ions continues. At the same time, Ag^+ and Cl^- ions come together to form AgCl (k) solid. THE RESOLUTION BALANCE also occurs when these dissolution and precipitation rates are equal. In other words, in the case of equilibrium, both some solids continue to dissolve and some solids are formed. When the SPEEDS of these two conditions are EQUAL, the BALANCE status is also present.

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities: Teacher exemplifies the explanation as follows.

We can exemplify the state of equilibrium using a treadmill. For example, if you are running on a treadmill you are in constant motion. However, you are not moving forward or backwards. As fast as you run forward the treadmill is moving you backwards. You are in equilibrium with the treadmill.

Teacher then asked students to give more concrete examples on chemical equilibrium.

Students' Activities: Students attempt to answer teacher's question.

Period II

Content Development

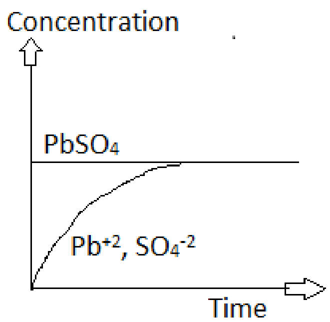
Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

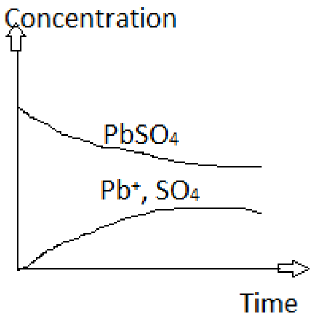
Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

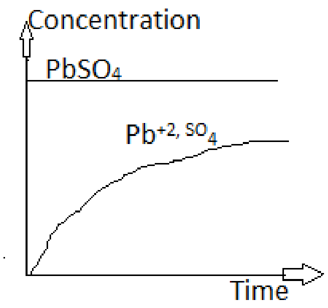
Teacher Activities: In the following, graphs showing the change of $PbSO_4$(k) concentration, Pb^{+2} and SO_4^{-2} ion concentrations of $PbSO_4$ solution in equilibrium with solids at a certain temperature are given.



Graph I



Graph II



Graph III

Which of the graphs showing the change of PbSO4 (k) concentration, Pb^{+2} and SO_4^{-2} ion concentrations of $PbSO_4$ solution over time was correctly drawn above? Why is that?

Before reading what is written on the next page, write down your answer and reason below………………………………………………………………….

Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students think that the concentration of each ion is equal to the concentration of solid salt when they are in equilibrium with solution solids (those who choose Graph I). Students who think so can often be because they think that being in balance requires two things to be equal. Another reason is that since we do not write solids in the equilibrium solubility equation, the concentration of solid salt should be equal to the concentration of each of the ions. Some students, without considering the concentration of the solids dissolved in the bottom, consider the concentration of solids dissolved in the solvent alone and consider that the concentration of solid salt decreases (Graph II). The main reason for this error is that some of the solids found in the bottom are ionized and their concentration is decreased and they fall into the error.

In fact, if there is a solid at the bottom of a solution, it would be wrong to think that the concentration of solid salt and ions is equal. The students who choose Graph II are mistaken that the ionization of some of the solid salt will change the concentration of the solid salt. In fact, the concentration of solids does not change with external influences.

Let's try to understand this with an example. For example, let 4 people stay in a house and earn 300Naira each month. The monthly income per person of this house will be 300Naira. What happens to the per capita income if a person leaves this house? Does it change? It will not change and will be 300Naira again. The concentration of solids will likewise not change even if a quantity ionizes because the reduction in quantity is proportional to the decrease in volume.

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

The variation of $PbSO_4$ (k) concentration, Pb^{+2} and SO_4^{2-} ion concentrations over time is plotted in graph III is TRUE. Pb^{+2} and SO_4^{-2} ion concentrations increase because some of the solids ionize. This increase decreases over time and takes a constant value in equilibrium because the dissolution and precipitation rates are equalized and therefore the concentration of ions does not change.

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities:

Teacher evaluates the lesson based on the stated objectives.

Students' Activities: Students attempt to answer teacher's question.

Week 2

Period 1

Subject	: Chemistry
Class	: SSII
Age	: 15+
Duration	: 45 minutes
Topic	: Chemical Equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Establish the solubility multiplication of solution

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, conceptual change texts on chemical equilibrium.

Entry behaviour: Students can explain dissociation and precipitation during chemical equilibrium.

Content Development

Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: Teacher asks students: Solubility multiplication (Kc) of MgF_2 solution, which is in equilibrium with its solid at a given temperature, would be like?

$$MgF_2(k) \rightleftharpoons Mg^{+2}(aq) + 2F^{-}(aq)$$

(I) $K_c = \frac{[Mg+2][F-]}{[MgF2]}$

(II) $K_c = \frac{[Mg+2][F-]2}{[MgF2]}$

(III) $K_C = [Mg^{+2}][F^{-}]^2$

(IV) $K_C = [Mg^{+2}]\ 2[F^-]$

Before reading what is written on the next page, write down your answer and reason………………………………………………………………………………… ……………………………………………………………………………………… …………….

Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some student thinks that when writing the resolution product (K), there are also solids whose concentration does not change with external influences. If anyone chooses equations I and II, they may have this misconception. Therefore, they will benefit from reading the rest of the article carefully. The main reason for having the above misconception is that while the equilibrium relation in chemical reactions is written, the students generally prefer to find the product multiplied by the product of the product. In chemical reactions, solids are NOT included when writing equilibrium relations. However, since teachers and books are usually examples of gas reactions, our students find the correlation relation by dividing the product multiplications by the product multiplications. Therefore, the equilibrium relation will be written for each case in the same way, that is, in equilibrium equations including solids, they fall into the error that the equilibrium correlation or solubility product can be found by dividing the concentration of products by the concentration of the entrant as in gas reactions.

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

What is TRUE? How to write equilibrium relation? Considering our example in the question, $MgF_{2(k)} \rightleftarrows Mg^{+2}_{(aq)} + 2F^{-}_{(aq)}$, at equilibrium, $K = \frac{[Mg+2][F-]2}{[MgF2]}$ is written. However, since the concentration of pure solids (MgF2 (k) in our example) is constant, the product K * [MgF2] will be constant since K and [MgF2] values are constant. In other words, since the concentration of both K and MgF2 is constant, the product of the two constant numbers will also be a fixed number. Thus, the new expression is written as K * [MgF2] = Kc = [Mg + 2] [F-] 2, and K k values written for each solid in the books are calculated at a set temperature. Therefore, the product K * [MgF2] is equal to K k, and solids do not take place when K k is written.

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities: Teacher exemplifies the explanation as follows.

So why is the concentration of solids constant? A little thought? Let's try to understand this with an example. We have 40 g of XY (k) compound and when it is thrown into the water, 20 g of XY remain undissolved. Accordingly, what is the concentration of XY (k) in the first and last cases? (Mxy = 40 g, dxy = 2)

Case I(40 grams of solid is not dissolved)

Volume (V) of compound XY, $d = \frac{m}{V}$, then $2 = \frac{40}{V}$, V = 20

Number of moles of compound XY (n), $n = \frac{m}{Mxy}$, then $n = \frac{40}{40}$, n = 1mol

Concentration of XY compound (M), $M = \frac{n}{V}$, then $M = \frac{1}{20}$,

Case II (20 grams of solid is not dissolved)

Volume (V_2) of compound XY, $d = \frac{m}{V}$, then $2 = \frac{20}{V}$, $V_2 = 10$

Number of moles of compound XY (n_2), $n = \frac{m}{Mxy}$, then $n = \frac{20}{40}$, $n_2 = 1/2$mol

Concentration of XY compound (M_2), $M = \frac{n}{V}$, then $M_2 = \frac{1/2}{10}$. As you can see, in the first and last case the concentration of the solid is the same and therefore constant

Teacher then asked students to give more concrete examples on chemical equilibrium.

Students' Activities: Students attempt to answer teacher's question.

Period II

Content Development

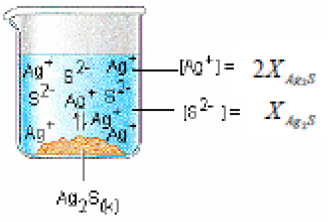
Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: The figure below shows the Ag_2S solution in equilibrium with the solid. (Ag_2S: K = 6.3 x 10-50).



$$Ag_2S_{(k)} \rightleftarrows Ag_{(aq)} + S^-_{(aq)}$$

For the Ag_2S solution, which is in equilibrium with the solid above, what is the relationship between K and ion concentrations?

Before reading what is written on the next page, write down your answer and reason below

……………………………………………………………………………………………

…………………………………………………………………………………………

Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students have a misconception that Kc is written as the sum of the concentrations of the substances whose coefficient is different in the equilibrium equation (the coefficient of Ag + ion in the example above is 2). The source of this idea stems from the error that we are already adjusting the concentrations while balancing the equations. For example, for the above solution Kc value should be written as follows. $K_c = 2[Ag^+][S^{2-}]$.

In general, the question is why we multiply the Ag + ion concentration by two and then square it, and we don't collect Ag + concentration twice. The source of this problem is mainly due to the fact that the students do not fully understand the meaning of the symbols used in the calculations and the definition of the K r correlation. If we look carefully at the above equation, two Ag^+ ions and one S^{-2} ions are formed for each Ag_2S. Therefore, in equilibrium, the concentration of Ag+ ion is twice the concentration of Ag_2S, i.e., and the concentration of S^{-2} ions is equal to that of Ag_2S. The reason why we squared the Ag+ ion concentration while writing the K r correlation comes from the definition of K r correlation. Thus, for the solution in equilibrium with the solid above, K?

$K_c = [Ag^+]^2[S^{2-}]$.

Some students are asked to write the concentration of one ion in the form of the concentration of other ions when asked about the relationship of ions in solution with each other. For example, let us write the relationship between Ag+ and S^{2-} ion concentrations in our example. Write your answer to the blank section below.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………

Looking at the equilibrium equation of saturated Ag_2S solution and writing the following equation does not even work.

$[S^{2-}] = 2[Ag^+]$

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

This expression may seem very reasonable for some students who think that Ag + ion concentration in the solution is twice the concentration of S^{2-} ion. However, the equation is incorrectly established because two Ag+ ions are formed for each S^{2-} ion formation. Thus, the Ag+ ion concentration is twice the concentration of S2- ion and is expressed as an equation as follows.

$[Ag^+] = 2 [S^{2--}]$

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities:

Teacher evaluates the lesson based on the stated objectives.

Students' Activities: Students attempt to answer teacher's question.

Week 3

Period 1

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 45 minutes

Topic : Chemical Equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Explain precipitation and equilibrium
2. Established that dissolution rate increases or decreases over time.

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, conceptual change texts on chemical equilibrium.

Entry behaviour: Students can explain solubility equilibrium multiplication.

Content Development

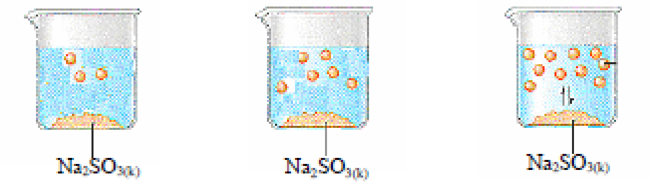
Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: The following shows the dissolution of Na_2SO_3 solid and its equilibrium with the solution solid.



Is there any precipitation before the Na_2SO_3 solution equilibrates with the solid?

Before reading what is written on the next page, write down your answer and reason……………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………

Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

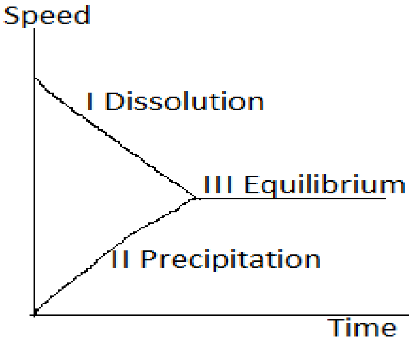
Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students believe that there is no precipitation before reaching equilibrium with solution solids. The main reason for accepting this is that they think that one thing has to be finished and the other must be finished. That is, they think that dissolution must end before precipitation can begin. But is there really no precipitation before the solution is saturated? In fact, after the salt (Na_2SO_3(k)) begins to dissolve, the number of ions in the solution starts to increase, which increases the likelihood of the ions to combine to form a solid salt. Therefore, solid salt is formed in the solution before equilibration (in our example Na_2SO_3 (k)). Already, the definition of solubility equilibrium was not that the dissolution rate was equal to the precipitation rate. As the definition implies, in order for the sedimentation rate to be equal to the dissolution rate, there must be some sedimentation before the equilibrium, right?

Let's try to understand this with an example. Passengers from Agofure park represent the ionizing solid and incoming passengers represent the precipitate formed by the collision of ions with each other. What did we say at the time of balance? Isn't the arrival and departure speed of the passengers coming and coming from the walking bands at the entrance of Agofure park equal? What happens before the moment of equilibrium since the equilibrium speeds are equalized? Before the moment of equilibrium, there will be some passengers and some passengers will arrive. However, the departing passengers will be more until the moment of equilibrium and the arrival and departure speeds of the arriving and departing passengers will be equal at the moment of equilibrium. Therefore, some passengers will arrive before the balance. Doesn't that mean that if we go back to our example, there should be some precipitation? Thus, some solid Na_2SO_3 is formed before equilibrium with the solution solid.

Let's try to understand the speed-time graph.



Graph I

But before that, I want you to answer the following question. Does the dissolution rate increase until equilibrium with the solution solid? Or less? Write your answer in the blank section below.

……………………………………………………………………………......

Some students think that the dissolution rate increases with time. The main reason for such thinking is that students misinterpret some of the dissolution reactions they encounter in daily life. For example, if the sugar is thrown into the tea and thinks that the dissolution occurs very quickly, they think that the resolution increases over time. In fact, it is the temperature that increases the solubility and the increase in the area where the solute comes into contact with the solvent, which is usually achieved by pulverizing or mixing.

Then what can we say about whether the dissolution rate at a given temperature increases over time? We know that a solvent can dissolve a certain amount of solid at a given temperature. Thus, the rate of dissolution decreases over time because the number of water or solvent molecules that interact with the soluble (solid salt) over time will decrease because some of them interact with the ions in the solution.

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

Then what can we say about whether the dissolution rate at a given temperature increases over time? We know that a solvent can dissolve a certain amount of solid at a given temperature. Thus, the rate of dissolution decreases over time because the number of water or solvent molecules that interact with the soluble (solid salt) over time will decrease because some of them interact with the ions in the solution.

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities: Teacher exemplifies the explanation as follows.

Let's try to explain this with Nigeria. Let all companies in Nigeria get solvent molecules. The number of passengers these companies can carry will be the definition of the resolution. So if the number of passengers increases over time, the number of passengers that these companies can carry will decrease. So if the number of ions in our solution increases, our dissolution rate will decrease.As a result, the dissolution rate decreases over time. Initially, the dissolution rate is very fast and decreases until it reaches equilibrium, and the equilibrium rate of dissolution equals the dissolution rate.

Returning to Graph 1, line I shows how dissolution rate changes over time, line II shows how precipitation rate changes over time, and line III shows precipitation and dissolution rates when in equilibrium. As we explained above, the dissolution rate decreases with time, the precipitation rate increases with time, and when equilibrium is reached, the precipitation and dissolution rates are equal. As the graph shows, the sedimentation continued before the system reached equilibrium.

When you look at Graph 1 carefully, you will see that line II starts from zero. What could be the reason for this? It starts at the point of the firing point because initially there is no ion soluble in the solvent. Over time, the number of ions increases, which increases the likelihood of ions colliding with each other. Therefore, the sedimentation rate begins to increase over time and equals the dissolution rate at equilibrium. The dissolution rate will be the opposite. So it will decrease over time because the shims in the solution will increase over time and that the solvent can dissolve at that temperature. Since the amount of solute is certain, the dissolution rate will decrease over time.

Students' Activities: Students attempt to answer teacher's question.

Period II

Content Development

Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: You can see the $BaSO_3$solution in Figure 1 at a certain temperature. To this saturated solution, some $BaSO_3$ (k) solids are added at the same temperature as in Figure 2.

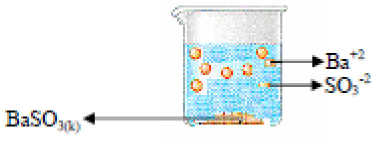


Figure I

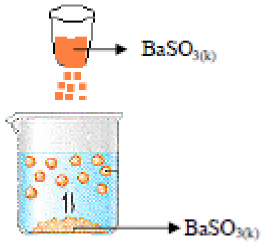


Figure II

Before reading what is written on the next page, write down your answer and reason

……………………………………………………………………………………

……………………………………………………………………………………

……….

Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students think that adding some more solids to a saturated solution increases ion concentrations. The main reason for such thinking is that if we add something to one side by considering the equilibrium equation, there must be an increase on the other side of the equation so that they can think of equilibrium. But if a solution is in equilibrium, it has dissolved the maximum solids it can dissolve, and even if we add more solids to it, it cannot dissolve any more solid salt at the temperature it is at. Since more solids do not dissolve, the number of moles of ions does not change. At the same time, the volume does not change because the volume is constant.

Let's try to explain this again with the example of Agofure. Let all the buses in Agofure be our solvent molecules. The maximum number of passengers that these solvent molecules can carry is 1000 (ions in the solution). If more passengers arrive in Agofure, will the number of passengers that companies can carry change? NO because this is only possible with the increase in the number of buses. Therefore, even if 2000 passengers arrive, only 1000 of them can be transported. If our solution is in equilibrium, this means that we already have 1000 passengers, then if we put another 2000 ($BaSO_3$ added later), the amount of solids added will remain undissolved as much as the amount of solids added. Therefore, adding solid $BaSO_3$ to the saturated $BaSO_3$ solution will not affect the ion concentration.

We said the ion concentration does not change, but Kc what happens?

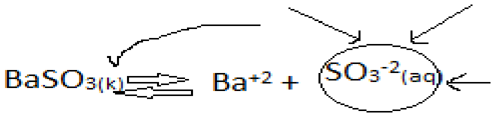
Some students believe that the addition of solids to the solution at a given temperature, or the addition of common ions, provided that the volume of the solution does not change, changes the Kc value. The main reason for such a belief is that they do not understand that the solvent has solved the maximum amount of substance that can be dissolved in a saturated solution. Therefore, they think that adding the solids to the solution will increase the ion concentration in the medium and this will change the K value. Again, when we add a common ion, they forget the precipitation reaction and think that the current concentration of the ion increases again. Students who think so are mistaken because, as we mentioned in the previous example, a saturated solution has already solved the maximum solute it can solve. Therefore, adding some more solids at the same temperature will not change the ion concentrations. Since the Kc is the product of ion concentrations in a solution, it will not change. As a result, if we go back to our first question; In the case of Figure II (when some amount of $BaSO_3$ (k) is added), the Kc value will not change.

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

Why does Kc not change when we add common ions? If we add common ions to a saturated solution (in our example, add SO_3^{-2} ions to the $BaSO_3$ solution), when an effect is made on one side by making use of the Le Chatelier principle, the system shifts to the other side to reduce that effect. In this case, the precipitation reaction is accelerated and when the system equilibrates, the Kc product does not change since the concentration of the ion added to the common ion increases but the concentration of the other ions ($[Ba^{+2}]$) decreases at the same rate.



If we increase the SO_3^{-2} ion concentration, the number of ions in the solution will increase and therefore the probability of ions to collide to form $BaSO_3$ (k) solids will increase.

Thus, the precipitation rate will be greater than the dissolution rate until it equilibrates with the solution solid. At the same time, since the concentration of Ba^{+2} ions in the solution comes only from the dissolution of the $BaSO_3$ (k) solid, when the solution reaches equilibrium, the SO_3^{-2} ion concentration will be greater than the Ba^{+2} ion concentration, but Kc will not change because the same TEMPERATURE the amount of solvent that the solvent can dissolve is the same. In other words, the increase in SO_3^{-2} ion concentration in the solution is compensated by the decrease in Ba^{+2} ion concentration and the same Kc product is obtained.

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities:

Teacher evaluates the lesson based on the stated objectives.

Students' Activities: Students attempt to answer teacher's question.

Week 4

Period 1

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 45 minutes

Topic : Chemical Equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Establish the relationship between resolution and solubility product constant

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, conceptual change texts on chemical equilibrium.

Entry behaviour: Students can explain solubility equilibrium multiplication.

Content Development

Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: Figure 1 shows the resolution-temperature graph of the X_2Y solid.

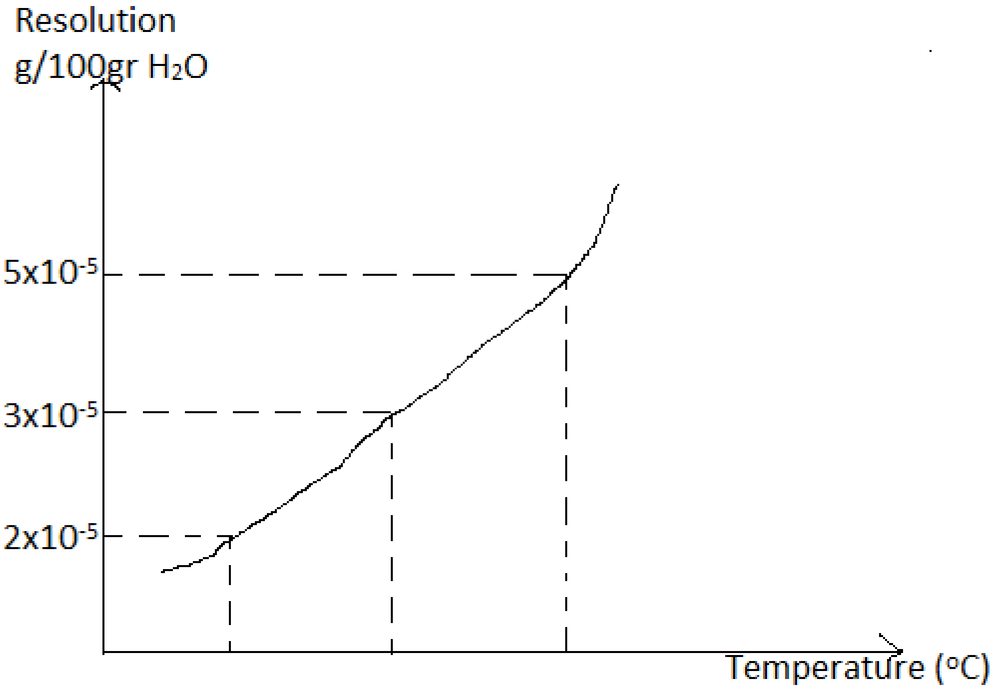


Figure 1

Cool the concentrated X_2Y solution at 45 ° C to 20 ° C and wait for a while and then heat to 45 °C again; How does the Kc in the last case change from the Kc in the first case?

Before reading what is written on the next page, write down your answer and reason……………………………………………………………………………………

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Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students believe that poorly soluble salts in water have different Kc Values at the same temperature. Those who have this view generally have this misjudgment because the Kç value of the same substance is given differently without specifying the temperature in textbooks or test books, or the Kc value is rounded (for example, writing $1.8x10^{-5}$ as $2x10^{-5}$).

In fact, the Kc value has the same value at the same temperature as the LOW SOLVED salts. For example, at 25 °C the Ag value of AgBr is $7x10^{-13}$, because the amount of solid that the solvent can dissolve at a given temperature is determined. Therefore, the K k value is constant at a certain temperature since it is the product of the concentrations of dissolved ions. If Kc had different values at the same temperature, could the above graph be drawn? No, it couldn't be drawn, because Kc was no longer a fixed number, and so the ion concentrations would have different values at that temperature.

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

Returning to the original question, the solubility of the solid at 45 °C is $3x10^{-5}$. If we cool to 20 °C, the resolution decreases as shown in the graph and drops to $2x10^{-5}$, which means that some solids have precipitated. If we heat this solution back to 45 °C and wait for a while to reach equilibrium, its resolution will be $3x10^{-5}$. Therefore Kc value will not change in the first and last cases, so it will remain the same. Finally, the K k value of the LOW SOLVED salts changes with the TEMPERATURE and has the same value at the same temperature.

Students' Activities: Listen to teacher explanations

Period II

Content Development

Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: Does the temperature always decrease as the solubility decreases? Before reading what is written on the next page, write down your answer and reason below

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Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students think that as the temperature decreases, the solubility decreases, and therefore the ion concentrations decrease, the Kc value always decreases. The reason some students think so is that textbooks always include solutions that always decrease in resolution with temperature decrease or increase with temperature increase. As such, some students can make such a wrong generalization. In fact, the increase in temperature with the increase in solubility or the decrease in resolution with the decrease of temperature is ONLY true for ENDOTHERMIC dissolution. Solubility in exothermic dissolution where solubility decreases as temperature increases, solubility increases as temperature decreases. As can be seen in the endothermic and exothermic dissolution TEMPERATURE affects the solubility in different ways.

Temperature WHY have different effects on exothermic and endothermic dissolution?

Think and state the answer the reason behind the answer in the blank space below……………………………………………………

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

Firstly, the dissolution in which the dissolution is exothermic, the temperature increases due to the outflow of heat; In the case of endothermic dissolution, we should remember that the temperature of the environment decreases due to external heat. Therefore, if the temperature is increased, the system reacts according to the Le Chatelier principle to reduce this effect.

$XY_{(k)}$ + Heat $\rightleftharpoons X^{+}_{(aq)} + Y^{-}_{(aq)}$ endothermic (takes heat)

$BM_{(k)} \rightleftharpoons B^{+}_{(aq)} + M^{-}_{(aq)}$ + heat exothermic (gives heat)

Increasing the temperature of the environment in endothermic dissolution system gives heat. It wants to lower the temperature. As we mentioned at the beginning, the temperature of the ambient heat is reduced in endothermic dissolution. Therefore, lowering the increasing temperature will result in further dissolution.

As you can see in the exothermic dissolution, the temperature of the environment increases during dissolution. Therefore, if we increase the temperature, the system will want to reduce this effect and the precipitation will work in favor of lowering the temperature because heat is taken from the outside during the deposition, which reduces the temperature of the environment. In short, heat dissolving substances will dissolve more in the temperature rise, whereas heat dissolving substances will dissolve less in the temperature rise.

The following example helps us better understand this topic. The higher the solar energy rays, the more energy is obtained, which means a greater distance. In cloudy weather, it cannot go a long way because it can obtain less energy. Do you think this is an example of endothermic dissolution or exothermic dissolution?

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Endothermic reaction is increasing because of the endothermic dissolution. In our example, as the sun rays increase, our energy increases and therefore the path we take increases (resolution increases)

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities:

Teacher evaluates the lesson based on the stated objectives.

Students' Activities: Students attempt to answer teacher's question.

Week 5

Period 1

Subject	: Chemistry
Class	: SSII
Age	: 15+
Duration	: 45 minutes
Topic	: Chemical Equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Relate solubility constant to unsaturated solution.
2. Establish the resolution of a substance in equilibrium

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, conceptual change texts on chemical equilibrium.

Entry behaviour: Students can explain solubility equilibrium multiplication.

Content Development

Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: Asks students, Can Kc be calculated for unsaturated solutions?

Before reading what is written on the next page, write down your answer and reason…………………………………………………………………………………………

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Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students think that the K value can be calculated in unsaturated solutions. The only reason for this error is that the questions about the equilibrium of solubility in chemistry books are generally directed to problem solving and processing skills. Because the questions are generally asked for saturated solutions at a certain temperature, in other words for solutions which are in equilibrium with their solids. Therefore, some friends make a wrong generalization and conclude that Kc can be calculated in all cases (saturated, unsaturated).

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

But we shouldn't forget that Kc is an equilibrium constant that is the product of ion concentrations of a solution in equilibrium. Can we talk about the equilibrium state in an unsaturated solution? Of course no. Because it has not solved the maximum solute it can solve, so we cannot talk about the equality of dissolution and precipitation rates. Because the dissolution of unsaturated solutions occurs faster than precipitation. As a result, if our solution is not saturated, we cannot talk about equilibrium. Therefore, we cannot calculate Kc.

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities: Teacher exemplifies the explanation as follows.

We calculate the value that we call the ion product (Qi) and compare it with Kc. If Qi = Kc, the solution is saturated; that is, the precipitation and dissolution rates are equal and the solution is stable. If Qi> Kc, the ion concentrations in the solution are greater than the equilibrium concentration, so ions form precipitates until Qi = Kc. If Qi <Kc, the solution is unsaturated. Since the ion concentrations are smaller than the equilibrium concentrations, no precipitation occurs. If there is solid in the solution, it is dissolved until Qi = K?

As a result, there may be three conditions for the multiplication of the concentrations of ions calculated at any time by a salt that is slightly soluble in water. 1. The solution is saturated and in equilibrium with the solid (Qi = Kc). 2. The solution is unsaturated and we cannot speak of equilibrium (Qi <Kc). 3. It precipitates until the solution equilibrates with some salt solids (if Qi> Kc).

Students' Activities: Students attempt to answer teacher's question.

Period II

Content Development

Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: Figure 1 shows the saturated ZnCO3 solution in equilibrium with its solid.

$$ZnCO_{3(k)} \rightleftharpoons Zn^{+2}{}_{(aq)} + CO_3{}^{-2}{}_{(aq)}$$

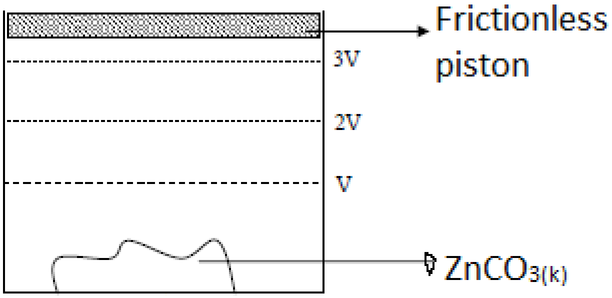

Figure 1

As shown in Figure 1, there is a $ZnCO_3$ solution in equilibrium with V volume solids. When this solution is filled with water up to 3V, it is observed that some of the bottom solid does not dissolve. What can we say about the resolution of $ZnCO_3$ in the new case?

Before reading what is written on the next page, write your answer and reason below

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Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students think that increasing or decreasing the volume of the salt at the bottom of the solutions of the water-insoluble salts, provided that some of the solids remain, changes the solubility of that salt. Those who think like this make such a mistake by thinking that the change in volume will change the concentration and this will affect the resolution. However, when we look at the question carefully, we see that the solution also has some solid at the bottom. So in the new case (because the temperature does not change) Kc is the same. Since Kc of our solution is the same, solubility will not change. Okay but why?

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

When we add some more water, the volume of the solution will increase. At the same time, however, a portion of the solid at the bottom of the solution will become more ionized and thus the number of ions will increase. However, the concentration of the dissolved ions will not change because the ratio of the molar numbers and the volume increase of the dissolved ions will remain constant. Since the temperature does not change, the maximum amount of material that can dissolve the solution will not change, which explains why the ion concentrations do not change. Since there is also some solid at the bottom of the solution, it will re-equilibrate with the solution solid at the same temperature. That is, in the new case, the equilibrium will be restored when the dissolution rate equals the precipitation rate. Consequently, adding the solvent to the solution, provided that some solids remain at the bottom, will not alter the solubility of the solid salt at the same temperature.

What can we say about the resolution of ZnCO3 if the pressure of the vessel in Figure 1 is increased (by pressing the piston down)?

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Some students think that the solubility of the poorly soluble salts in water changes with the change of pressure. We know that since gases have compression properties, their solubility increases in proportion to the applied pressure. But we know that solids and liquids cannot be compressed, right? Therefore, the increase in pressure does not affect the solubility of solids (in our example $ZnCO_3$).

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities:

Teacher evaluates the lesson based on the stated objectives.

Students' Activities: Students attempt to answer teacher's question.

Week 6

Period 1

Subject	: Chemistry
Class	: SSII
Age	: 15+
Duration	: 45 minutes
Topic	: Chemical Equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Identify the most soluble solid in water among a set.
2. Explain change in solubility of AgCl with the addition of unknown salt.

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, conceptual change texts on chemical equilibrium.

Entry behaviour: Students can explain solubility equilibrium multiplication.

Content Development

Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: Asks students, which solids are more soluble in water than those given below at the same temperature?

XY_2 ------ $Kc = 3.2x10^{-6}$

XY ------ $Kc = 5.2x10^{-5}$

X_3Y ------ $Kc = 4.2x10^{-7}$

Before reading what is written on the next page, write down your answer and reason………………………………………………………………………………………

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Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students think that they can compare the solubility of salts in water only by looking at their K values. The main reason for having this idea is that the Kç values of the examples given in the textbooks are appropriate for such a comparison. So if Kç values are dissolved as ions with different coefficients, can we still compare their solubility in water by looking at Kç values? Of course no. First the equilibrium equation should be written and then Kç expression should be written. Then we can calculate the solubility of the solid with the help of ion concentrations.

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

Let's write the equilibrium equation and the K r relations in the question we ask.

$XY_{2(k)} \rightleftharpoons X^{+}_{(aq)} + 2Y^{-}_{(aq)},$ $Kc = [X^{+}][Y^{-}]^{2}$

s 2s $Kc = s.\,(2s)^{2} = 4s^{3}$

$XY_{(k)} \rightleftharpoons X^{+}_{(aq)} + Y^{-}_{(aq)},$ $Kc = [X^{+}][Y^{-}]$

s s $Kc = s.\,s = s^{2}$

$X_{3}Y_{(k)} \rightleftharpoons X^{+}_{(aq)} + Y^{-3}_{(aq)},$ $Kc = [X^{+}]^{3}[Y^{-3}]$

3s s $Kc = (3s)^{3}.s = 27s^{4}$

The solubility of these salts would be $XY > XY_{2} > X_{3}Y$ if we only ordered Kc values. Is this statement correct?

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities: Teacher exemplifies the explanation as follows.

For each equation, let's consider the solubility of salts in water (s). Therefore, we can find the solubility of each solid by using Kt relations, right?

I. Equation $4s^{3} = 3.2x10^{-6}$, $s = 9.3x10^{-3}$

II. For the equation $s^{2} = 5.2x10^{-5}$, $s = 7.2x10^{-3}$

III. For slimming $27s^{4} = 4.2x10^{-7}$, $s = 1.1x10^{-2}$

As you can see, the ranking took the form $X_{3}Y > XY_{2} > XY$ and we see that it is different from the above first ranking. Therefore, we cannot compare the solubility of salts by simply looking at Kc values.

Students' Activities: Students attempt to answer teacher's question.

Period II

Content Development

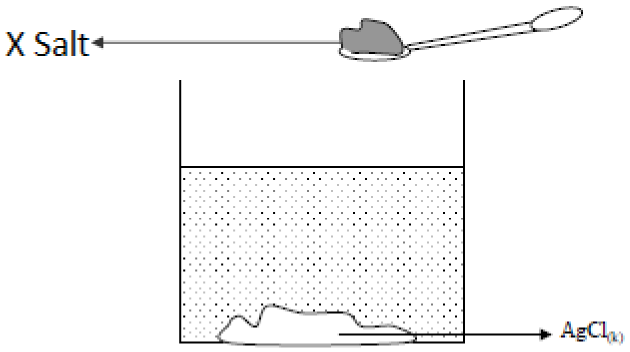
Step 1

Teacher Activities: Teacher responds to students greeting, group students and gives students conceptual change texts in each group.

Students' Activities: Greets teacher and glance through the conceptual change texts.

Step 2

Teacher Activities: In Figure 1, the saturated salt of AgCl is added with a small amount of X salt, which does not form compounds with Ag+ and Cl^- ions.



Figure

How do we change the solubility of AgCl if we add some X salt to the saturated AgCl solution?

Before reading what is written on the next page, write down your answer and reason

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Students' Activities: Students in group think out the answer and the reason(s) behind their answers in the group.

Step 3

Teacher Activities: Teacher presents students with some common misconceptions.

Some students think that the solubility will not change by dissolving another solid salt in a saturated solution (which is not compounded with ions in the solution). The main reason for this idea is that the ions in the solution and the ions from the added salt do not form compounds, so they think that the solubility will not change. But doesn't the resolution really change?

In fact, foreign ions (in our example, the ions formed by dissolution of the X salt) increase the ionic strength of the solution (remember that the number of ions increases due to the ions coming from the added salt), which increases the solubility of the less soluble substance ions in that solvent. The main reason for this is the increase in the electrostatic attraction and repulsion effect of the ions in the solution (due to new ions added). So how will the solubility of AgCl in our sample change with the X salt added? Will it increase or decrease? AgCl's solubility will increase due to the reasons mentioned above

Students' Activities: Listen to teacher's explanation. Ask questions to clarify their misconceptions.

Step 4

Teacher Activities: Teacher gives explanation acceptable in the scientific community.

So how will the solubility of AgCl in our sample change with the X salt added? Will it increase or decrease? Because of the reasons mentioned above, the solubility of AgCl will increase.

For solutions formed by dissolution of a solid, can we say that it dissolves faster with a K value? Why is that? Some students think that the larger the K value, the faster the solids dissolve in liquids. Those who think like this arrived to this generalization with a faster dissolution approach as they are more dissolved. But Kc is only related to the amount of dissolution, or rather, how much a solid is dissolved in a solvent. However, the dissolution rate depends on the temperature and the contact surface on which the solid contacts the solvent. Therefore, there is no direct relationship between Kç and dissolution rate.

Students' Activities: Listen to teacher explanations

Step 5

Teacher Activities:

Teacher evaluates the lesson based on the stated objectives.

Students' Activities: Students attempt to answer teacher's question.

Appendix IX

Concept Mapping Lesson Plan

Week 1

Subject	: Chemistry
Class	: SSII
Age	: 15+
Duration	: 90 minutes (45 minutes per period)
Topic	: Chemical equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Define chemical equilibrium.
2. Differentiate between reversible and irreversible reactions.
3. State Le Chatelier’s principle

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, silver nitrate, nitrogen, hydrogen, water, concept map on chemical equilibrium.

Entry behaviour: Students have been taught enthalpy change.

Revision of previous lesson: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Teacher asks students to construct a concept map on the topic with the following words; meaning of chemical equilibrium, static equilibrium, dynamic equilibrium, reversible and irreversible reactions and Le Chatelier's principle.

Students' Activities: Listen to teacher and construct their concept map on the topic with their alternative conceptions.

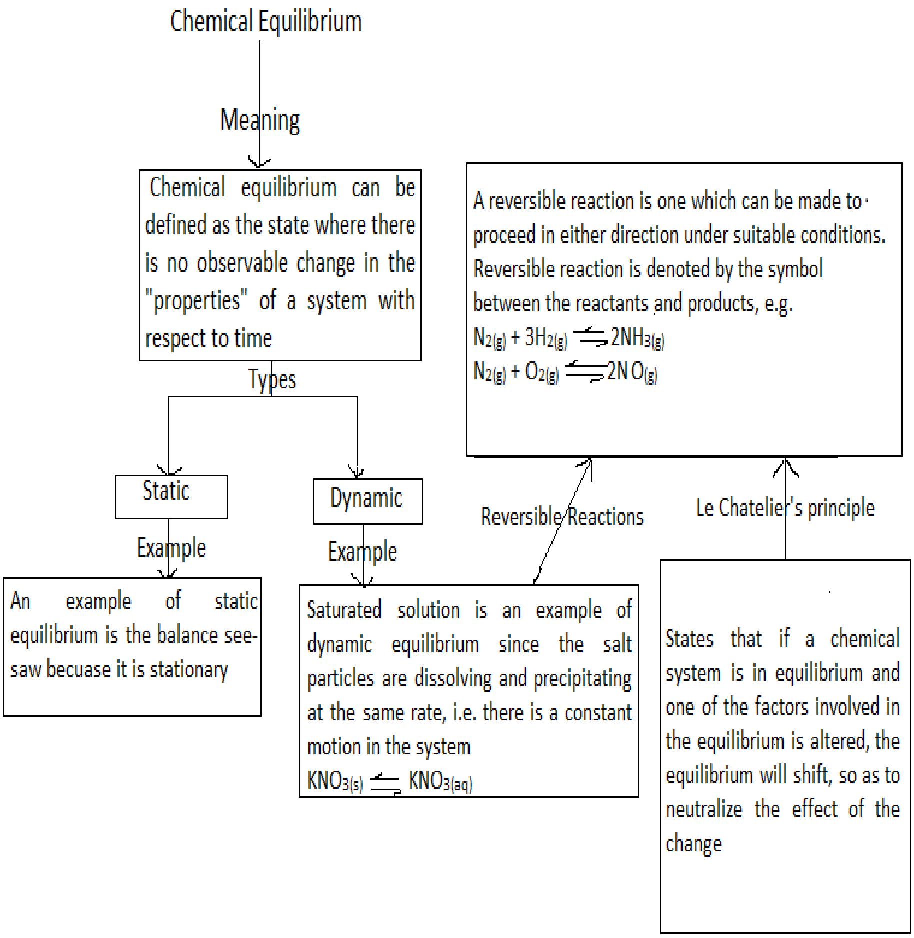
Step 3

Teacher Activities: Teacher evaluates students' concept maps and identifies students' misconceptions on the topic.

Students' Activities: Pay attention to the teacher.

Step 4

Teacher Activities: Teacher presents students with a concept map on the topic that aligns with the scientific explanation to clear students' misconceptions on the topic.



Chemical equilibrium can be defined as the state where there is no observable change in the "properties" of a system with respect to time

A reversible reaction is one which can be made to proceed in either direction under suitable conditions. Reversible reaction is denoted by the symbol between the reactants and products, e.g.

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

An example of static equilibrium is the balance see-saw becuase it is stationary

Saturated solution is an example of dynamic equilibrium since the salt particles are dissolving and precipitating at the same rate, i.e. there is a constant motion in the system

$KNO_{3(s)} \rightleftharpoons KNO_{3(aq)}$

States that if a chemical system is in equilibrium and one of the factors involved in the equilibrium is altered, the equilibrium will shift, so as to neutralize the effect of the change

Students' Activities: Students observe and listen to teacher's explanation.

Chalkboard Summary

Meaning of Chemical Equilibrium

Chemical equilibrium can be defined as the state where there is no observable change in the "properties" of a system with respect to time. For example, in saturated potassium trioxonitrate(V) solution, there is no observable change in the properties of the system, because the salt dissolves in water until some salt is left undissolved in the solution. In this system, at any given moment, undissolved salt particle are dissolving, while the same number of dissolved salt particles are precipitating. Here two opposing processes- dissolution and precipitating are taking place at the same rate. As a result, the net number of dissolved particles in the solution remains the same.

$KNO_{3(s)} \rightleftharpoons KNO_{3(aq)}$

Equilibrium systems may be static or dynamic. An example of static equilibrium is the balanced see-saw because it is stationary, while the saturated solution is an example of dynamic equilibrium; since the salt particles are dissolving and precipitating at the same rate, i.e. there is constant motion in the system.

In a chemical equilibrium, the reactants undergo a change in composition to form the products, which in turn, are reconverted to the original reactants at the same rate.

Equilibrium in Reversible Reactions

A reversible reaction is one which can be made to proceed in either direction under suitable conditions. Reversible reaction is denoted by the symbol $\rightleftharpoons$ between the reactants and products. E.g.

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

All reversible reactions can proceed in either direction, depending on the condition of the reactions. In some cases, both forward and backward reactions operate under the same conditions, while in others they operate under different conditions, e.g. the reaction between iron and steam is reversible under the same conditions, since red heat is needed for the forward and backward reactions.

$3Fe_{(s)} + 4H_2O_{(g)} \rightleftharpoons Fe_3O_{4(s)} + 4H_{2(g)}$

However, when crystalline salt of ammonium chloride is heated strongly, it sublimes and dissociates into ammonia and hydrogen chloride gases. These two gaseous products readily recombine to form solid ammonium chloride again when cooled. In this case, the forward reaction takes place, when heat is supplied, while the backward reaction occurs in the cold.

$NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$

Le Chatelier' Principle

Le Chatelier's principle states that if a chemical system is in equilibrium and one of the factors involved in the equilibrium is altered, the equilibrium will shift, so as to neutralize the effect of the change. The principle is of the view that whenever a system in equilibrium is affected by increase or decrease in one of the factors keeping the system in equilibrium, the other factors will change their value so as to restore the equilibrium.

Week 2

Subject	: Chemistry
Class	: SSII
Age	: 15+
Duration	: 90 minutes (45 minutes per period)
Topic	: Factors affect equilibrium position

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Mention the factors affecting equilibrium.
2. Explain the effect of concentration on equilibrium.
3. How does temperature change affect equilibrium

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, silver nitrate, nitrogen, hydrogen, water, concept map on factors affecting equilibrium.

Entry behaviour: Students can define chemical equilibrium and state Le Chatelier's principle.

Revision of previous lesson: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Teacher asks students to construct a concept map on the topic with the following words; concentration change, pressure change, temperature change and catalyst.

Students' Activities: Listen to teacher and construct their concept map on the topic with their alternative conceptions.

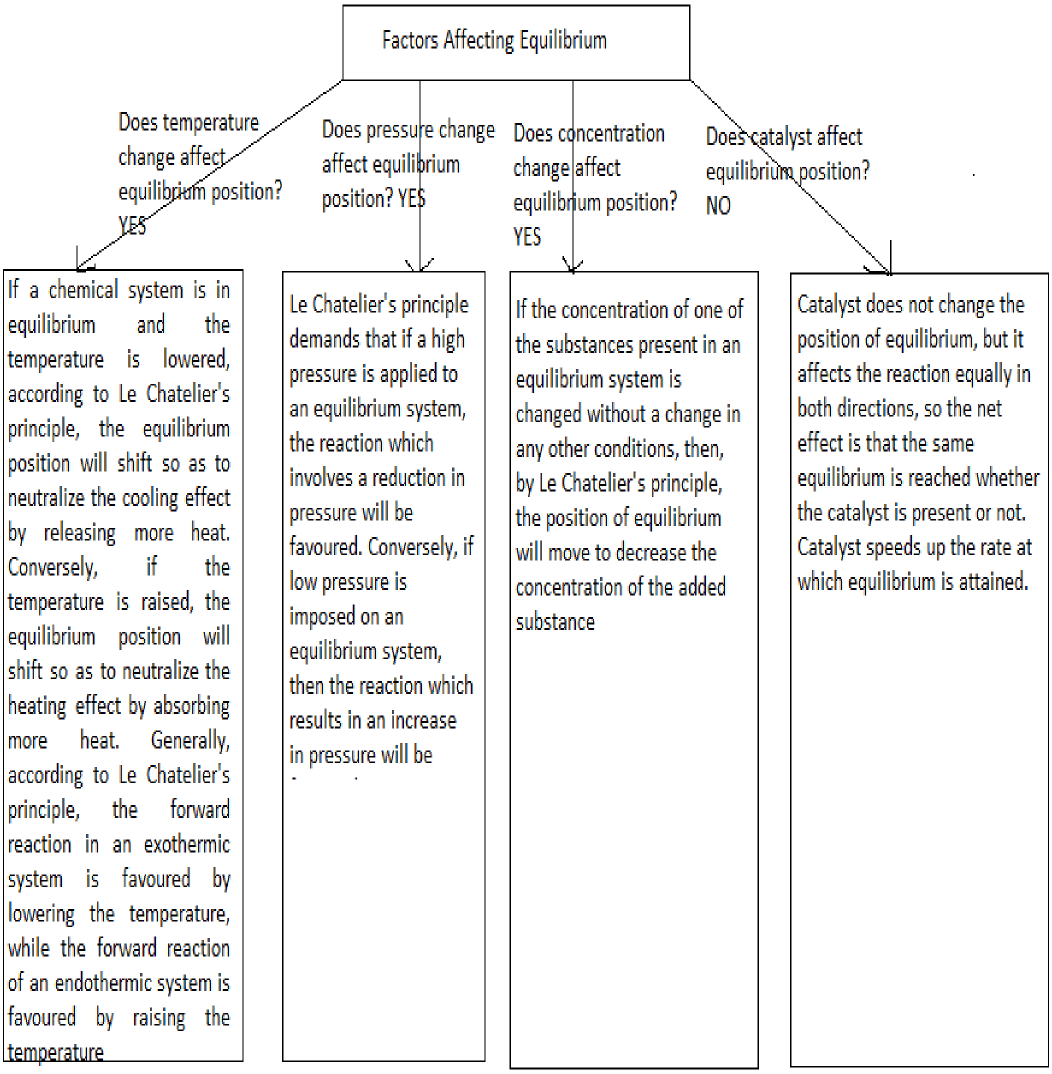
Step 3

Teacher Activities: Teacher evaluates students' concept maps and identifies students' misconceptions on the topic.

Students' Activities: Pay attention to the teacher.

Step 4

Teacher Activities: Teacher presents students with a concept map on the topic that aligns with the scientific explanation to clear students' misconceptions on the topic.



If a chemical system is in equilibrium and the temperature is lowered, according to Le Chatelier's principle, the equilibrium position will shift so as to neutralize the cooling effect by releasing more heat. Conversely, if the temperature is raised, the equilibrium position will shift so as to neutralize the heating effect by absorbing more heat. Generally, according to Le Chatelier's principle, the forward reaction in an exothermic system is favoured by lowering the temperature, while the forward reaction of an endothermic system is favoured by raising the temperature

Le Chatelier's principle demands that if a high pressure is applied to an equilibrium system, the reaction which involves a reduction in pressure will be favoured. Conversely, if low pressure is imposed on an equilibrium system, then the reaction which results in an increase in pressure will be

If the concentration of one of the substances present in an equilibrium system is changed without a change in any other conditions, then, by Le Chatelier's principle, the position of equilibrium will move to decrease the concentration of the added substance

Catalyst does not change the position of equilibrium, but it affects the reaction equally in both directions, so the net effect is that the same equilibrium is reached whether the catalyst is present or not. Catalyst speeds up the rate at which equilibrium is attained.

Students' Activities: Students observe and listen to teacher's explanation.

Chalkboard Summary

Factors Affecting Equilibrium

The factors affecting equilibrium position are temperature, concentration and pressure of the reactants and products. Catalyst does not change the position of equilibrium, but it affects the reaction equally in both directions, so the net effect is that the same equilibrium is reached whether the catalyst is present or not. It speed up the rate at which equilibrium is attained.

Effects of temperature changes on equilibrium mixture

If a chemical system is in equilibrium and the temperature is lowered, according to Le Chatelier's principle, the equilibrium position will shift so as to neutralize the cooling effect by releasing more heat. Conversely, if the temperature is raised, the equilibrium position will shift so as to neutralize the heating effect by absorbing more heat.

A common example of the effect of temperature on the position of equilibrium is the equilibrium between water and steam, $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$. Here, the forward reaction is accompanied by an absorption of heat, i.e. it is an endothermic reaction. Thus, if the temperature of the system is raised, this will tend to produce more steam, then the equilibrium position will shift to the right, whereas if the temperature is lowered, more water will be formed, then the equilibrium position will shift to the left and the steam condenses. You will observe that the condensation of steam is an exothermic process which is why a steam scald is usually worse than the one caused by water.

Generally, according to Le Chatelier's principle, the forward reaction in an exothermic system is favoured by lowering the temperature, while the forward reaction of an endothermic system is favoured by raising the temperature.

Effect of pressure change on equilibrium mixture

The effects of pressure changes are much more noticeable in reversible reactions; (i) occurring in the gaseous state than those occurring between solids and liquids. (ii) in which the total number of moles of gaseous molecules on the left side of the equation differs from that on the right side of the equation.

Consider the gas phase reaction involving the formation of ammonia from nitrogen and hydrogen

$$\underset{\text{4moles or volumes}}{N_{2(g)} + 3H_{2(g)}} \rightleftharpoons \underset{\text{2moles or volumes}}{2NH_{3(g)}}$$

Here, 4 moles of reactants give only 2 moles of the products. The forward reaction results in a decrease in the number of moles and hence, a decrease in the pressure of the system. The backward reaction results in an increase in the number of moles and hence, an increase in the pressure of the system.

Le Chatelier's principle demands that if a high pressure is applied to an equilibrium system, the reaction which involves a reduction in pressure will be favoured. Conversely, if low pressure is imposed on an equilibrium system, then the reaction which results in an increase in pressure will be favoured.

Effect of concentration change on equilibrium change on equilibrium mixture

If the concentration of one of the substances present in an equilibrium system is changed without a change in any other conditions, then, by Le Chatelier's principle, the position of equilibrium will move to decrease the concentration of the added substance. Thus the reaction

$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

If more reactants (N_2 and O_2) are introduced into the equilibrium system, the balance will be upset. In order to relieve this constraint (i.e. the increase in the concentration of the reactant), the equilibrium position will shift to the right, favouring the forward reaction. This results in a proportional increase in the concentration of the products, and so the equilibrium constant remains unchanged. In a similar way, if the product formed is continually removed from the system, the equilibrium position will change (i.e. shift to the right) to produce more of the product, thus, neutralizing the constants. This is again in accordance with Le Chatelier's principle.

In the reversible reaction of Iron with steam; $3Fe_{(s)} + 4H_2O_{(g)} \rightleftharpoons Fe_3O_{4(s)} + 4H_{2(g)}$, the hydrogen is constantly removed by a current of steam that passes over the heat iron until all the iron is converted to tri Iron tetraoxide. The reverse process occurs if water vapour is removed.

Week 3

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 90 minutes (45 minutes per period)

Topic : Equilibrium constant

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Write the equilibrium constant of chemical equations
2. Perform calculations using equilibrium constant

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, silver nitrate, nitrogen, hydrogen, water concept map on equilibrium constant.

Entry behaviour: Students can mention 3 factors affect equilibrium position.

Revision of previous lesson: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Teacher asks students to construct a concept map on the topic with the following words; equilibrium constant, equation for equilibrium constant of solid, liquid and solution, equilibrium constant of gaseous reactants.

Students' Activities: Listen to teacher and construct their concept map on the topic with their alternative conceptions.

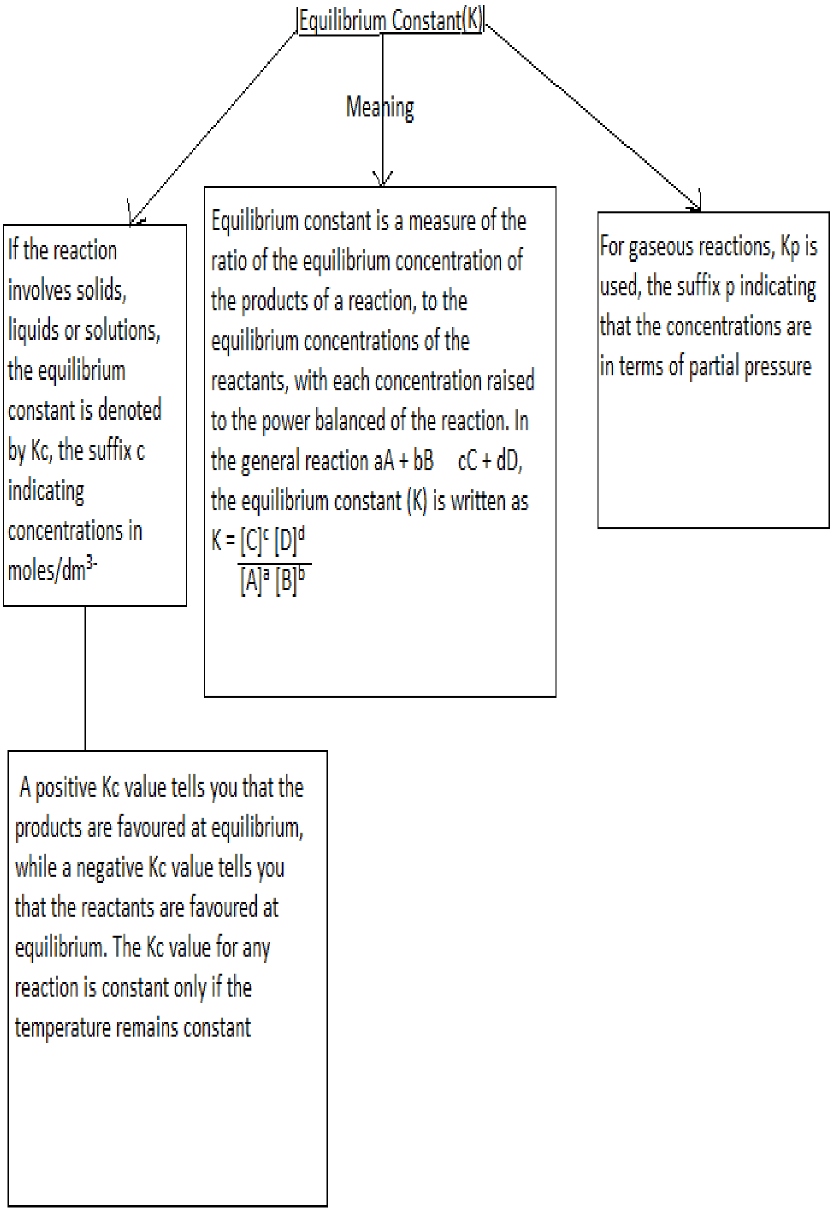
Step 3

Teacher Activities: Teacher evaluates students' concept maps and identifies students' misconceptions on the topic.

Students' Activities: Pay attention to the teacher.

Step 4

Teacher Activities: Teacher presents students with a concept map on the topic that aligns with the scientific explanation to clear students' misconceptions on the topic.



Equilibrium Constant(K)

Meaning

If the reaction involves solids, liquids or solutions, the equilibrium constant is denoted by Kc, the suffix c indicating concentrations in moles/dm^{3-}

Equilibrium constant is a measure of the ratio of the equilibrium concentration of the products of a reaction, to the equilibrium concentrations of the reactants, with each concentration raised to the power balanced of the reaction. In the general reaction aA + bB   cC + dD, the equilibrium constant (K) is written as

$$K = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

For gaseous reactions, Kp is used, the suffix p indicating that the concentrations are in terms of partial pressure

A positive Kc value tells you that the products are favoured at equilibrium, while a negative Kc value tells you that the reactants are favoured at equilibrium. The Kc value for any reaction is constant only if the temperature remains constant

Students' Activities: Students observe and listen to teacher's explanation.

Chalkboard Summary

Equilibrium Constant

The equilibrium constant, K, may be derived by the use of **law of mass action.** This law by Guldberg and Waage states that at constant temperature, the rate of a chemical reaction is directly proportional to the active mass of the reacting substances.

For most practical purposes, the active mass may be taken as the molar concentration, expressed in mol^{-1}. Equilibrium constant is a measure of the ratio of the equilibrium concentration of the products of a reaction, to the equilibrium concentration of the reactants; with each concentration raised to the power balanced equation of the reaction. In the general reaction $aA + bB \rightleftharpoons cC + dD$, the equilibrium constant (k) is written as

$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Where [ ] stands for equilibrium concentration. If the reaction involves solids, liquids or solutions, the equilibrium constant is denoted by K_c, the suffix c indicating concentration in moles/dm^3; but for gaseous reactions, Kp is used, the suffix p indicating that the concentrations are in terms of partial pressure.

A positive Kc value tells you that the products are favoured at equilibrium, while, a negative Kc value tells you that the reactants are favoured at equilibrium. The Kc value for any reaction is constant only if the temperature remains constant.

Calculation based on equilibrium constant, K

1. The following results were obtained during the analysis of a reaction

   $CO_{2(s)} + H_{2(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$, $[CO_2] = 0.75M$, $[H_2] = 0.32M$, $[H_2O] = 0.30M$, $[CO] = 0.55M$.

   Calculate the equilibrium constant for the reaction

Solution

$K = \frac{[H2O][CO]}{[H2][CO2]} = \frac{0.30\ x\ 0.55}{0.32\ x\ 0.75} = 0.688.$

2. Calculate (a) the equilibrium constant (Kp) for the reaction at 45°C (b) the equilibrium constant (Kp) for the backward reaction

$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$. Given that the partial pressures of the following substances at 45^0C are $[H_2]$ = 0.065atm, $[I_2]$ = 0.45 atm, [HI] = 0.245 atm.

The backward reaction, the ammonium ion donates as proton to the hydroxide ion.

Solution

a. $K = \frac{[HI]2}{[H2][I2]} = \frac{[0.245]2}{[0.065][0.45]} = 2.05$

b. $K = \frac{1}{Kp} = \frac{1}{2.05} = 0.49.$

Week 4

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 90 minutes (45 minutes per period)

Topic : Solubility Product Constant

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Explain solubility product constant (Ksp)
2. Deduce the solubility product constant of some common compounds
3. Explain some common effect affecting solubility product constant (Ksp)

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, Silver Chromate, Magnesium fluoride.

Entry behaviour: Students can differentiate between Kc and Kp.

Revision of previous lesson: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Teacher asks students to construct a concept map on the topic with the following words; solubility product constant, common effects, solid solution.

Students' Activities: Listen to teacher and construct their concept map on the topic with their alternative conceptions.

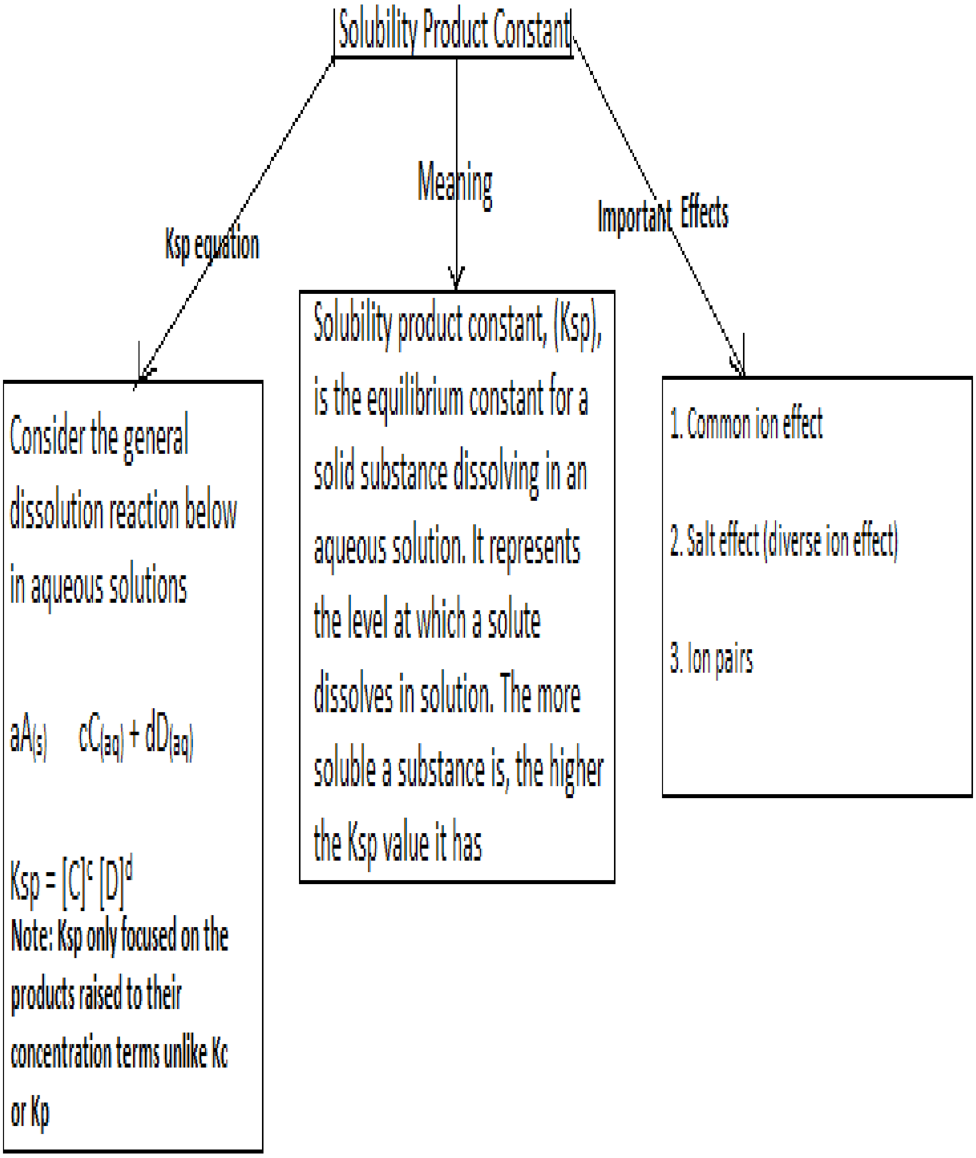
Step 3

Teacher Activities: Teacher evaluates students' concept maps and identifies students' misconceptions on the topic.

Students' Activities: Pay attention to the teacher.

Step 4

Teacher Activities: Teacher presents students with a concept map on the topic that aligns with the scientific explanation to clear students' misconceptions on the topic.



Consider the general dissolution reaction below in aqueous solutions

$aA_{(s)} \quad cC_{(aq)} + dD_{(aq)}$

$Ksp = [C]^c [D]^d$

Note: Ksp only focused on the products raised to their concentration terms unlike Kc or Kp

Solubility product constant, (Ksp), is the equilibrium constant for a solid substance dissolving in an aqueous solution. It represents the level at which a solute dissolves in solution. The more soluble a substance is, the higher the Ksp value it has

1. Common ion effect
2. Salt effect (diverse ion effect)
3. Ion pairs

Students' Activities: Students observe and listen to teacher's explanation.

Chalkboard Summary

Solubility Product Constant

The solubility product constant, Ksp**,** is the equilibrium constant for a solid substance dissolving in an aqueous solution. It represents the level at which a solute dissolves in solution. The more soluble a substance is, the higher the Ksp value it has.

Consider the general dissolution reaction below (in aqueous solutions):

$$aA_{(s)} \rightleftharpoons cC_{(aq)} + dD_{(aq)} \qquad (1)$$

To solve for the Ksp it is necessary to take the molarities or concentrations of the products (cC and dD) and multiply them. If there are coefficients in front of any of the products, it is necessary to raise the product to that coefficient power (and also multiply the concentration by that coefficient). This is shown below:

$$Ksp = [C]^c\,[D]^d \qquad (2)$$

Note that the reactant, aA, is not included in the Ksp equation. Solids are not included when calculating equilibrium constant expressions, because their concentrations do not change the expression; any change in their concentrations are insignificant, and therefore omitted. Hence, Ksp represents the maximum extent that a solid that can dissolved in solution.

Example: What is the solubility product constant expression for MgF_2?

Solution

The relevant equilibrium is $MgF_{2(s)} \rightleftharpoons Mg^{2+}{}_{(aq)} + 2F^-{}_{(aq)}$

So the association equilibrium constant is

$Ksp = [Mg^{2+}][F^-]^2$

Important Effects

- For highly soluble ionic compounds the ionic activities must be found instead of the concentrations that are found in slightly soluble solutions.
- **Common Ion Effect:** The solubility of the reaction is reduced by the common ion. For a given equilibrium, a reaction with a common ion present has a lower Ksp, and the reaction without the ion has a greater Ksp.
- **Salt Effect (diverse ion effect):** Having an opposing effect on the Ksp value compared to the common ion effect, uncommon ions increase the Ksp value. Uncommon ions are ions other than those involved in equilibrium.
- **Ion Pairs:** With an ionic pair (a cation and an anion), the Ksp value calculated is less than the experimental value due to ions involved in pairing. To reach the calculated Ksp value, more solute must be added.

Week 5

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 90 minutes (45 minutes per period)

Topic : Industrial Application of Chemical Equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Explain the industrial uses of chemical equilibrium using (i) Haber process for the production of ammonia and (ii) contact process for the manufacture of tetraoxosulphate(IV) acid.

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, Silver Chromate, Magnesium fluoride.

Entry behaviour: Students can differentiate between Kc and Kp.

Revision of previous lesson: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Teacher asks students to construct a concept map on the topic with the following words; industrial application of chemical equilibrium, contact process, Haber process, ammonia production, tetraoxosulphate(VI) acid.

Students' Activities: Listen to teacher and construct their concept map on the topic with their alternative conceptions.

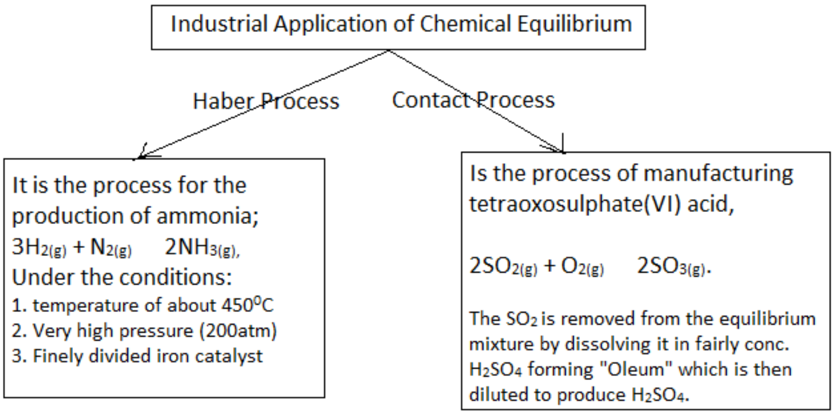
Step 3

Teacher Activities: Teacher evaluates students' concept maps and identifies students' misconceptions on the topic.

Students' Activities: Pay attention to the teacher.

Step 4

Teacher Activities: Teacher presents students with a concept map on the topic that aligns with the scientific explanation to clear students' misconceptions on the topic.



It is the process for the production of ammonia;
$3H_{2(g)} + N_{2(g)} \quad 2NH_{3(g)}$,
Under the conditions:
1. temperature of about 450°C
2. Very high pressure (200atm)
3. Finely divided iron catalyst

Is the process of manufacturing tetraoxosulphate(VI) acid,

$2SO_{2(g)} + O_{2(g)} \quad 2SO_{3(g)}$.

The SO_2 is removed from the equilibrium mixture by dissolving it in fairly conc. H_2SO_4 forming "Oleum" which is then diluted to produce H_2SO_4.

Students' Activities: Students observe and listen to teacher's explanation.

Chalkboard Summary

Industrial Applications of Chemical Equilibrium

In industrial processes involving reversible reactions, the concept of chemical equilibrium and Le Chatelier's principle are applied to decide on the optimum conditions of operation. The way this is achieved in practice is described briefly for two important industrial processes- the Haber process for the production of ammonia and the contact process for the manufacture of tetraoxosulphate(VI) acid. These conditions are chosen by industrial chemists with the aim of obtaining the maximum yield of the product at minimum cost by ensuring that:

(i) The starting materials are cheap

(ii) The capital cost of the plant is not too high

(iii) The shortest possible time is taken to reach equilibrium

(iv) The equilibrium position shift in the desired direction

(v) The value of the equilibrium constant, for the concerned process is increased.

The Haber process

Haber's process uses the reaction;

$3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$ $\Delta H = -46.1KJ\ mol^{-1}$

3moles 1moles 2moles

From the equation, 3 moles of hydrogen gas react with 1 mole of nitrogen gas to yield 2 moles of ammonia. The forward reaction is exothermic, while, the backward reaction is endothermic.

Since the forward reaction is exothermic, decreasing the temperature will give a high yield of ammonia. Thus, the temperature of the system is kept at 450^0C. A lower temperature of about 250^0C will give better yield of ammonia, but is not economically feasible, as it will take too long for the reaction system to attain equilibrium. Thus, a catalyst which speeds up the reaction rate and enable equilibrium to be attained in a shorter time, in spite of a relatively low temperature is introduced.

The forward reaction results in a decrease in the pressure of the system. According to Le Chatelier's principle, if the pressure of the system is increased by supplying more of the gaseous reactants in the right proportion, the equilibrium position will shift to favour the forward reaction. The Habor process is always operated at very high pressure of about 200 atm in order to get high yields of ammonia. A higher pressure such as 1000 atm would give a higher yield. However, it would be extremely costly to build production plants that would be strong enough to withstand such a high pressure.

The ammonia produced is absorbed in water or liquefied by refrigeration and the unused gases recycled. The conditions chosen in accordance with the above discussion are:

(i) Temperature of bout 450^0C

(ii) Very high pressure of about 200 atm

(iii) Catalyst-finely divided iron

Contact process

The first step in the contact process is the conversion of sulphur(IV) oxide to sulphur(VI) oxide according to the reaction

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} \quad \Delta H = -395.7KJ\ mol^{-1}$$

2moles 1mole 2moles

Since the reaction is exothermic, a low temperature will favour the forward reaction. In practice, however, a temperature of 450^0C – 500^0C and a catalyst are used. These conditions increase the reaction rate and enable equilibrium to be reached in a short time.

The production of sulphur(VI) oxide is accompanied by a reduction in pressure. According to Le Chatelier's principle, increasing the pressure of the system will favour forward reaction. In practice, atmospheric pressure is sufficient to give a high yield of sulphur(IV) oxide. An increase in the concentration of one of the reactants (i.e. oxygen) shifts the equilibrium position to the right and favours product formation.

The sulphur(VI) oxide is removed from the equilibrium mixture by dissolving it in fairly concentrated tetraoxosulphate(VI) acid forming "Oleum" which is then diluted to produce tetraoxosulphate(VI) acid of the required concentration. The conditions are:

(i) Temperature of about 450^0C – 500^0C

(ii) Pressure of about 1 atm

(iii) Catalyst- Vanadium(V) oxide, V_2O_2.

Lesson 6

Subject	: Chemistry
Class	: SSII
Age	: 15+
Duration	: 90 minutes (45 minutes per period)
Topic	: Heat content and heat of reaction, exothermic and endothermic reactions

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Define energy, enthalpy change.
2. Differentiate between exothermic and endothermic reactions using examples
3. Draw an energy profile diagram of exothermic and endothermic reactions.

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, charts of energy profile diagram calcium oxide, water, trioxochlorate(V).

Entry behaviour: Students can establish the order of a given reaction.

Revision of previous lesson: The teacher revises the previews lesson by asking students to:

1. Explain Haber process.
2. Name the end product of contact process

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Teacher asks students to construct a concept map on the topic with the following words; energy, enthalpy, exothermic reaction, endothermic reaction, energy profile diagram.

Students' Activities: Listen to teacher and construct their concept map on the topic with their alternative conceptions.

Step 3

Teacher Activities: Teacher evaluates students' concept maps and identifies students' misconceptions on the topic.

Students' Activities: Pay attention to the teacher.

Step 4

Teacher Activities: Teacher presents students with a concept map on the topic that aligns with the scientific explanation to clear students' misconceptions on the topic.

Energy: Is the ability to do work

Kinetic energy

Kinetic energy is the energy of substance as a result of the motion of the particles of that substance

Heat content (Enthalpy)

The heat content of a substance is the characteristic internal energy possessed by the substance, which is due to its structure and physical state.

Enthalpy change = heat content of products – heat content of reactants

$\Delta H = H_p - H_r$

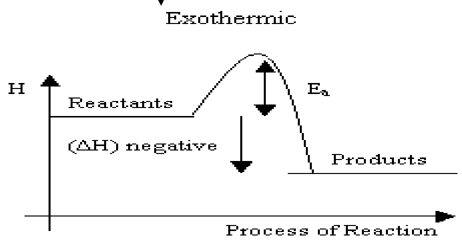
Potential energy

Is the energy stored within a substance as a result of the position of the particles contained in the substance

Exothermic reaction

A chemical reaction in which heat is given off to the surroundings

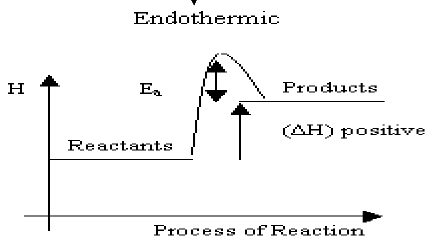
Energy profile diagram



Endothermic reaction

A chemical reaction in which heat is absorbed from the surroundings

Energy profile diagram



Students' Activities: Students observe and listen to teacher's explanation.

Chalkboard Summary

Energy and Chemical Reactions

Energy is the ability to do work. All matter possesses energy in one form or another. Some substances have energy as a result of the particles in motion. Such energy is known as **kinetic energy.** Other substances have energy stored within them as a result of the position of the particles contained in them. This stored energy is known as **potential energy.**

The various forms of energy are interconvertible, e.g. an electric bulb converts electrical energy to heat energy and light energy. When energy changes from one form to another, the total amount of energy before and after the change is always the same i.e. energy cannot be created or destroyed; it simple changes from one form to another. This is the law of conservation of energy. The study of energy changes is known as **energetic.**

Energy changes occur in chemical reactions, as the reactants change to products. This is because the reactants and products of a given chemical reaction possess different amount of chemical energy. The commonest form of energy change in chemical reactions is the heat change. Each mole of as substance has a characteristic heat content.

Heat content and heat of reaction

The heat content (enthalpy) of a substance is the characteristic internal energy possessed by the substance, which is due to its structure and physical state. Generally, an enthalpy change is the heat that would be exchanged with the surroundings, if the temperature and pressure of the system were the same before and after the reaction, i.e enthalpy change (heat of reaction) = heat content of products – heat content of reactants. Therefore, heat of reaction is the amount of heat absorbed or evolved when a chemical reaction occurs between molar quantities of the substances as represented in the equation of reaction under standard conditions.

Exothermic and endothermic reactions

In the course of any chemical reaction, energy in form of heat is either given out or taken in from the surroundings, depending on the heat content of the reactants and products. A chemical reaction in which heat is given off to the surroundings is known as **exothermic reaction,** while that in which heat is absorbed from the surroundings is known as **endothermic reaction.**

The terms exothermic and endothermic apply not only to chemical changes, but also to physical changes. Some examples of exothermic and endothermic reactions are as follows:

Exothermic reactions

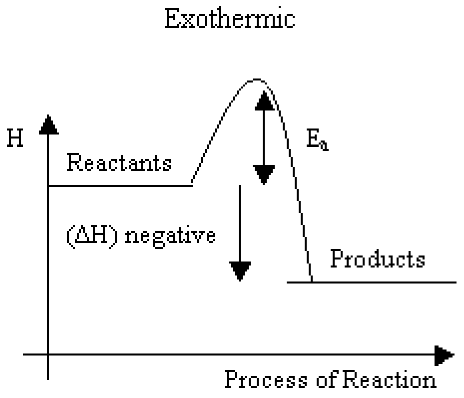
1. Reaction between calcium oxide and water, $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_2$
2. Reaction between an acid and base, $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

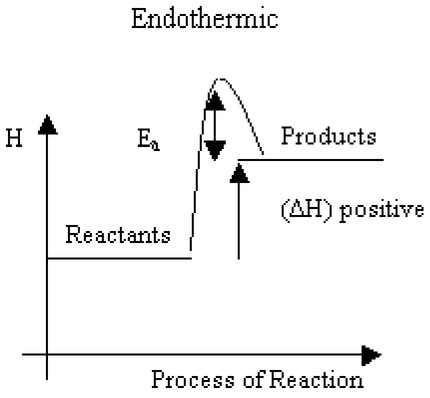
Endothermic reactions

1. Thermal decomposition of potassium trioxoxchlorate(V), $2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$.
2. Thermal dissociation of ammonium chloride, $NH_4Cl_{(s)} \longrightarrow NH_{3(g)} + HCl_{(g)}$

ΔH Notation: The term enthalpy is simple the heat content of a chemical reaction. It is represented by the letter, H. The heat content of the reactant is represented as Hr, while the heat content of the product is represented as Hp. The difference between the heat content of the product and reactant is known as the **enthalpy change,** or heat of reaction and is represented by the symbol, ΔH**.** Therefore, $\Delta H = Hp - Hr$.

ΔH is negative for an exothermic reaction, since the products have a smaller heat content than the reactants; while it is positive for an endothermic reaction, since the heat content of the product is more than that of the reactant.





Heat change during chemical reaction

Units of heat change: The basic unit for measuring heat change is the kilocalorie (Kcal) which is defined as the amount of heat needed to raise the temperature of one kilogram of water by 1^{o}C. 1 Kilocalorie = 1000 calories

Since heat is a form of energy and with the introduction of the S.I units of measurement, the calorie has been replaced by the Joule as the international unit of energy, 1 calorie = 4.2 joules. Hence, 4.2J of heat is required to raise the temperature of 1.0g of water by 1K or 1^{o}C. Therefore, one joule is the energy required to raise the temperature of 1.0g of water by 0.239K.

IKJ = 1000J.

Appendix X

Lecture Method Lesson Plan

Week 1

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 90 minutes (45 minutes per period)

Topic : Chemical equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Define chemical equilibrium.
2. Differentiate between reversible and irreversible reactions.
3. State Le Chatelier’s principle

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, silver nitrate, nitrogen, hydrogen, water.

Entry behaviour: Students have been taught enthalpy change.

Revision of previous lesson: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Explain the concept of chemical equilibrium, reversible reaction and Le Chatelier’s principle.

Students’ Activities: Listen to teacher and write down important points.

Step 3

Teacher Activities: Teacher evaluates the lesson as follows:

1. Define chemical equilibrium
2. Write a balanced reversible reaction
3. State Le Chatelier's principle

Students' Activities: Attempt to answer questions.

Step 4

Teacher Activities: Teacher summarizes the lesson and gives students note to copy.

Students' Activities: Students listen to teacher and write down note.

Step 5

Teacher Activities: Teacher asks students to read up factors affecting equilibrium.

Students' Activities: Write down assignment.

Chalkboard Summary

Meaning of Chemical Equilibrium

Chemical equilibrium can be defined as the state where there is no observable change in the "properties" of a system with respect to time. For example, in saturated potassium trioxoni-trate(V) solution, there is no observable change in the properties of the system, because the salt dissolves in water until some salt is left undissolved in the solution. In this system, at any given moment, undissolved salt particle are dissolving, while the same number of dissolved salt particles are precipitating. Here two opposing processes- dissolution and precipitating are taking place at the same rate. As a result, the net number of dissolved particles in the solution remains the same.

$KNO_{3(s)} \rightleftharpoons KNO_{3(aq)}$

Equilibrium systems may be static or dynamic. An example of static equilibrium is the balanced see-saw because it is stationary, while the saturated solution is an example of dynamic equilibrium; since the salt particles are dissolving and precipitating at the same rate, i.e. there is constant motion in the system.

In a chemical equilibrium, the reactants undergo a change in composition to form the products, which in turn, are reconverted to the original reactants at the same rate.

Equilibrium in Reversible Reactions

A reversible reaction is one which can be made to proceed in either direction under suitable conditions. Reversible reaction is denoted by the symbol $\rightleftharpoons$ between the reactants and products. E.g.

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

All reversible reactions can proceed in either direction, depending on the condition of the reactions. In some cases, both forward and backward reactions operate under the same conditions, while in others they operate under different conditions, e.g. the reaction between iron and steam is reversible under the same conditions, since red heat is needed for the forward and backward reactions.

$3Fe_{(s)} + 4H_2O_{(g)} \rightleftharpoons Fe_3O_{4(s)} + 4H_{2(g)}$

However, when crystalline salt of ammonium chloride is heated strongly, it sublimes and dissociates into ammonia and hydrogen chloride gases. These two gaseous products readily recombine to form solid ammonium chloride again when cooled. In this case, the forward reaction takes place, when heat is supplied, while the backward reaction occurs in the cold.

$NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$

Le Chatelier' Principle

Le Chatelier's principle states that if a chemical system is in equilibrium and one of the factors involved in the equilibrium is altered, the equilibrium will shift, so as to neutralize the effect of the change. The principle is of the view that whenever a system in equilibrium is affected by increase or decrease in one of the factors keeping the system in equilibrium, the other factors will change their value so as to restore the equilibrium.

Week 2

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 90 minutes (45 minutes per period)

Topic : Factors affect equilibrium position

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Mention the factors affecting equilibrium.
2. Explain the effect of concentration on equilibrium.
3. How does temperature change affect equilibrium

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, silver nitrate, nitrogen, hydrogen, water.

Entry behaviour: Students can define chemical equilibrium and state Le Chatelier's principle.

Revision of previous lesson: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Enumerates factors affecting equilibrium and explain the effect of each of the factors.

Students' Activities: Listen to teacher and write down important points.

Step 3

Teacher Activities: Teacher evaluates the lesson as follows:

1. Mention the factors affecting equilibrium.
2. Explain the effect of concentration on equilibrium.
3. How does temperature change affect equilibrium

Students' Activities: Attempt to answer questions.

Step 4

Teacher Activities: Teacher summarizes the lesson and gives students note to copy.

Students' Activities: Students listen to teacher and write down note.

Step 5

Teacher Activities: Teacher asks students to read up calculations on equilibrium constant (Kc and Kp).

Students' Activities: Write down assignment.

Chalkboard Summary

Factors Affecting Equilibrium

The factors affecting equilibrium position are temperature, concentration and pressure of the reactants and products. Catalyst does not change the position of equilibrium, but it affects the reaction equally in both directions, so the net effect is that the same equilibrium is reached whether the catalyst is present or not. It speed up the rate at which equilibrium is attained.

Effects of temperature changes on equilibrium mixture

If a chemical system is in equilibrium and the temperature is lowered, according to Le Chatelier's principle, the equilibrium position will shift so as to neutralize the cooling effect by releasing more heat. Conversely, if the temperature is raised, the equilibrium position will shift so as to neutralize the heating effect by absorbing more heat.

A common example of the effect of temperature on the position of equilibrium is the equilibrium between water and steam, $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$. Here, the forward reaction is accompanied by an absorption of heat, i.e. it is an endothermic reaction. Thus, if the temperature of the system is raised, this will tend to produce more steam, then the equilibrium position will shift to the right, whereas if the temperature is lowered, more water will be formed, then the equilibrium position will shift to the left and the steam condenses. You will observe that the condensation of steam is an exothermic process which is why a steam scald is usually worse than the one caused by water.

Generally, according to Le Chatelier's principle, the forward reaction in an exothermic system is favoured by lowering the temperature, while the forward reaction of an endothermic system is favoured by raising the temperature.

Effect of pressure change on equilibrium mixture

The effects of pressure changes are much more noticeable in reversible reactions; (i) occurring in the gaseous state than those occurring between solids and liquids. (ii) in which the total number of moles of gaseous molecules on the left side of the equation differs from that on the right side of the equation.

Consider the gas phase reaction involving the formation of ammonia from nitrogen and hydrogen

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$
4moles or volumes 2moles or volumes

Here, 4 moles of reactants give only 2 moles of the products. The forward reaction results in a decrease in the number of moles and hence, a decrease in the pressure of the system. The backward reaction results in an increase in the number of moles. Hence, there is an increase in the pressure of the system.

Le Chatelier's principle demands that if a high pressure is applied to an equilibrium system, the reaction which involves a reduction in pressure will be favoured. Conversely, if low pressure is imposed on an equilibrium system, then the reaction which results in an increase in pressure will be favoured.

Effect of concentration change on equilibrium change on equilibrium mixture

If the concentration of one of the substances present in an equilibrium system is changed without a change in any other conditions, then, by Le Chatelier's principle, the position of equilibrium will move to decrease the concentration of the added substance. Thus the reaction

$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

If more reactants (N_2 and O_2) are introduced into the equilibrium system, the balance will be upset. In order to relieve this constraint (i.e. the increase in the concentration of the reactant), the equilibrium position will shift to the right, favouring the forward reaction. This results in a proportional increase in the concentration of the products, and so the equilibrium constant remains unchanged. In a similar way, if the product formed is continually removed from the system, the equilibrium position will change (i.e. shift to the right) to produce more of the product, thus, neutralizing the constants. This is again in accordance with Le Chatelier's principle.

In the reversible reaction of Iron with steam; $3Fe_{(s)} + 4H_2O_{(g)} \rightleftharpoons Fe_3O_{4(s)} + 4H_{2(g)}$, the hydrogen is constantly removed by a current of steam that passes over the heat iron until all the iron is converted to tri Iron tetraoxide. The reverse process occurs if water vapour is removed.

Week 3

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 90 minutes (45 minutes per period)

Topic : Equilibrium constant

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Write the equilibrium constant of chemical equations
2. Perform calculations using equilibrium constant

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, silver nitrate, nitrogen, hydrogen, water.

Entry behaviour: Students can mention 3 factors affect equilibrium position.

Revision of previous lesson: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Derived equilibrium constant and solved problems using equilibrium constant.

Students' Activities: Listen to teacher and write down important points.

Step 3

Teacher Activities: Teacher evaluates the lesson as follows:

1. Write the equilibrium constant of; $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

2. When one mole of each of ethanoic acid and ethanol are heated together at a constant temperature of 25^0C until equilibrium has been reached, titration of the reaction mixture with standard alkali shows that two thirds of the acid have been used up. Calculate the equilibrium constant for the reaction.

Students' Activities: Attempt to answer questions.

Step 4

Teacher Activities: Teacher summarizes the lesson and gives students note to copy.

Students' Activities: Students listen to teacher and write down note.

Step 5

Teacher Activities: Teacher asks students to read up solubility product constant (Ksp).

Students' Activities: Write down assignment.

Chalkboard Summary

Equilibrium Constant

The equilibrium constant, K, may be derived by the use of **law of mass action.** This law by Guldberg and Waage states that at constant temperature, the rate of a chemical reaction is directly proportional to the active mass of the reacting substances.

For most practical purposes, the active mass may be taken as the molar concentration, expressed in mol^{-1}. Equilibrium constant is a measure of the ratio of the equilibrium concentration of the products of a reaction, to the equilibrium concentration of the reactants; with each concentration raised to the power balanced equation of the reaction. In the general reaction $aA + bB \rightleftharpoons cC + dD$, the equilibrium constant (k) is written as

$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Where [ ] stands for equilibrium concentration. If the reaction involves solids, liquids or solutions, the equilibrium constant is denoted by K_c, the suffix c indicating concentration in moles/dm^3; but for gaseous reactions, Kp is used, the suffix p indicating that the concentrations are in terms of partial pressure.

A positive Kc value tells you that the products are favoured at equilibrium, while, a negative Kc value tells you that the reactants are favoured at equilibrium. The Kc value for any reaction is constant only if the temperature remains constant.

Calculation based on equilibrium constant, K

1. The following results were obtained during the analysis of a reaction

   $CO_{2(s)} + H_{2(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$, $[CO_2] = 0.75M$, $[H_2] = 0.32M$, $[H_2O] = 0.30M$, $[CO] = 0.55M$.

   Calculate the equilibrium constant for the reaction

   Solution

   $K = \frac{[H2O][CO]}{[H2][CO2]} = \frac{0.30 \, x \, 0.55}{0.32 \, x \, 0.75} = 0.688.$

2. Calculate (a) the equilibrium constant (Kp) for the reaction at 45^{o}C (b) the equilibrium constant (Kp) for the backward reaction

   $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$. Given that the partial pressures of the following substances at 45^{0}C are $[H_2] = 0.065$atm, $[I_2] = 0.45$ atm, $[HI] = 0.245$ atm.

   The backward reaction, the ammonium ion donates as proton to the hydroxide ion.

   Solution

a. $K = \frac{[HI]2}{[H2][I2]} = \frac{[0.245]2}{[0.065][0.45]} = 2.05$

b. $K = \frac{1}{Kp} = \frac{1}{2.05} = 0.49.$

Week 4

Subject	: Chemistry
Class	: SSII
Age	: 15+
Duration	: 90 minutes (45 minutes per period)
Topic	: Solubility Product Constant

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Explain solubility product constant (Ksp)
2. Deduce the solubility product constant of some common compounds
3. Explain some common effect affecting solubility product constant (Ksp)

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, Silver Chromate, Magnesium fluoride.

Entry behaviour: Students can differentiate between Kc and Kp.

Revision of previous lesson and attendance: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Explain solubility product constant and derived it with examples.

Students' Activities: Listen to teacher and write down important points.

Step 3

Teacher Activities: Teacher evaluates the lesson as follows:

1. What is the solubility product constant expression for Ag_2CrO_4?

Students' Activities: Attempt to answer questions.

Step 4

Teacher Activities: Teacher summarizes the lesson and gives students note to copy.

Students' Activities: Students listen to teacher and write down note.

Step 5

Teacher Activities: Teacher asks students to read up industrial application of chemical equilibrium.

Students' Activities: Write down assignment.

Chalkboard Summary

Solubility Product Constant

The solubility product constant, Ksp**,** is the equilibrium constant for a solid substance dissolving in an aqueous solution. It represents the level at which a solute dissolves in solution. The more soluble a substance is, the higher the Ksp value it has.

Consider the general dissolution reaction below (in aqueous solutions):

$$aA_{(s)} \rightleftharpoons cC_{(aq)} + dD_{(aq)} \qquad (1)$$

To solve for the Ksp it is necessary to take the molarities or concentrations of the products (cC and dD) and multiply them. If there are coefficients in front of any of the products, it is necessary to raise the product to that coefficient power (and also multiply the concentration by that coefficient). This is shown below:

$$Ksp = [C]^c\,[D]^d \qquad (2)$$

Note that the reactant, aA, is not included in the Ksp equation. Solids are not included when calculating equilibrium constant expressions, because their concentrations do not change the expression; any change in their concentrations are insignificant, and therefore omitted. Hence, Ksp represents the maximum extent that a solid that can dissolved in solution.

Example: What is the solubility product constant expression for MgF_2?

Solution

The relevant equilibrium is $MgF_{2(s)} \rightleftharpoons Mg^{2+}_{(aq)} + 2F^{-}_{(aq)}$

So the association equilibrium constant is

$Ksp = [Mg^{2+}][F^{-}]^2$

Important Effects

- For highly soluble ionic compounds the ionic activities must be found instead of the concentrations that are found in slightly soluble solutions.
- **Common Ion Effect:** The solubility of the reaction is reduced by the common ion. For a given equilibrium, a reaction with a common ion present has a lower Ksp, and the reaction without the ion has a greater Ksp.
- **Salt Effect (diverse ion effect):** Having an opposing effect on the Ksp value compared to the common ion effect, uncommon ions increase the Ksp value. Uncommon ions are ions other than those involved in equilibrium.
- **Ion Pairs:** With an ionic pair (a cation and an anion), the Ksp value calculated is less than the experimental value due to ions involved in pairing. To reach the calculated Ksp value, more solute must be added.

Week 5

Subject	: Chemistry
Class	: SSII
Age	: 15+
Duration	: 90 minutes (45 minutes per period)
Topic	: Industrial Application of Chemical Equilibrium

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Explain the industrial uses of chemical equilibrium using (i) Haber process for the production of ammonia and (ii) contact process for the manufacture of tetraoxosulphate(IV) acid.

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, Silver Chromate, Magnesium fluoride.

Entry behaviour: Students can differentiate between Kc and Kp.

Revision of previous lesson: The teacher presents a brief summary of the last lesson

Instructional Procedure

Step 1

Teacher Activities: Teacher greets students and introduces the topic.

Student Activities: Respond to teachers greeting

Step 2

Teacher Activities: Explain the industrial applications of chemical equilibrium using the Haber and contact processes.

Students' Activities: Listen to teacher and write down important points.

Step 3

Teacher Activities: Teacher evaluates the lesson as follows:

1. How is chemical equilibrium useful in the Haber and contact process?

Students' Activities: Attempt to answer questions.

Step 4

Teacher Activities: Teacher summarizes the lesson and gives students note to copy.

Students' Activities: Students listen to teacher and write down note.

Step 5

Teacher Activities: Teacher asks students to read up heat content and heat of reaction, exothermic and endothermic reactions.

Students' Activities: Write down assignment.

Chalkboard Summary

Industrial Applications of Chemical Equilibrium

In industrial processes involving reversible reactions, the concept of chemical equilibrium and Le Chatelier's principle are applied to decide on the optimum conditions of operation. The way this is achieved in practice is described briefly for two important industrial processes- the Haber process for the production of ammonia and the contact process for the manufacture of tetraoxosulphate(VI) acid. These conditions are chosen by industrial chemists with the aim of obtaining the maximum yield of the product at minimum cost by ensuring that:

(i) The starting materials are cheap
(ii) The capital cost of the plant is not too high
(iii) The shortest possible time is taken to reach equilibrium
(iv) The equilibrium position shift in the desired direction
(v) The value of the equilibrium constant, for the concerned process is increased.

The Haber process

Haber's process uses the reaction;

$3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$ $\Delta H = -46.1KJ\ mol^{-1}$

3moles 1moles 2moles

From the equation, 3 moles of hydrogen gas react with 1 mole of nitrogen gas to yield 2 moles of ammonia. The forward reaction is exothermic, while, the backward reaction is endothermic.

Since the forward reaction is exothermic, decreasing the temperature will give a high yield of ammonia. Thus, the temperature of the system is kept at 450^0C. A lower temperature of about 250^0C will give better yield of ammonia, but is not economically feasible, as it will take too long for the reaction system to attain equilibrium. Thus, a catalyst which speeds up the reaction rate and enable equilibrium to be attained in a shorter time, in spite of a relatively low temperature is introduced.

The forward reaction results in a decrease in the pressure of the system. According to Le Chatelier's principle, if the pressure of the system is increased by supplying more of the gaseous reactants in the right proportion, the equilibrium position will shift to favour the forward reaction. The Habor process is always operated at very high pressure of about 200 atm in order to get high yields of ammonia. A higher pressure such as 1000 atm would give a higher yield. However, it would be extremely costly to build production plants that would be strong enough to withstand such a high pressure.

The ammonia produced is absorbed in water or liquefied by refrigeration and the unused gases recycled. The conditions chosen in accordance with the above discussion are:

(i) Temperature of bout 450^0C

(ii) Very high pressure of about 200 atm

(iii) Catalyst-finely divided iron

Contact process

The first step in the contact process is the conversion of sulphur(IV) oxide to sulphur(VI) oxide according to the reaction

$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ $\Delta H = -395.7KJ\ mol^{-1}$

2moles 1mole 2moles

Since the reaction is exothermic, a low temperature will favour the forward reaction. In practice, however, a temperature of $450^0C - 500^0C$ and a catalyst are used. These conditions increase the reaction rate and enable equilibrium to be reached in a short time.

The production of sulphur(VI) oxide is accompanied by a reduction in pressure. According to Le Chatelier's principle, increasing the pressure of the system will favour forward reaction. In practice, atmospheric pressure is sufficient to give a high yield of sulphur(IV) oxide. An increase in the concentration of one of the reactants (i.e. oxygen) shifts the equilibrium position to the right and favours product formation.

The sulphur(VI) oxide is removed from the equilibrium mixture by dissolving it in fairly concentrated tetraoxosulphate(VI) acid forming "Oleum" which is then diluted to produce tetraoxosulphate(VI) acid of the required concentration. The conditions are:

(i) Temperature of about $450^0C - 500^0C$

(ii) Pressure of about 1 atm

(iii) Catalyst- Vanadium(V) oxide, V_2O_2.

Lesson 6

Subject : Chemistry

Class : SSII

Age : 15+

Duration : 90 minutes (45 minutes per period)

Topic : Heat content and heat of reaction, exothermic and endothermic reactions

Behavioural Objectives: At the end of the lesson, all the students should be able to:

1. Define energy, enthalpy change.
2. Differentiate between exothermic and endothermic reactions using examples
3. Draw an energy profile diagram of exothermic and endothermic reactions.

Instructional materials: Essential Chemistry for senior secondary schools by Odesina, charts of energy profile diagram calcium oxide, water, trioxochlorate(V).

Entry behaviour: Students can establish the order of a given reaction.

Revision of previous lesson and attendance: The teacher reviews the previews lesson by asking the following questions:

1. Explain Haber process.
2. Name the end product of contact process

Instructional Procedure

Step 1

Teacher Activities: Teacher greets and introduces the lesson.

Student Activities: Students respond to teachers greetings

Step 2

Teacher Activities: Explain in detail the characteristics of catalyst and order of a reaction.

Students' Activities: Listen to teacher and write down important points.

Step 3

Teacher Activities: Teacher asks the following questions to be answered by each group:

1. Define energy, enthalpy change.
2. Differentiate between exothermic and endothermic reactions using examples
3. Draw an energy profile diagram of exothermic and endothermic reactions

Students' Activities: Attempt to answer questions.

Step 4

Teacher Activities: Teacher summarizes the lesson and gives students note to copy.

Students' Activities: Students listen to teacher and write down note.

Step 5

Teacher Activities: Teacher asks students to read up: standard condition for energy changes, types of heat change in chemical reaction.

Chalkboard Summary

Energy and Chemical Reactions

Energy is the ability to do work. All matter possesses energy in one form or another. Some substances have energy as a result of the particles in motion. Such energy is known as **kinetic energy.** Other substances have energy stored within them as a result of the position of the particles contained in them. This stored energy is known as **potential energy.**

The various forms of energy are interconvertible, e.g. an electric bulb converts electrical energy to heat energy and light energy. When energy changes from one form to another, the total amount of energy before and after the change is always the same i.e. energy cannot be created or destroyed; it simple changes from one form to another. This is the law of conservation of energy. The study of energy changes is known as **energetic.**

Energy changes occur in chemical reactions, as the reactants change to products. This is because the reactants and products of a given chemical reaction possess different amount of chemical energy. The commonest form of energy change in chemical reactions is the heat change. Each mole of as substance has a characteristic heat content.

Heat content and heat of reaction

The heat content (enthalpy) of a substance is the characteristic internal energy possessed by the substance, which is due to its structure and physical state. Generally, an enthalpy change is the heat that would be exchanged with the surroundings, if the temperature and pressure of the system were the same before and after the reaction, i.e enthalpy change (heat of reaction) = heat content of products – heat content of reactants. Therefore, heat of reaction is the amount of heat absorbed or evolved when a chemical reaction occurs between molar quantities of the substances as represented in the equation of reaction under standard conditions.

Exothermic and endothermic reactions

In the course of any chemical reaction, energy in form of heat is either given out or taken in from the surroundings, depending on the heat content of the reactants and products. A chemical reaction in which heat is given off to the surroundings is known as **exothermic reaction,** while that in which heat is absorbed from the surroundings is known as **endothermic reaction.**

The terms exothermic and endothermic apply not only to chemical changes, but also to physical changes. Some examples of exothermic and endothermic reactions are as follows:

Exothermic reactions

a. Reaction between calcium oxide and water, $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_2$

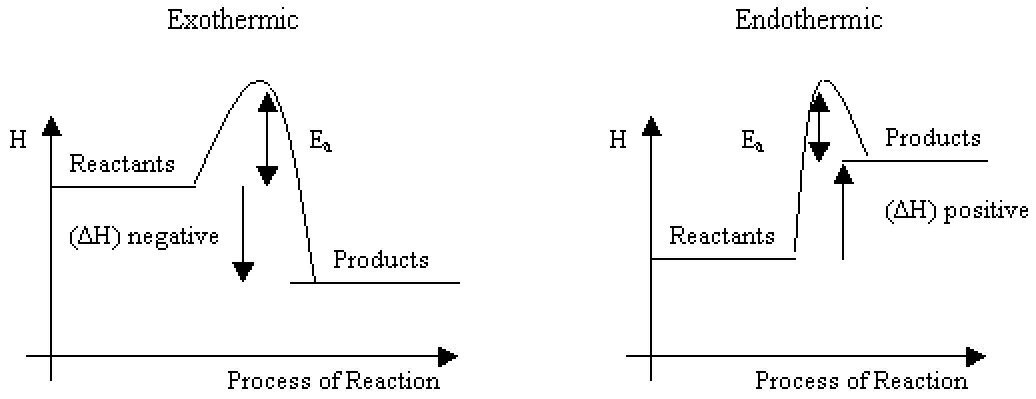
b. Reaction between an acid and base, $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

Endothermic reactions

1. Thermal decomposition of potassium trioxoxchlorate(V), $2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$.
2. Thermal dissociation of ammonium chloride, $NH_4Cl_{(s)} \longrightarrow NH_{3(g)} + HCl_{(g)}$

ΔH Notation: The term enthalpy is simple the heat content of a chemical reaction. It is represented by the letter, H. the heat content of the reactant is represented as Hr, while the heat content of the product is represented as Hp. The difference between the heat content of the product and reactant is known as the **enthalpy change,** or heat of reaction and is represented by the symbol, ΔH**.** Therefore, $\Delta H = Hp - Hr$.

ΔH is negative for an exothermic reaction, since the products have a smaller heat content than the reactants; while it is positive for an endothermic reaction, since the heat content of the product is more than that of the reactant.



Exothermic

Endothermic

Heat change during chemical reaction

Units of heat change: The basic unit for measuring heat change is the kilocalorie (Kcal) which is defined as the amount of heat needed to raise the temperature of one kilogram of water by $1^{o}C$. 1 Kilocalorie = 1000 calories

Since heat is a form of energy and with the introduction of the S.I units of measurement, the calorie has been replaced by the Joule as the international unit of energy, 1 calorie = 4.2 joules. Hence, 4.2J of heat is required to raise the temperature of 1.0g of water by 1K or 1^oC. Therefore, one joule is the energy required to raise the temperature of 1.0g of water by 0.239K.

IKJ = 1000J.

Appendix XI

Analysis Output

Research Question 1 and Hypothesis 1

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Misconception posttest scores of students in conceptual change text group	60.06	108	13.571	1.306
	Misconception pretest scores of students in conceptual change text group	16.08	108	5.554	.534
Pair 2	Misconception posttest scores of students in concept mapping group	56.72	92	12.241	1.276
	Misconception pretest scores of students in concept mapping group	16.51	92	5.758	.600
Pair 3	Misconception posttest scores of students in lecture method group	50.77	128	12.756	1.127
	Misconception pretest scores of students in lecture method group	16.75	128	5.708	.505

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Misconception posttest scores of students in conceptual change text group - Misconception pretest scores of students in conceptual change text group	43.972	14.593	1.404	41.189	46.756	31.315	107	.000
Pair 2	Misconception posttest scores of students in concept mapping group - Misconception pretest scores of students in concept mapping group	40.207	13.808	1.440	37.347	43.066	27.930	91	.000
Pair 3	Misconception posttest scores of students in lecture method group - Misconception pretest scores of students in lecture method group	34.016	14.308	1.265	31.513	36.518	26.898	127	.000

Research Question 2 and Hypothesis 2

Oneway

Descriptives

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Misconception pretest scores	Conceptual change texts	108	16.08	5.554	.534	15.02	17.14	7	27
	Concept mapping	92	16.51	5.758	.600	15.32	17.70	7	27
	Lecture	128	16.75	5.708	.505	15.75	17.75	7	27
	Total	328	16.46	5.662	.313	15.85	17.08	7	27
Misconception posttest scores	Conceptual change texts	108	60.06	13.571	1.306	57.47	62.64	40	90
	Concept mapping	92	56.72	12.241	1.276	54.18	59.25	38	90
	Lecture	128	50.77	12.756	1.127	48.53	53.00	4	82
	Total	328	55.49	13.461	.743	54.03	56.96	4	90

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Misconception pretest scores	Between Groups	26.322	2	13.161	.409	.665
	Within Groups	10455.239	325	32.170		
	Total	10481.561	327			
Misconception posttest scores	Between Groups	5246.700	2	2623.350	15.786	.000
	Within Groups	54009.288	325	166.182		
	Total	59255.988	327			

Post Hoc Tests

Multiple Comparisons

Scheffe

						95% Confidence Interval	
Dependent Variable	(I) Teaching methods	(J) Teaching methods	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Misconception pretest scores	Conceptual change texts	Concept mapping	-.428	.805	.868	-2.41	1.55
		Lecture	-.667	.741	.668	-2.49	1.16
	Concept mapping	Conceptual change texts	.428	.805	.868	-1.55	2.41
		Lecture	-.239	.775	.954	-2.15	1.67
	Lecture	Conceptual change texts	.667	.741	.668	-1.16	2.49
		Concept mapping	.239	.775	.954	-1.67	2.15
Misconception posttest scores	Conceptual change texts	Concept mapping	3.338	1.829	.191	-1.16	7.84
		Lecture	9.290*	1.684	.000	5.15	13.43
	Concept mapping	Conceptual change texts	-3.338	1.829	.191	-7.84	1.16

		Lecture	5.952*	1.762	.004	1.62	10.28
	Lecture	Conceptual change texts	-9.290*	1.684	.000	-13.43	-5.15
		Concept mapping	-5.952*	1.762	.004	-10.28	-1.62

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Misconception pretest scores

Scheffe[a,b]

Teaching methods	N	Subset for alpha = 0.05 1
Conceptual change texts	108	16.08
Concept mapping	92	16.51
Lecture	128	16.75
Sig.		.690

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 107.368.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Misconception posttest scores

Scheffe[a,b]

		Subset for alpha = 0.05	
Teaching methods	N	1	2
Lecture	128	50.77	
Concept mapping	92		56.72
Conceptual change texts	108		60.06
Sig.		1.000	.167

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 107.368.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Research Question 3 and Hypothesis 3

T-Test

Group Statistics

	Male and female students in conceptual change texts group	N	Mean	Std. Deviation	Std. Error Mean
Misconception scores in conceptual change texts group	1	74	59.95	13.677	1.590
	2	34	60.29	13.539	2.322

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Misconception scores in conceptual change texts group	Equal variances assumed	.008	.931	-.123	106	.902	-.348	2.825	-5.949	5.252
	Equal variances not assumed			-.124	64.765	.902	-.348	2.814	-5.969	5.272

T-Test

Group Statistics

	Male and female students in concept mapping group	N	Mean	Std. Deviation	Std. Error Mean
Misconception scores in concept mapping group	1	57	56.63	11.809	1.564
	2	35	56.86	13.091	2.213

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Misconception scores in concept mapping group	Equal variances assumed	.400	.529	-.085	90	.932	-.226	2.643	-5.477	5.026
	Equal variances not assumed			-.083	66.402	.934	-.226	2.710	-5.635	5.184

Research Question 4 and Hypothesis 4

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Achievement posttest scores of students in conceptual change text group	61.81	108	12.757	1.228
	Achievement pretest scores of students in conceptual change text group	16.18	108	5.554	.534
Pair 2	Achievement posttest scores of students in concept mapping group	60.11	92	13.656	1.424
	Achievement pretest scores of students in concept mapping group	16.61	92	5.758	.600
Pair 3	Achievement posttest scores of students in lecture method group	50.77	128	12.756	1.127
	Achievement pretest scores of students in lecture method group	16.85	128	5.708	.505

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Achievement posttest scores of students in conceptual change text group - Achievement pretest scores of students in conceptual change text group	45.731	13.580	1.307	43.141	48.322	34.996	107	.000
Pair 2	Achievement posttest scores of students in concept mapping group - Achievement pretest scores of students in concept mapping group	43.598	14.414	1.503	40.613	46.583	29.012	91	.000
Pair 3	Achievement posttest scores of students in lecture method group - Achievement pretest scores of students in lecture method group	34.016	14.308	1.265	31.513	36.518	26.898	127	.000

Research Question 5 and Hypothesis 5

Oneway

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Achievement pretest scores	Conceptual change texts	108	16.08	5.554	.534	15.02	17.14	7	27
	Concept mapping	92	16.51	5.758	.600	15.32	17.70	7	27
	Lecture	128	16.75	5.708	.505	15.75	17.75	7	27
	Total	328	16.46	5.662	.313	15.85	17.08	7	27
Achievement posttest scores	Conceptual change texts	108	61.81	12.757	1.228	59.38	64.25	40	90
	Concept mapping	92	60.11	13.656	1.424	57.28	62.94	38	92
	Lecture	128	50.77	12.756	1.127	48.53	53.00	4	82
	Total	328	57.02	13.926	.769	55.51	58.54	4	92

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Achievement pretest scores	Between Groups	26.322	2	13.161	.409	.665
	Within Groups	10455.239	325	32.170		
	Total	10481.561	327			
Achievement posttest scores	Between Groups	8367.627	2	4183.813	24.701	.000
	Within Groups	55048.178	325	169.379		
	Total	63415.805	327			

Post Hoc Tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Teaching methods	(J) Teaching methods	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Achievement pretest scores	Conceptual change texts	Concept mapping	-.428	.805	.868	-2.41	1.55
		Lecture	-.667	.741	.668	-2.49	1.16
	Concept mapping	Conceptual change texts	.428	.805	.868	-1.55	2.41
		Lecture	-.239	.775	.954	-2.15	1.67
	Lecture	Conceptual change texts	.667	.741	.668	-1.16	2.49
		Concept mapping	.239	.775	.954	-1.67	2.15
Achievement posttest scores	Conceptual change texts	Concept mapping	1.706	1.846	.653	-2.83	6.25
		Lecture	11.049*	1.700	.000	6.87	15.23
	Concept mapping	Conceptual change texts	-1.706	1.846	.653	-6.25	2.83
		Lecture	9.343*	1.779	.000	4.97	13.72

	Lecture	Conceptual change texts	-11.049*	1.700	.000	-15.23	-6.87
		Concept mapping	-9.343*	1.779	.000	-13.72	-4.97

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Achievement pretest scores

Scheffe[a,b]

Teaching methods	N	Subset for alpha = 0.05
		1
Conceptual change texts	108	16.08
Concept mapping	92	16.51
Lecture	128	16.75
Sig.		.690

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 107.368.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Achievement posttest scores

Scheffe[a,b]

Teaching methods	N	Subset for alpha = 0.05	
		1	2
Lecture	128	50.77	
Concept mapping	92		60.11
Conceptual change texts	108		61.81
Sig.		1.000	.631

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 107.368.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Research Question 6 and Hypothesis 6

T-Test

Group Statistics

	Male and female students in conceptual change texts group	N	Mean	Std. Deviation	Std. Error Mean
Achievement scores in conceptual change texts group	1	74	62.00	12.558	1.460
	2	34	61.41	13.362	2.292

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Achievement scores in conceptual change texts group	Equal variances assumed	.128	.721	.222	106	.825	.588	2.655	-4.675	5.852
	Equal variances not assumed			.216	60.698	.829	.588	2.717	-4.845	6.022

T-Test

Group Statistics

	Male and female students in concept mapping group	N	Mean	Std. Deviation	Std. Error Mean
Achievement scores in concept mapping group	1	57	61.47	13.698	1.814
	2	35	57.89	13.486	2.280

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Achievement scores in concept mapping group	Equal variances assumed	.123	.727	1.227	90	.223	3.588	2.925	-2.222	9.398
	Equal variances not assumed			1.232	72.950	.222	3.588	2.913	-2.219	9.395

Research Question 7 and Hypothesis 7

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Attitude pretest scores of students in conceptual change text group	24.26	108	8.945	.861
	Attitude posttest scores of students in conceptual change text group	62.64	108	5.439	.523
Pair 2	Attitude pretest scores of students in concept mapping group	23.49	92	5.611	.585
	Attitude posttest scores of students in concept mapping group	60.38	92	9.083	.947
Pair 3	Attitude pretest scores of students in lecture method group	22.90	128	7.186	.635
	Attitude posttest scores of students in lecture method group	57.97	128	8.907	.787

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Attitude pretest scores of students in conceptual change text group - Attitude posttest scores of students in conceptual change text group	-38.380	10.787	1.038	-40.437	-36.322	-36.977	107	.000
Pair 2	Attitude pretest scores of students in concept mapping group - Attitude posttest scores of students in concept mapping group	-36.891	10.523	1.097	-39.071	-34.712	-33.626	91	.000
Pair 3	Attitude pretest scores of students in lecture method group - Attitude posttest scores of students in lecture method group	-35.070	10.450	.924	-36.898	-33.243	-37.969	127	.000

Research Question 8 and Hypothesis 8

Oneway

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Attitude pretest scores	Conceptual change texts	108	24.26	8.945	.861	22.55	25.97	6	40
	Concept mapping	92	23.49	5.611	.585	22.33	24.65	15	40
	Lecture	128	22.90	7.186	.635	21.64	24.16	10	42
	Total	328	23.51	7.438	.411	22.70	24.32	6	42
Attitude posttest scores	Conceptual change texts	108	62.64	5.439	.523	61.60	63.68	46	72
	Concept mapping	92	60.38	9.083	.947	58.50	62.26	40	78
	Lecture	128	57.97	8.907	.787	56.41	59.53	40	86
	Total	328	60.18	8.208	.453	59.29	61.07	40	86

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Attitude pretest scores	Between Groups	108.542	2	54.271	.981	.376
	Within Groups	17983.410	325	55.334		
	Total	18091.951	327			
Attitude posttest scores	Between Groups	1282.548	2	641.274	10.045	.000
	Within Groups	20748.476	325	63.841		
	Total	22031.024	327			

Post Hoc Tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Teaching methods	(J) Teaching methods	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Attitude pretest scores	Conceptual change texts	Concept mapping	.770	1.055	.766	-1.83	3.37
		Lecture	1.361	.972	.376	-1.03	3.75
	Concept mapping	Conceptual change texts	-.770	1.055	.766	-3.37	1.83
		Lecture	.591	1.017	.845	-1.91	3.09
	Lecture	Conceptual change texts	-1.361	.972	.376	-3.75	1.03
		Concept mapping	-.591	1.017	.845	-3.09	1.91
Attitude posttest scores	Conceptual change texts	Concept mapping	2.258	1.134	.139	-.53	5.05
		Lecture	4.670*	1.044	.000	2.10	7.24
	Concept mapping	Conceptual change texts	-2.258	1.134	.139	-5.05	.53
		Lecture	2.412	1.092	.049	-.27	5.10
	Lecture	Conceptual change texts	-4.670*	1.044	.000	-7.24	-2.10
		Concept mapping	-2.412	1.092	.049	-5.10	.27

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Attitude pretest scores

Scheffe^{a,b}

Teaching methods	N	Subset for alpha = 0.05 1
Lecture	128	22.90
Concept mapping	92	23.49
Conceptual change texts	108	24.26
Sig.		.408

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 107.368.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Attitude posttest scores

Scheffe^{a,b}

Teaching methods	N	Subset for alpha = 0.05	
		1	2
Lecture	128	57.97	
Concept mapping	92	60.38	60.38
Conceptual change texts	108		62.64
Sig.		.088	.119

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 107.368.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Research Question 9 and Hypothesis 9

T-Test

Group Statistics

	Male and female students in conceptual change texts group	N	Mean	Std. Deviation	Std. Error Mean
Attitude scores in conceptual change texts group	1	74	62.30	5.625	.654
	2	34	63.38	5.009	.859

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Attitude scores in conceptual change texts group	Equal variances assumed	.600	.440	-.963	106	.338	-1.085	1.127	-3.320	1.150
	Equal variances not assumed			-1.005	71.466	.318	-1.085	1.080	-3.237	1.067

T-Test

Group Statistics

	Male and female students in concept mapping group	N	Mean	Std. Deviation	Std. Error Mean
Attitude scores in concept mapping group	1	57	59.93	9.241	1.224
	2	35	61.11	8.904	1.505

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Attitude scores in concept mapping group	Equal variances assumed	.006	.937	-.605	90	.547	-1.184	1.957	-5.073	2.704
	Equal variances not assumed			-.611	74.151	.543	-1.184	1.940	-5.050	2.681

Research Question 10 and Hypothesis 10

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Teaching methods	1	Conceptual change texts	108
	2	Concept mapping	92
	3	Lecture	128
Students sex	1	Male	201
	2	Female	127

Descriptive Statistics

Dependent Variable: Misconception pretest scores

Teaching methods	Students sex	Mean	Std. Deviation	N
Conceptual change texts	Male	15.78	5.465	74
	Female	16.74	5.770	34
	Total	16.08	5.554	108
Concept mapping	Male	16.89	5.821	57
	Female	15.89	5.682	35
	Total	16.51	5.758	92
Lecture	Male	16.94	5.626	70
	Female	16.52	5.847	58
	Total	16.75	5.708	128
Total	Male	16.50	5.622	201
	Female	16.40	5.745	127
	Total	16.46	5.662	328

Descriptive Statistics

Dependent Variable: Misconception posttest scores

Teaching methods	Students sex	Mean	Std. Deviation	N
Conceptual change texts	Male	59.95	13.677	74
	Female	60.29	13.539	34
	Total	60.06	13.571	108
Concept mapping	Male	56.63	11.809	57
	Female	56.86	13.091	35
	Total	56.72	12.241	92
Lecture	Male	49.89	13.843	70
	Female	51.83	11.334	58
	Total	50.77	12.756	128
Total	Male	55.50	13.862	201
	Female	55.48	12.856	127
	Total	55.49	13.461	328

Tests of Between-Subjects Effects

Dependent Variable: Misconception posttest scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5433.327[a]	6	905.555	5.401	.000
Intercept	111302.811	1	111302.811	663.813	.000
PretestMis	63.092	1	63.092	.376	.540
Methods	4805.386	2	2402.693	14.330	.000
Sex	50.920	1	50.920	.304	.582
Methods * Sex	49.615	2	24.807	.148	.863
Error	53822.661	321	167.672		
Total	1069356.000	328			
Corrected Total	59255.988	327			

a. R Squared = .092 (Adjusted R Squared = .075)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: Misconception posttest scores

		95% Confidence Interval	
Mean	Std. Error	Lower Bound	Upper Bound
55.907[a]	.749	54.432	57.381

a. Covariates appearing in the model are evaluated at the following values: Misconception pretest scores = 16.46.

2. Teaching methods

Estimates

Dependent Variable: Misconception posttest scores

			95% Confidence Interval	
Teaching methods	Mean	Std. Error	Lower Bound	Upper Bound
Conceptual change texts	60.104[a]	1.342	57.465	62.744
Concept mapping	56.739[a]	1.390	54.003	59.474
Lecture	50.877[a]	1.150	48.615	53.140

a. Covariates appearing in the model are evaluated at the following values: Misconception pretest scores = 16.46.

Pairwise Comparisons

Dependent Variable: Misconception posttest scores

					95% Confidence Interval for Difference[b]	
(I) Teaching methods	(J) Teaching methods	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
Conceptual change texts	Concept mapping	3.365	1.932	.082	-.436	7.167
	Lecture	9.227*	1.768	.000	5.749	12.704
Concept mapping	Conceptual change texts	-3.365	1.932	.082	-7.167	.436
	Lecture	5.861*	1.805	.001	2.311	9.412
Lecture	Conceptual change texts	-9.227*	1.768	.000	-12.704	-5.749
	Concept mapping	-5.861*	1.805	.001	-9.412	-2.311

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Misconception posttest scores

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	4805.386	2	2402.693	14.330	.000
Error	53822.661	321	167.672		

The F tests the effect of Teaching methods. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

3. Students sex

Estimates

Dependent Variable: Misconception posttest scores

Students sex	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Male	55.494[a]	.919	53.685	57.302
Female	56.320[a]	1.184	53.991	58.649

a. Covariates appearing in the model are evaluated at the following values: Misconception pretest scores = 16.46.

Pairwise Comparisons

Dependent Variable: Misconception posttest scores

(I) Students sex	(J) Students sex	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
Male	Female	-.826	1.499	.582	-3.775	2.123
Female	Male	.826	1.499	.582	-2.123	3.775

Based on estimated marginal means
a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Misconception posttest scores

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	50.920	1	50.920	.304	.582
Error	53822.661	321	167.672		

The F tests the effect of Students sex. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

4. Teaching methods * Students sex

Dependent Variable: Misconception posttest scores

Teaching methods	Students sex	Mean	Std. Error	95% Confidence Interval Lower Bound	 Upper Bound
Conceptual change texts	Male	59.893[a]	1.508	56.927	62.859
	Female	60.315[a]	2.221	55.946	64.685
Concept mapping	Male	56.665[a]	1.716	53.289	60.041
	Female	56.812[a]	2.190	52.504	61.121
Lecture	Male	49.923[a]	1.549	46.876	52.970
	Female	51.832[a]	1.700	48.487	55.177

a. Covariates appearing in the model are evaluated at the following values: Misconception pretest scores = 16.46.

Research Question 11 and Hypothesis 11

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Teaching methods	1	Conceptual change texts	108
	2	Concept mapping	92
	3	Lecture	128
Students sex	1	Male	201
	2	Female	127

Descriptive Statistics

Dependent Variable: Achievement pretest scores

Teaching methods	Students sex	Mean	Std. Deviation	N
Conceptual change texts	Male	15.78	5.465	74
	Female	16.74	5.770	34
	Total	16.08	5.554	108
Concept mapping	Male	16.89	5.821	57
	Female	15.89	5.682	35
	Total	16.51	5.758	92
Lecture	Male	16.94	5.626	70
	Female	16.52	5.847	58
	Total	16.75	5.708	128
Total	Male	16.50	5.622	201
	Female	16.40	5.745	127
	Total	16.46	5.662	328

Descriptive Statistics

Dependent Variable: Achievement posttest scores

Teaching methods	Students sex	Mean	Std. Deviation	N
Conceptual change texts	Male	62.00	12.558	74
	Female	61.41	13.362	34
	Total	61.81	12.757	108
Concept mapping	Male	61.47	13.698	57
	Female	57.89	13.486	35
	Total	60.11	13.656	92
Lecture	Male	49.89	13.843	70
	Female	51.83	11.334	58
	Total	50.77	12.756	128
Total	Male	57.63	14.439	201
	Female	56.06	13.071	127
	Total	57.02	13.926	328

Tests of Between-Subjects Effects

Dependent Variable: Achievement posttest scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8789.357[a]	6	1464.893	8.608	.000
Intercept	109761.019	1	109761.019	644.986	.000
PretestAch	14.903	1	14.903	.088	.767
Methods	7450.718	2	3725.359	21.891	.000
Sex	40.724	1	40.724	.239	.625
Methods * Sex	392.547	2	196.273	1.153	.317
Error	54626.447	321	170.176		
Total	1130000.000	328			
Corrected Total	63415.805	327			

a. R Squared = .139 (Adjusted R Squared = .122)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: Achievement posttest scores

		95% Confidence Interval	
Mean	Std. Error	Lower Bound	Upper Bound
57.414[a]	.755	55.929	58.899

a. Covariates appearing in the model are evaluated at the following values: Achievement pretest scores = 16.46.

2. Teaching methods

Estimates

Dependent Variable: Achievement posttest scores

			95% Confidence Interval	
Teaching methods	Mean	Std. Error	Lower Bound	Upper Bound
Conceptual change texts	61.714[a]	1.352	59.054	64.373
Concept mapping	59.682[a]	1.401	56.927	62.438
Lecture	50.847[a]	1.159	48.567	53.126

a. Covariates appearing in the model are evaluated at the following values: Achievement pretest scores = 16.46.

Pairwise Comparisons

Dependent Variable: Achievement posttest scores

(I) Teaching methods	(J) Teaching methods	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]

					Lower Bound	Upper Bound
Conceptual change texts	Concept mapping	2.031	1.946	.297	-1.798	5.860
	Lecture	10.867*	1.781	.000	7.364	14.370
Concept mapping	Conceptual change texts	-2.031	1.946	.297	-5.860	1.798
	Lecture	8.836*	1.818	.000	5.259	12.413
Lecture	Conceptual change texts	-10.867*	1.781	.000	-14.370	-7.364
	Concept mapping	-8.836*	1.818	.000	-12.413	-5.259

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Achievement posttest scores

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	7450.718	2	3725.359	21.891	.000
Error	54626.447	321	170.176		

The F tests the effect of Teaching methods. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

3. Students sex

Estimates

Dependent Variable: Achievement posttest scores

			95% Confidence Interval	
Students sex	Mean	Std. Error	Lower Bound	Upper Bound
Male	57.784[a]	.926	55.962	59.605
Female	57.045[a]	1.193	54.698	59.391

a. Covariates appearing in the model are evaluated at the following values: Achievement pretest scores = 16.46.

Pairwise Comparisons

Dependent Variable: Achievement posttest scores

					95% Confidence Interval for Difference[a]	
(I) Students sex	(J) Students sex	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
Male	Female	.739	1.510	.625	-2.232	3.709
Female	Male	-.739	1.510	.625	-3.709	2.232

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Achievement posttest scores

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	40.724	1	40.724	.239	.625
Error	54626.447	321	170.176		

The F tests the effect of Students sex. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

4. Teaching methods * Students sex

Dependent Variable: Achievement posttest scores

Teaching methods	Students sex	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Conceptual change texts	Male	62.026[a]	1.519	59.037	65.014
	Female	61.401[a]	2.237	56.999	65.803
Concept mapping	Male	61.457[a]	1.729	58.056	64.858
	Female	57.908[a]	2.206	53.567	62.248
Lecture	Male	49.868[a]	1.560	46.798	52.937
	Female	51.826[a]	1.713	48.456	55.196

a. Covariates appearing in the model are evaluated at the following values: Achievement pretest scores = 16.46.

Research Question 12 and Hypothesis 12

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Teaching methods	1	Conceptual change texts	108
	2	Concept mapping	92
	3	Lecture	128
Students sex	1	Male	201
	2	Female	127

Descriptive Statistics

Dependent Variable: Attitude pretest scores

Teaching methods	Students sex	Mean	Std. Deviation	N
Conceptual change texts	Male	24.19	8.747	74
	Female	24.41	9.494	34
	Total	24.26	8.945	108
Concept mapping	Male	23.05	5.838	57
	Female	24.20	5.223	35
	Total	23.49	5.611	92
Lecture	Male	23.53	7.021	70
	Female	22.14	7.369	58
	Total	22.90	7.186	128
Total	Male	23.64	7.395	201
	Female	23.31	7.531	127
	Total	23.51	7.438	328

Descriptive Statistics

Dependent Variable: Attitude posttest scores

Teaching methods	Students sex	Mean	Std. Deviation	N
Conceptual change texts	Male	62.30	5.625	74
	Female	63.38	5.009	34
	Total	62.64	5.439	108
Concept mapping	Male	59.93	9.241	57
	Female	61.11	8.904	35
	Total	60.38	9.083	92
Lecture	Male	60.43	10.483	70
	Female	55.00	5.228	58
	Total	57.97	8.907	128
Total	Male	60.98	8.628	201
	Female	58.93	7.356	127
	Total	60.18	8.208	328

Tests of Between-Subjects Effects

Dependent Variable: Attitude posttest scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2319.803[a]	6	386.634	6.296	.000
Intercept	101685.635	1	101685.635	1655.965	.000
PretestAtt	44.673	1	44.673	.728	.394
Methods	1386.836	2	693.418	11.292	.000
Sex	82.718	1	82.718	1.347	.247
Methods * Sex	772.569	2	386.284	6.291	.062
Error	19711.221	321	61.406		
Total	1210042.000	328			
Corrected Total	22031.024	327			

a. R Squared = .105 (Adjusted R Squared = .089)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: Attitude posttest scores

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
60.355[a]	.454	59.463	61.247

a. Covariates appearing in the model are evaluated at the following values: Attitude pretest scores = 23.51.

2. Teaching methods

Estimates

Dependent Variable: Attitude posttest scores

Teaching methods	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Conceptual change texts	62.800[a]	.813	61.201	64.400
Concept mapping	60.516[a]	.841	58.861	62.172
Lecture	57.748[a]	.697	56.377	59.119

a. Covariates appearing in the model are evaluated at the following values: Attitude pretest scores = 23.51.

Pairwise Comparisons

Dependent Variable: Attitude posttest scores

(I) Teaching methods	(J) Teaching methods	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Conceptual change texts	Concept mapping	2.284	1.170	.052	-.017	4.586
	Lecture	5.052*	1.073	.000	2.942	7.162
Concept mapping	Conceptual change texts	-2.284	1.170	.052	-4.586	.017
	Lecture	2.768*	1.093	.012	.618	4.918
Lecture	Conceptual change texts	-5.052*	1.073	.000	-7.162	-2.942
	Concept mapping	-2.768*	1.093	.012	-4.918	-.618

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Attitude posttest scores

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	1386.836	2	693.418	11.292	.000
Error	19711.221	321	61.406		

The F tests the effect of Teaching methods. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

3. Students sex

Estimates

Dependent Variable: Attitude posttest scores

Students sex	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	60.881[a]	.556	59.787	61.976
Female	59.829[a]	.716	58.419	61.238

a. Covariates appearing in the model are evaluated at the following values: Attitude pretest scores = 23.51.

Pairwise Comparisons

Dependent Variable: Attitude posttest scores

(I) Students sex	(J) Students sex	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Male	Female	1.053	.907	.247	-.732	2.837
Female	Male	-1.053	.907	.247	-2.837	.732

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Attitude posttest scores

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	82.718	1	82.718	1.347	.247
Error	19711.221	321	61.406		

The F tests the effect of Students sex. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

4. Teaching methods * Students sex

Dependent Variable: Attitude posttest scores

				95% Confidence Interval	
Teaching methods	Students sex	Mean	Std. Error	Lower Bound	Upper Bound
Conceptual change texts	Male	62.263[a]	.912	60.470	64.057
	Female	63.337[a]	1.345	60.691	65.983
Concept mapping	Male	59.953[a]	1.038	57.910	61.995
	Female	61.080[a]	1.325	58.473	63.687
Lecture	Male	60.428[a]	.937	58.585	62.270
	Female	55.069[a]	1.032	53.038	57.099

a. Covariates appearing in the model are evaluated at the following values: Attitude pretest scores = 23.51.