CHAPTER ONE
INTRODUCTION

Background to the Problem

Scientific investigations require diverse strategies in their approach and only in so doing can science grow in new discoveries. Science is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe. According to Britain's Science Council (2009), science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence. Science according to Okeke (2007) is the systematic investigation of nature with a view to understanding and harnessing them to serve human needs. Science is a dynamic and changing enterprise and must be presented as such in the classroom. Science is not a body of static, disparate and certain facts to be taught in isolation. It is an organized body of knowledge, a way of knowing, a process and indeed a way of thinking.

Every society depends on its science education programme for sustainable development. Science education according to Akpan (2010) is defined as the cultivation and disciplining of an individual to utilize science for improving his/her life, cope with an increasingly technological world or pursue science academically and professionally and for dealing responsibly with science related social issues. Science education is important in presenting science as an organized body of knowledge. The aims of science education according to Ajaja (2009), include helping students to gain an understanding of as much of the established body of scientific knowledge as is appropriate to their needs, interests and developing students' understanding of the methods by which this knowledge has been gained and the grounds for confidence in it.

In many Nigerian schools, science teachers still rely heavily on the traditional approach to science teaching (Adesoji, 2008; Ajaja, 2009; Ajeyalemi, 2011). Traditional approach to science teaching is dominated by total reliance on the textbook and expository and authoritative presentation of facts. This authoritative presentation of facts is contrary to the nature of science. Science educators have continued to stress the need for teaching methods in science that will result in meaningful learning by the students. These teaching methods should be geared towards inquiry modes of presentation of science materials. These methods emphasize the importance of laboratories for science teaching to inculcate the skills of science. Science is concerned with explaining nature and the explanations must be tested by controlled research investigations that are referred to as experiments. Experimental observations according to Burns (1999) are only a bare but necessary beginning to the intellectual process of science observations that give rise to ideas that must be tested. The interplay of ideas and observations therefore assist in modifying our understanding of nature.

Chemistry is the branch of science that deals with the characteristics and composition of all materials and with the changes they can undergo. Students encounter the process of science through experimental data that support scientific laws. Chemistry is an experimental science. Chemistry and other branches of science deal with much more than searching for answers to individual problems. Solving problems in Chemistry often involves the use of experiments, facts, terminologies, laws and theories in the search for answers.

Redox (oxidation - reduction) reaction is an important topic of general chemistry. Redox reaction in Chemistry is one of the most difficult topics to teach and to learn (Njoku 2004;Ojokuku & Amadi 2010; Obomona & Ekenobi 2011; Udo 2011). Redox reactions are described as one of the three most common (precipitation, acid-base and oxidation and reduction (redox)) reaction processes and perhaps the most important of these three, because they explain an amazing variety of chemical reactions (Osterlund 2010). Redox not only explains important inorganic reactions such as the reduction of ores to obtain metals, the production of fertilizers or production of electro-chemical cells, it also explains vital biochemical processes such as photosynthesis and metabolism or the organic combustion reaction, (Mumuni & Mumuni, 2006; Achimugu, 2009; Udo, 2011). Thus the redox reactions continually taking place are a large part of us and our surroundings. To teach redox reactions teachers must employ strategies that will enable the students make meaning from the concepts. A redox titration uses the technique of titration but is applied to reactants in a redox reaction to measure the concentrations of the reactants.

The science laboratory is a critical component of the learning resource. Science teachers and students world over know that practical work is a very essential component of science teaching yet the teachers largely use the expository method. The major factors that lead teachers to adopt the expository method in preference to laboratory work include lack of confidence in handling science equipment and apparatus, lack of adequate professional preparation during the pre-service years, and lack of technical know-how on improvisation of science equipment (Adesoji & Arowosegbe, 2004; Ajeyalemi 2011).

Science education researches have been conducted on what students gain from science laboratory experiences. One consistent finding according to Greenbowe and Hand (2006) is that if traditional laboratory experiments are used with the traditional laboratory notebook format, students may learn some laboratory techniques but they learn little else. In traditional laboratory experiment students are expected to blindly accept the information they are given without questioning the instructor. Also, under these conditions, students develop a poor attitude towards science and consider the laboratory activity a huge waste of time. Students often view the data collected during a laboratory experiment as artificial. Using a traditional laboratory experiment, students will blindly follow the directions.

Greenbowe and Hand (2006) found that when students are asked to solve problems on examination or laboratory practical tasks that match what has been presented in lecture and in the laboratory, average student performance is poor. Ajeyalemi (2011) reported that in most secondary schools in Nigeria, laboratory practical work is performed in a “cook-book’ fashion whereby students only follow direct instructions. By this practice, the impression is created that only the final results and calculations based on laboratory practical matter. Njoku (2007) found that students perform poorly in practical chemistry mostly in the area of linking theory to practical aspect of chemistry. This, he explained, is because students receive poor teaching in the theory of practical work and hence fail to develop adequate knowledge of practical work in the theoretical sense. On the development of standardized instrument for assessing practical work in science, Ugwu (2014), suggested among other strategies to be adopted, the identification of teaching strategies and identification of learning strategies in practical work.

Ajeyalemi (2011) observed that the salient aims and objectives of laboratory practical work are not being achieved in the Nigerian school system. This, he said, may be due to the poor learning environment and the fact that teachers have remained inflexible in their methods of teaching.

A heuristic tool for learning from laboratory activities in science is the Science Writing Heuristic (SWH). Heuristic teaching is a method that allows a learner to discover things by himself. The science writing heuristic (SWH) can be understood as an instructional approach that has been devised to encourage students to use hands- on guided inquiry laboratory activities and collaborative group work to actively negotiate meaning and construct conceptual knowledge,(Burke, Greenbowe & Hand 2005). It can also be understood as an alternative format students use for their laboratory reports, and a teaching technique used by the instructor to help format the flow of activities associated with the experiment (Greenbowe & Hand, 2006).

The science writing heuristic provides learners with a heuristic template to guide science activity and reasoning in writing. Further it provides learners with a template of suggested strategies to enhance learning from laboratory activities. Students can use this template in writing their laboratory reports or participating in the classroom or laboratory activities. In other words, the science writing heuristic enables the learner to understand his own laboratory activity and connect this knowledge to other science ideas. It is aimed at promoting both scientific thinking and reasoning in the laboratory, as well as metacognition where learners become aware of the basis of their knowledge. Metacognition involves planning, monitoring and evaluating one's cognitive processes.

Using a traditional laboratory experiment students usually follow the experimental procedure blindly. Many researchers have argued that this traditional laboratory practice lacks evidence of producing meaningful learning (Akkus, Gunel & Hand 2007; Ajeyalemi, 2011). Instead of the traditional laboratory format, the science writing heuristic asks students to write statements about their research questions, followed by the process of making claims and framing evidence from their investigations.

The SWH laboratory report format is an alternative to the traditional approach in the laboratory. This format is patterned in such a manner that students explore concepts to look for trends or patterns rather than verify an expected outcome. In the traditional laboratory format, students follow a given set of procedures to verify a fact and if students obtain what they are supposed to obtain, writing up the laboratory report requires little difficulty as the explanations and answers are provided.

The SWH provides students with an experiment with no direct answers, but rather many possibilities based on previous concepts covered.

As the experiment is being completed, students record their data on the blackboard. These data serve as the class data and allow students to look for their trends or patterns. This allows for the introduction of new terms and concepts based on the data generated. By using the data obtained during an experiment, students can use the trends or patterns found to make conclusions about examples in different contexts.

In the traditional laboratory format the opposite is true. Students follow a given set of procedures to verify a fact or synthesize a compound. According to Pickering (1985), with the possibility of only verifying one correct answer, students are not encouraged to reconcile their results if these results do not agree with what they were supposed to obtain. Ali (1988) stated that laboratory activities may achieve very limited science objectives because science teachers believe and tell students that they must get the expected results as if science is a cook-book recipe exercise where results are made-to-order. Science teachers sometimes forget or do not care to know that science activities are meant for students investigating science phenomena as well as for their self development in inquiry skills. Training students on development of inquiry skills has been shown to enable students gain self confidence in scientific abilities, (Caukin, 2010).

In education it is important to take into account cognitive, affective and psychomotor factors. Self-efficacy is an affective construct influencing learning. Self -efficacy is used to measure how confident students are in their ability to understand and do science. Self -efficacy is the measure of one's competence to complete tasks and reach goals. It is concerned with people's beliefs in their capabilities to produce given attainments (Bandura, 1997). People differ in the areas in which they cultivate their efficiency and in the levels to which they develop it even within their given pursuits. Perceived self- efficacy is a judgement of capability.

> Perceived efficacy plays a key role in human functioning because it affects behaviour not only directly, but by its impact on other determinants such as goals and aspirations, outcome expectations, affective proclivities, and perception of impediments and opportunities in the social environment, (Bandura 1995, 1997).

Efficacy beliefs influence whether people act erratically or strategically, optimistically or pessimistically.

> They also influence the courses of action people choose to pursue, the challenges and goals they set for themselves and their commitment to them, how much effort they put forth in given endeavours, the outcomes they expect their efforts to produce, how long they persevere in the face of obstacles, their resilience to adversity, the quality of their emotional life and how much stress and depression they experience in coping with taxing environmental demands, and the life choices they make and the accomplishments they realize.(Bandura 1995).

In a study that investigated the impact of problem-solving instructional strategy on the performances of students of different ability levels, Adesoji (2008) found that although there was no significant difference in the performance of students in the different ability levels, problem solving in science depends on the students' cognitive ability level. Ability level as a variable in students' achievement has not been sufficiently examined hence the need to examine it as a variable in this study.

The influence of gender on students' achievement in science has for a long time been a concern to many researchers and science educators. The results of these researches are varied. While some authors like Oloyede, (2011) concluded that there was gender difference in science achievement, others like Nwaiwu and Audu (2005), Ndirika (2013), reported that gender had no influence on students' achievement in science.

Some researches have documented gender differences favouring men, in Science, Technology, Engineering and Mathematics (STEM) self-efficacy and also in the probability of success in STEM-related fields, (American Association of University Women (AAUW) 1991, Pajares 2005). Gender differences in self efficacy have also been reported in some works in favour of women for instance Britner and Pajares (2006) reported that girls had higher self efficacy beliefs and attainment in science than boys. Pajares, Miller and Johnson (1999) investigated gender differences and self-efficacy for writing and reported that girls had a stronger self efficacy for self-regulated learning coupled with higher attainment. This shows that studies on gender influence in science achievement and self-efficacy are inconclusive hence the need for further research on gender. In explaining the need for students to be grounded in practical work Maskil (2000) stated that since practical work is supposed to elucidate theoretical work, it is expected that students would have some previous theoretical background to the experiments they would be performing and that while performing the experiments they would be thinking about the underlying principles.

The extent to which teachers use an instructional practice that moves away from the traditional expository lesson in science but rather make the rationale of scientific explanation explicit is the extent to which students learning of scientific explanations is influenced.

Statement of the Problem

A significant challenge in science education is how to move students from thinking that science facts are to be memorized toward a deeper understanding of concepts and scientific ways of thinking. The objective of the chemistry programme at the NCE level is to produce highly qualified middle-level manpower knowledgeable in the processes of chemistry and capable of inculcating these in the students. The basic science and technology curriculum is very practical in nature and should ideally be taught through methods that maximize the active participation of the learner (Akuezuilo, 2007).

Despite the importance placed on laboratory work in chemistry curricula, there have been few research studies showing that conventional (traditional) laboratory experiments are an effective tool for promoting understanding of chemistry (Greenbowe & Hand 2006). However, laboratory activities that are inquiry -based have been reported to have potential for improving pedagogical value of laboratory work, (Caukin, 2010). Research has shown that a heuristic tool known as the science writing heuristic SWH facilitated students to generate meaning from data, make connections among procedures, data, evidence and claims and engage in metacognition (Keys, Hand, Prain & Collins, 1999; Caukin, 2010; Arnold, 2011). In Nigeria literature is scarce on the use of this heuristic tool, the science writing heuristic by science teachers.

It is important that in addition to developing knowledge and skill, Science teachers help develop students' science self-efficacy. Students exposed to both the conventional (traditional) and inquiry laboratories (SWH) are reported as being fairly confident that they could perform specific tasks and apply science skills in the context of daily life (Pajares 2005).

The concern that laboratory practical work is performed in a manner that students follow only direct instructions from the teacher making them unable to link theory to practical calls for a study on how to improve on science laboratory practical work. The study therefore is on the effect of science writing heuristic – a guided inquiry laboratory instructional approach on students' self efficacy and achievement in redox reactions.

Purpose of the Study

The main purpose of this study is to ascertain the effect of Science Writing Heuristic (SWH) on College of Education chemistry students' self-efficacy and achievement in redox reactions. Specifically the study sought to:

1. Compare the mean achievement scores of chemistry students taught redox reactions using SWH and conventional laboratory instructional modes.
2. Determine the mean achievement scores of male and female chemistry students taught redox reactions using SWH and conventional laboratory instructional modes.
3. Determine the mean achievement scores of students of low, middle and high ability level taught redox reactions using SWH and conventional laboratory instructional modes.

4. Compare the mean self-efficacy scores of chemistry students taught redox reactions using SWH and conventional laboratory instructional modes.
5. Determine the mean self-efficacy scores of male and female chemistry students taught redox reactions using SWH and conventional laboratory instructional modes.
6. Explore the interaction effect between treatment and gender on the achievement of College of Education chemistry students in redox reactions.
7. Explore the interaction effect between treatment and ability level on College of Education chemistry students' achievement in redox reactions.
8. Explore the interaction effect among treatment, gender and ability level on College of Education chemistry students' achievement in redox reactions.

Significance of the Study

The results of the study will be beneficial to chemistry students, chemistry teachers, science teachers, school administrators, curriculum planners, government and society.

For the chemistry students, the use of the science writing heuristic is likely to enhance achievement. It is expected that students who use the science writing heuristic will find it beneficial in terms of helping them understand their laboratory work and hence to achieve better in chemistry.

The chemistry teachers as well as other science teachers will find the study beneficial because it will help them use pedagogical approaches in inquiry for improving the quality of instruction. It is expected that teachers who implement the science writing heuristic will change their own misconceptions about science and science concepts. The extent the teachers are able to use this heuristic tool will greatly influence students learning of scientific explanations.

The type of learning environment and teaching method can improve self-efficacy in the classroom. Students who have a strong sense of self-efficacy are most likely to have the mindset of rising to a challenge rather than avoiding a perceived difficulty. Additionally teachers can gain insight into whether students' confidence levels increase as they engage in more complex tasks (inquiry laboratory practices) hence enabling them to choose instructional strategies that are most effective in building confidence among students to achieve scientific breakthroughs.

For the school administrators the effectiveness of the science writing heuristic could mean greater achievement in chemistry and other science subjects. The failure rate of students in the sciences can be minimized with improved understanding of science concepts.

For curriculum developers, the findings of the study will add to the body of knowledge related to instructional strategies in science.

Government and society will benefit from the study when the science graduates have a better understanding of science concepts for improved scientific and technological society.

Scope of the Study

The study focused on the effect of science writing heuristic as an instructional strategy on College of Education chemistry students' self-efficacy and achievement in redox reactions. Second year students in the NCE programme were used. The study examined the effect of SWH on male and female students' achievement and self-efficacy as well as the effect of SWH on the achievement of students of different ability levels. The study used redox titrations as the practical work to elucidate the theory of redox reactions. The delimitation to this unit was to enable students acquire in-depth theoretical and practical experiences. The independent variables were treatment (SWH and conventional laboratory instructional modes), gender (male and female) and ability level (low, middle and high). The dependent variables were achievement and self-efficacy.

Research Questions

1. What are the mean achievement scores of chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes?
2. What are the mean achievement scores of male and female chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes?
3. What are the mean achievement scores of students of low, middle and high ability taught redox reactions using SWH and those taught using conventional laboratory instructional modes?
4. What are the mean self-efficacy scores of chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes?
5. What are the self-efficacy scores of male and female chemistry students' taught redox reactions using SWH and those taught using conventional laboratory instructional modes?
6. What is the interaction effect between treatment and gender on chemistry students' mean achievement scores in redox reactions using SWH and conventional laboratory instructional modes?

7. What is the interaction effect between treatment and ability level on chemistry students' mean achievement scores in redox reactions using SWH and conventional laboratory instructional modes?
8. What is the interaction effect among treatment, gender and ability level on chemistry students' mean achievement scores in redox reactions?

Hypotheses

Eight (8) Null hypotheses were formulated to guide this study. The null hypotheses were tested at the 0.05 level of significance.

1. There is no significant difference in the mean achievement scores of chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.
2. There is no significant difference in the mean achievement scores of male and female chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.
3. There is no significant difference in the mean achievement scores of chemistry students of low, middle and high ability taught redox reactions using SWH and those taught using conventional laboratory instructional modes.

4. There is no significant difference in the self-efficacy of chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.
5. There is no significant difference in the self-efficacy of male and female chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.
6 There is no significant interaction effect between treatment and gender on the achievement of chemistry students in redox reactions.
7 There is no significant interaction effect between treatment and ability level on chemistry students' achievement in redox reactions.
8 There is no significant interaction effect among treatment, gender and ability level on chemistry students achievement in redox reactions.

CHAPTER TWO
REVIEW OF RELATED LITERATURE

This chapter deals with the review of related literature under the following headings.

Conceptual Framework

Concepts of :

Science writing heuristic

Self-efficacy

Theoretical Framework

Constructivist theory

Learning theory by Jerome Bruner, Lev Vygotsky and David Ausubel

Science, Technology, Engineering and Mathematics (STEM)

Self-Efficacy

Gender Differences in Academic Self-Efficacy

Gender Differences in Mathematics/Science Self- Efficacy

Self-Efficacy and Education

Gender Differences in Science Achievement

Science Laboratory Practical Teaching

Empirical Studies

Studies on the Effectiveness of Science Writing Heuristic

Studies on Science Self-efficacy

Studies on the Application of the SWH in Different Fields of Science

Summary of Related Literature Reviewed.

CONCEPTUAL FRAMEWORK

In science education reforms, success is associated with inquiry based instructional approach where the student is an active learner. Transitioning science education from the more direct teaching models to more student centred, collaborative models involved the use of resources that offer best practices of inquiry based instruction, Arnold (2011). Prevalent among the best practices is the use of the science of the science writing heuristic which is adapted toward the guided inquiry instructional approach. The SWH promotes students' participation in laboratory work by requiring them to frame questions, propose methods to address these questions and carry out appropriate investigations. Self-efficacy is a person's belief in his or her ability to complete a future task or solve a future problem.

The conceptual framework of the study is, therefore utilizing the Science Writing-Heuristic (SWH) instructional approach which integrates guided inquiry processes and interactive group work with writing-to-learn strategies in students' learning. Writing -to -learn strategies are techniques used by teachers to aid students in constructing understanding and knowledge through writing. The research is to establish the effect of science writing heuristic on College of Education Chemistry students' self-efficacy and achievement as a function of the variables of gender and ability level.

Science Writing Heuristic (SWH):

The science writing heuristic (SWH) can be understood as an alternative format students use for their laboratory reports, and a teaching technique used by the teacher to help format the flow of activities associated with the experiment (Greenbowe and Hand 2006).

A heuristic is a tool, a problem solving device. Specifically the science writing heuristic is used to organize how the laboratory classroom functions and how students write their laboratory reports. So there are two aspects of the science writing heuristic. One is what happens during the laboratory experiments with respect to the classroom dynamic that is created and the other is the actual writing of laboratory reports. Both parts are used together as a tool for successful understanding of chemical concepts in the laboratory, (Poock n.d). Constructing science knowledge is not a casual but a purposeful activity based upon posing questions, determining claims, and providing evidence. The Science Writing Heuristic, SWH, is a process that has been devised to encourage students to use hands-on guided inquiry laboratory activities and collaborative group work to actively negotiate meaning and construct conceptual knowledge. The method has been effectively incorporated into science curricula (including biology, chemistry, general science, geology, physical science, and physics) from prekindergarten/ elementary through post-secondary levels (at two- and four-year institutions). It has also been successfully incorporated into pre-service teacher training courses. Keys, Hand, Prain & Collins, 1999; Burke, Hand, Poock & Greenbowe (2005); Hand & Prain, 2010.

The Science Writing Heuristic (SWH) approach integrates guided inquiry processes and interactive group work with writing to learn strategies. Interactive, guided-inquiry laboratory activities are coupled with student-centred classroom practices that include intra-and inter-group discussion (Burke, Hand, Poock, Greenbowe 2005). Instructors encourage students to use interactive constructivist techniques (where meaning is socially constructed as well as personally constructed) to frame their questions, hypotheses, and experimental designs. The science writing heuristic provides an alternate format for students to guide their peer discussions and their thinking and writing about how hands-on guided inquiry activities relate to their own prior knowledge via beginning questions, claims and evidence, and final reflections. Although making observations in the SWH format may be similar to traditional verification work, the process of making claims (drawing inferences) and supporting them with evidence from their experimental work helps the student to interactively construct a deeper understanding of the concept(s) being explored by the laboratory exercise (Greenbowe & Hand 2006).

In traditional laboratory format, procedures are uniform for each student, data are similar, and claims match expected outcomes; results and conclusions often lack opportunities for more extensive student learning about the topic or for developing scientific reasoning skills. The SWH is designed to help students think about the relationships among questions, evidence, and claims. The SWH promotes students' participation in laboratory work by requiring them to frame questions, propose methods to address these questions, and carry out appropriate investigations.

The science writing heuristic is rooted in constructivism; that knowledge is constructed in the mind of the learner. The teacher in charge of the laboratory needs to frame the experiment in such a fashion that students are placed in the centre of the learning process. This heuristic approach is like building a puzzle.

It is not feasible for the teacher to let the students pursue every avenue of exploration during a chemistry lesson. The teacher has a concept he wishes to impress upon the students during a chemistry lesson and so effectively creates a framework inside which the students can work, then the students can put the puzzle together without going astray. Simply put, the science writing heuristic is a teaching approach that the science teacher employs using templates that guide science laboratory activities of the students using student's questions, discussions and writing.

The science writing heuristic (SWH) consists of a framework to guide activities as well as a metacognitive support to prompt student reasoning about data (Greenbowe, Hand & Rudd 2006). The SWH provides learners with a heuristic template to guide science activity and reasoning in writing. It provides teachers with a template or suggested strategies to enhance learning from laboratory activities. Using the traditional laboratory report format students respond to the five traditional sections, purpose, methods, observation, results and conclusions, while in using the SWH students are expected to respond to prompt eliciting questioning, knowledge claims, evidence, description of data and observations, methods and to reflect on changes to their own thinking. An overview of the student template and the teacher template for the SWH according to Greenbowe, Hand and Rudd (2006).is shown on Table I

Table I: The SWH template for teacher and students.

The Science Writing Heuristic, Part I ***A template for teacher-designed activities to promote laboratory understanding.***	**The Science Writing Heuristic, Part II** ***A template for students.***
1. Exploration of pre-instruction understanding through individual or group concept mapping or working through a computer simulation.	2. Beginning ideas - What are my questions?
2. Pre-laboratory activities, including informal writing, making observations, brainstorming, and posing questions.	2. Tests - What did I do?
3. Participation in laboratory activity.	3. Observations - What did I see?
4 Negotiation phase I - writing personal meanings for laboratory activity. (For example, writing journals.)	4. Claims - What can I claim?
5 Negotiation phase II - sharing and Comparing data interpretations in small groups. (For example, making a graph based on data contributed by all students in the class.)	5. Evidence - How do I know? Why am I making these claims?
6 Negotiation phase III - comparing science ideas to textbooks or other printed resources. (For example, writing group notes in response to focus questions.)	6. Reading - How do my ideas Compare with other ideas?
7 Negotiation phase IV - individual reflection and writing. (For example, creating a presentation such as a poster or report for a larger audience.)	7. Reflection - How have my ideas changed?
8. Exploration of post-instruction Understanding through concept mapping, group discussion, or writing a clear explanation.	8. Writing - What is the best explanation that explains what I have learned?

The template for student thinking prompts the learner to generate questions, claims and evidence for claims. It also prompts them to compare their laboratory findings with others, including their peers and information in the textbook, internet or other sources. The template for student thinking also prompts learners to reflect on how their own ideas have changed during the experience of the laboratory activity. While the SWH recognizes the need for student to conduct laboratory investigations that develop their understanding of scientific methods and procedures, the teacher's template also seems to provide a stronger pedagogical focus for this learning.

The SWH emphasizes the collaborative nature of scientific activity that is, scientific argumentation where learners are expected to engage in a continuous cycle of negotiation and clarifying meanings and explanations with their peers and teacher (Greenbowe, Hand &Rudd 2006). In other words, the SWH is designed to promote classroom discussion where students' personal explanations and observations are tested against the perceptions and contributions of the broader group.

The SWH promotes students' participations in setting their own investigative agenda for laboratory work, framing questions, proposing methods to address these questions and carrying out appropriate investigations, compared to the traditional laboratory approach which follows a narrow teacher agenda and does not allow for broader questioning or more diverse data interpretation. In the traditional laboratory practice where procedures are uniform for all students, data are similar and claims match expected outcomes, and then the reportage of results and conclusions often lacks opportunities for deeper student learning about the topic or for developing scientific reasoning skill. (Greenbowe, Hand & Rudd 2006).

Using the Science Writing heuristic is part of an instructional sequence, the format requires:

Guided inquiry activities

Interactive group work

Meaning making via a collective negotiated exchange of ideas and argumentation

Reflective writing (Burke, Greenbowe & Hand 2005).

A comparison of the SWH and traditional (conventional) laboratory format is shown on table 2.

Table 2: comparison between SWH laboratory format and conventional laboratory format

SWH format	**Traditional format**
Beginning questions	Title, purpose
Test and procedure	Procedure
Observations	Data and observations
Claims	Discussions
Evidence	Equations, calculations, graphs
Reflection/Reading	No equivalent

Self- efficacy

Self-efficacy coined by Albert Bandura is a person's belief in his or her ability to complete a future task or solve a future problem. Self-efficacy refers to an individual's belief that he or she can master a given situation and produce favourable outcomes (Bandura, 1997). An individual's self-efficacy influences his or her choice of tasks, level of performance, amount of effort put toward performance, and perseverance. Self-efficacy is typically divided into several different facets, including academic self-efficacy. Academic self-efficacy is the belief that students have in their ability to perform academic tasks (Usher & Pajares, 2006). It is a measure of the degree to which individuals feel confident in their ability to succeed, understand, and perform at an appropriate level in academics. Academic self-efficacy can be measured as a global construct or as several distinct domains (e.g., math self- efficacy, science self-efficacy, language arts self-efficacy). For example if a person believes he is a brilliant scientist and can complete any scientific experiment, he has a high self efficacy in science because he believes in his competency to perform a future experiment. Whether it is true that he is brilliant in science or not doesn't really matter, it only matters what he believes.

Self-efficacy can also influence one's goals, actions and successes (or failure) in life. If your self-efficacy in an area is much lower than your ability, you will never challenge yourself or improve. If your self- efficacy in an area is much higher than your ability, you will set goals that are too high, fail and possibly quit. The ideal self-efficacy is slightly above a person's ability: high enough to be challenging while still being realistic. When defining self-efficacy researchers tend to mention the same five key features. First it is an assessment of competence to perform a task not a judgment of personal qualities. Individuals are asked to judge how well they can perform a task not a judgment of personal qualities.

Second, self-efficacy is domain specific i.e individuals can be highly efficacious in one domain but express low self efficacy beliefs in another. Third, it is context dependent. The execution of a task can be influenced by things such as competition, physiological state and environment.

Self efficacy is measured before the task is performed. It reflects ones perception of capability in light of the task demands rather than how one feels having completed the activity. Self-efficacy measurement does not depend on normative data. Self- efficacy questionnaires require respondents to rate their level of certainty about their own ability to perform a task without making reference to the performance of others.

Likert scale questionnaires are often used to measure self-efficacy beliefs. In this way the level of the task, the strength and generality of self efficacy can be ascertained. Some self-efficacy research has used self-report rating scales in conjunction with concrete activities or examples of particular tasks. However, the context and subject-matter specific nature of self-efficacy means that self-efficacy beliefs may differ according to the subject that is being taught, the teacher that is teaching, the classmates that are present etc.

THEORETICAL FRAMEWORK

Theory of Constructivism

The theoretical framework for this study is both cognitive and social constructivism. The theory of constructivism looks at the way a learner learns. Constructivists believe that the learner learns best when he/she is actively engaged. The relationship between the constructivist theory and the study is that in using the SWH students are encouraged to use hands -on guided inquiry laboratory activities and collaborative group work to actively negotiate meaning and construct conceptual knowledge.

According to Caukin (2010) the cognitive processes utilized in writing are complex and require students to select, assimilate organize and construct thoughts and information. This is an art of construction.

Constructivists do not treat knowledge as a truth to be transmitted or discovered, but as an internal process of interpretation (Fosnot, 2005), The basic idea is that learners are not a blank slate on which to be written, but rather learners construct or build knowledge and skills. In this process, the learner uses preexisting knowledge and experiences to construct new ideas, (Huitt, 2003). Constructivists believe that knowledge is dynamic rather than static. Knowledge is a process and a pattern of action rather than an object. The belief is that knowledge is not transmitted to learners via symbols or that the understanding of the learners will be exactly the same as the teacher understands since all approach learning from different past experiences and understandings (Gagnon & Collay 2001).

Social Construction

Social construction not only acknowledges the uniqueness and complexity of the learner, but actually encourages, utilizes and rewards it as an integral part of the learning process (Wertsch 1997).

Social construction or socio-culturalism encourages the learner to arrive at his or her version of the truth, influenced by his or her background, culture or embedded worldview. Historical development and symbol systems, such as language, logic and mathematical systems are inherited by the learner as a member of a particular culture and these are learned throughout the learner's life. This also stresses the importance of the nature of the learner's social interaction with knowledgeable members of the society. Within the social interaction with other more knowledgeable people, it is impossible to not acquire social meaning of important symbol systems and learn how to utilize them. Young children develop their thinking abilities by interacting with other children, adults and physical worlds. From the social constructivist viewpoint, it is thus important to take into account the background and culture of the learner throughout the learning process, as this background also helps to shape the knowledge and truth that the learner creates discourse and attains in the learning process (Wertsch 1997).

Furthermore, it is argued that the responsibility of learning should reside increasingly with the learner (Glasersfeld 1989). Social constructivism thus emphasizes the importance of the learner being actively involved in the learning process, unlike previous educational viewpoints where the responsibility rested with the instructor to teach and where the learner played a passive receptive role.

Constructivist Theorists

Among the educators who have added new perspectives to constructivist learning theory and practical are Jerome Bruner, Lev Vygotsky, and David Ausubel. A major theme in the theoretical framework of Bruner is that learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge. The learner selects and transforms information; constructs hypotheses and makes decisions, relying on a cognitive structure to do so. Bruner initiated curriculum change based on the notion that learning is an active, social process in which students constructs new ideas or concepts based on their current knowledge.

Vygotsky introduced the social aspect of learning into constructivism. He defined the zone of “proximal learning” according to which students solve problems beyond their actual development level (but within their level of potential development) under adult guidance or in collaboration with more capable peers.

Ausubel a follower of Piaget believes that learning comes from actively interpreting experiences using certain cognitive processes. Ausubel differentiates between reception learning and discovery learning, which involves students conducting experiments, which is how they develop understanding (Driscoll 2005).

Science, Technology, Engineering and Mathematics (STEM) Self-Efficacy

Self-efficacy beliefs are developed through the interpretation of performance outcomes. These beliefs as listed in the Association of Women in Energy AWE information sheet (2008) are based on four primary sources of information: mastery experience, vicarious experience, social persuasion, and physiological reaction.

1. ***Mastery experience*** refers to previous experience and performance with a given task. Mastery experiences provide evidence of whether an individual has the capability to succeed. Successful outcomes boost self-efficacy whereas failures lower it. Research shows that mastery experiences are significant predictors of self-efficacy (Bandura, 1997; Britner & Pajares, 2006). Accordingly, practitioners should integrate "mastery experience" opportunities into STEM courses:

Incorporate into the course curriculum hands-on, laboratory-based activities and projects that require self-regulation.

Tailor activities to students' ability-level so that they are challenging but not impossible.

Structure activities to include proximal goals.

Maximize the impact of the mastery experience by providing feedback and encouragement (i.e., social persuasion)- help students interpret these experiences in ways that enhance self-efficacy.

2. ***Vicarious experience*** refers to learning through observing others perform a given task. Role models are especially influential when they are perceived as similar to the observer. This suggests that interactions with female faculty members and advanced students in STEM would positively affect the self-efficacy of female STEM students and individuals with little or no first-hand task experience. Indeed, opportunities to observe the successes of others are

influential for the development of STEM self-efficacy for girls and women (Zeldin & Pajares, 2000). Practitioners should

- create vicarious learning experiences that incorporate opportunities for students to observe the practice and performance of their peers and STEM professionals in STEM courses
- Assign group-work in which the groups are carefully composed of similar ability students. Ideally, at least one group member has slightly higher math or science skills and serves as a model to the other members of the group.
- Invite more advanced (e.g., high school, undergraduate, or graduate) STEM students and STEM professionals into classrooms to work with students (e.g., solving math problems or conducting a science experiment) or share their STEM experiences and success.
- Provide role models, which are particularly influential (i.e., positively affect students' self-efficacy) when students perceive similarities between the models and themselves. For instance, a girl's science self-efficacy is more positively affected by interacting with a young female chemist than an older male chemist.

*3. **Social persuasion*** refers to others' judgments, feedback, and support. Positive feedback and encouragement, especially from influential others (e.g., parents, teachers) enhances self-efficacy. Feedback and praise is most effective when the individual has ability, at least some confidence in his or her capabilities, and a belief that success is attainable. Social persuasion is particularly instrumental in the development and maintenance of girls' and women's STEM and career self-efficacy (AAUW, 1991; Seymour & Hewitt, 1997; Zeldin & Pajares, 2000). To increase STEM self efficacy, practitioners should:

Give feedback and support that is positive, genuine, appropriate, and realistic-students see through false praise.

Encourage students to persist despite difficulties and setbacks; success in STEM is the result of effort.

Inform parents and guardians of the importance of supporting their students, especially girls and young women in their STEM studies and interests and educate students and their families about the importance, value, and range of STEM fields and careers.

Emphasize that STEM fields and careers are not more appropriate for males than females. Provide students and their families with information about extra-curricular STEM activities, such as after-school clubs, camps, local lectures and exhibits, and encourage them to participate.

4. ***Physiological reaction*** also affects self-efficacy. An individual's self-efficacy is based in part on interpretation of his or her emotional and physical states during task preparation and performance. Feeling calm and composed, rather than nervous and worried, when preparing for and performing a task leads to higher self-efficacy. To reduce anxiety and apprehension, practitioners should:

Discuss the experience of math- and science-related anxiety with students and tell them that they can control their physiological reactions.

Teach students effective anxiety-management strategies, including breathing and visualization exercises, as well as relaxation techniques.

Encourage students to attend fully to the task at hand, which should reduce attention paid to apprehensions and fears thereby reducing task-related anxiety.

It is important that in addition to developing students' knowledge and skill, STEM practitioners help develop students' self-efficacy in STEM pursuits. Greater self-efficacy—belief in one's ability to attain a specific goal—leads to greater effort, performance, and persistence. For girls and women, the lack of self-efficacy potentially leads to the avoidance of STEM-related courses and careers (Pajares, 2005). Educators can best build students' STEM self-efficacy by providing them with STEM opportunities, experiences, and role models and by encouraging them to pursue STEM interests and persist despite difficulties.

Gender Differences in Academic Self Efficacy

Academic self-efficacy is an area that has been widely researched. Research has demonstrated that males and females have different experiences and differences in their academic self-efficacy throughout their education (Bornholt, Goodnow, & Cooney, 1994; Jacobs, 1991; Oakes, 1990; Simpkins, Davis-Kean, & Eccles, 2006). Males have more positive perceptions of their abilities in mathematics and science with regards to perceived current performance (Bornholt, Goodnow, & Cooney, 1994). Interestingly, males' higher beliefs about their abilities in mathematics and science continue to exist, despite the fact that males and females have consistently equal grades in mathematics and science (Oakes, 1990; Simpkins, Davis-Kean, & Eccles, 2006). Males and females also differ in how they view their future performance (Bornholt, Goodnow, & Cooney, 1994; Jacobs, 1991). Findings suggest that males' perceptions of their abilities in mathematics with regards to future performance are higher than females' perceptions of their abilities.

Females perceive their likely success in math and science courses to be lower, and consequently, fewer women choose to major in fields related to mathematics and science once they reach college.

Gender Differences in Math/Science Self-Efficacy

An individual's math/science self-efficacy can be impacted by family characteristics and values, gender role stereotypes held by their parents, and the individual's gender role type. Factors that contribute to an individual's math/science self-efficacy include family factors, gender-type socialization and gender role type.

Family Factors

Parents tend to believe that girls perceive mathematics and science as more difficult than do boys and that advanced mathematics and science courses are more important for boys than for girls (Oakes, 1990). Though parents may not explicitly state this belief, their children comprehend it by the actions they observe in their parents. For example, they may encourage their son to take an advanced math course, while encouraging their daughter to take advanced English instead; even though their daughter is equally skilled in math. Parent involvement, support, and encouragement can also have a strong influence on math and science self-efficacy and on later choice of mathematics and science related college majors (Catsambis, 2005). Mothers' employment and the nature of that employment can also influence their daughters' self-efficacy with regards to mathematics and science as well as whether their daughters will pursue careers relating to mathematics and science.

Gender-Type Socialization

The term gender-type socialization refers to how individuals learn what is deemed appropriate behaviour for males and females in a given society (Basow, 1992). The socialization of gender roles begins very early in a child's life with the agents of socialization being parents. As children grow older and begin school, peers and teachers reinforce gender roles and what is appropriate for each gender. Gender-type socialization by parents can also influence children's' academic self efficacy. Children learn from their parents, peers, and society in general what is appropriate for a certain gender. They also learn that subjects such as mathematics, science, and computer are viewed as masculine and that subjects such as humanities are viewed as feminine. Because of the stereotype placed on these subjects children tend to view themselves as more able in the areas traditionally attributed their own gender (Bronlow,Jacobi, & Rogers, 2000). When parents hold traditional views on gender roles they tend to provide different learning opportunities depending on the gender of their child (Eccles, 1994). When girls and women believe that "math = male," this can have a negative impact on their attitudes towards mathematics as well and their performance (Nosek, Banaji, & Greenwald, 2002). Because of these stereotypes, girls become less interested in mathematics and science and this can impair their performance in these subjects. However, when girls do not endorse gender stereotypes related to these subjects they are more likely to have higher perceptions of their abilities and perform better in these subjects (Schmader, Johns, & Barquissau, 2004).

In a study examining gender differences in attitudes toward math and science relative to arts and language, 83 undergraduate students were administered implicit attitude tasks, an implicit identity task, and a paper-pencil questionnaire to assess their feelings toward math and arts as academic domains (Nosek, Banaji, & Greenwald, 2002).

Results revealed a statistically significant difference between implicit attitudes toward maths/science depending on gender, with women showing more negative evaluations of math/science than did men. Women also had stronger negative attitudes toward math relative to arts and science. Women also identified more strongly with arts than with math, whereas men did not preferentially identify with either arts or math. These findings provide additional support to the idea that women come to view math and science more negatively because they internalize the negative stereotypes that society in general places on women and math/science.

The term gender role type refers to whether an individual considers himself or herself to be more masculine, feminine, androgynous, or undifferentiated

(Basow, 1992). An individual with a masculine gender role type will display characteristics traditionally attributed to males such as: independence, aggressiveness, dominance, logicalness, little emotionality, and adventurousness. An individual with a feminine gender role type will have characteristics traditionally attributed to females such as: dependence, passiveness, subjectiveness, and emotionality.

An individual with an androgynous gender role type will show high amounts of both masculine and feminine characteristics. An individual with an undifferentiated gender role type will show low amounts of both masculine and feminine characteristics.

Research on gender role type and math/science self-efficacy has been limited. Andre, Whigham, Hendrickson, and Chambers (1999) found that both boys and girls rated mathematics and science occupations as more male-dominated, with boys viewing these jobs as more male-dominated than did girls. This suggests that males and females may view the occupations as more masculine or more appropriate for an individual with a masculine gender role type. Eccles (1994) stated that children are so strongly assimilated into the "culturally defined gender role schema" and that it has a profound effect on how they view the world and as a result, activities that are classified as part of the opposite gender role are rejected without evaluation or reflection.

When students select a college major, their choices are influenced by the expectations of their families, their gender-type socialization, and their gender role type.

Self-Efficacy and Education

Self-efficacy beliefs have been shown to affect educational performance through their effects on motivation, achievement and self-regulation. Motivation studies have found that three indicators of motivation (choice of activities, persistence and level of effort) are influenced by self-efficacy beliefs. For example, Bandura and Schunk,(1981) found that children with a high sense of perceived self-efficacy were more likely to choose to continue with a task than children with low self-efficacy, Schunk (1981) found that children with a high sense of self-efficacy persisted longer and were more successful on difficult arithmetic tasks than children with low self-efficacy and Bandura, (1997) , found that children with a stronger sense of self-efficacy solved more problems and chose to rework more problems than children of the same ability who maintained a low sense of self-efficacy. To Bandura (1997) these studies show that "students may perform poorly either because they lack the skills or because they have the skills but lack the perceived personal efficacy to make optimal use of them".

Achievement studies have demonstrated that self-efficacy beliefs are positively correlated with academic achievement (e.g. Jinks and Morgan, 1999; Pajares and Schunk, 2001 and Zimmerman, Bandura, and Martinez-Pons, 1992).

Gender Differences in Science Achievement

Gender issues have been of concern to science educators over the years. The gender dimension of science and technology according to Okoli (2012) came as a result of series of reports on international conferences and concerns expressed by science and technology experts about the situation of women in the fields of natural science, education, health and food security. Literature on the influence of gender on students achievement in science usually presents varied results. In chemistry, studies by Caukin (2010), and Arnold (2011) showed no significant differences in the achievement of male and female students while the study by Okwo & Otuba (2007) found a difference in the achievement of male and female students. Such inconclusive results show that in explaining achievement in science, gender as a variable continues to be important and significant.

Science Laboratory Practical Teaching

Practical works in chemistry are usually carried out in the laboratory which is a place equipped for experimental works. The importance of practical chemistry according to Achimugu (2012) includes among other things helping students develop science process skills, promoting the development of scientific attitudes, enhancing better understanding of concepts and principles and by so doing contributing to students achievement in chemistry. Chemistry curricula often emphasize the use of discovery or inquiry approach of teaching chemistry which emphasizes practical works in chemistry. Unfortunately many chemistry teachers shy away from conduct of practical work and even when they do, they follow a rigid pattern of experimentation leaving the students with little understanding of the scientific principles underlying the experiment.

The use of an inquiry approach in the science classroom allows teachers and students learn how to do science, learn the nature of science and learn science content (Arnold 2011). Through the process of inquiry, students enhance their understanding of the natural world around them and develop their science process skills. As students encounter science in an inquiry-based setting, they become more actively involved in their discovery, which in turn allows them to become more responsible for their own learning.

Review of Empirical Studies

Effectiveness of the Science Writing Heuristic (SWH)

Various studies on the effectiveness of the science writing heuristic (SWH) have been carried out in different fields of science including chemistry, physics, biology etc as well as self-efficacy surveys in different domains including sciences.

A study on implementing POGIL (Process Oriented Guided Inquiry Learning) in the lecture and the science writing heuristic in the laboratory: student perceptions and performance in undergraduate organic chemistry by Schroeder and Greenbowe (2008) investigated the possible connection between effective laboratory activities and student performance on lecture exams in an undergraduate organic chemistry course for non science majors in Iowa State USA. The study implemented POGIL activities in an organic chemistry course and the science writing heuristic in the laboratory to replace the standard lecture format and verification laboratory experiments. The performance of the study group was compared to the performance of the traditional group. For qualitative analysis a survey was given at the beginning of the course to gauge student perception of the format and what their expectations were for the course. An evaluation was given at the end of the course to see whether student perceptions had been changed as a result of the course.

The study focused on student performance on nucleophilic substitution reaction mechanisms on a class exam and their performance compared with 111 who had previously taken the course using the traditional approach. Performance on the question improved compared with students in past traditional classes. The result showed that while using the SWH format, students in the study group were more confident in attempting the problems and in terms of performance performed much better on the exams compared with the traditional group.

A study on Science Writing Heuristic a writing-to-learn strategy and its effect on students' science achievement, science self-efficacy, and scientific epistemological view was done by Caukin in 2010. The study was a mixed method study involving quasi experimental design and interviews. Data were collected for quantitative and qualitative analysis. The study involved secondary honours chemistry students in Tennessee with twenty three (23) students in the study group and eight (8) in the control group for a period of five (5) weeks on the study of gases. The treatment group received the instructional strategy known as the science writing heuristic and the control group received traditional teacher-centred science instruction. Forty-two (42) multiple choice tests on gas laws were used. Interview was also conducted as the qualitative portion of the study. Analysis was done with ANOVA. The results showed that females in the treatment group outscored their male counterparts by 11% on the science achievement portion of the study and the males in the control group had a more constructivist scientific epistemological view after the study than the males in the treatment group. Two representative students, one male one female, were chosen to participate in a case study for the qualitative portion of the study. Results of the case study showed that these students constructed meaning and enhanced their understanding of how gases behave, had a neutral (male) or positive (female) perception of how employing Science Writing Heuristic helped them to learn, had a favourable experience that positively influenced their self-confidence in science, and increased their scientific literacy as they engaged in science as scientists do.

A study on using the science writing heuristic approach as a tool for assessing and promoting students' conceptual understanding and perceptions in the general chemistry laboratory by Mohammed, (2007) examined the impact of implementing SWH (inquiry based approach) in a general chemistry lab on non-science major students' understanding of chemistry concepts and students perceptions towards writing in science and implementing SWH. This study was conducted in a large University in the Midwest of the United States in a college freshman chemistry laboratory for non-science major students. The study was based on quasi experimental mixed-method designs. Results from the study indicated that implementing the SWH approach has notably enhanced both male and female conceptual understanding and perception toward chemistry and implementing SWH. The findings also showed that implementing SWH helped closing the gap between male and female who started the semester with a statistically significant lower level of conceptual understanding of chemistry concepts among females than males.

Another study on using the Science Writing heuristic approach to promote student understanding in chemical changes and mixtures by Kingir, (2011) was done to investigate the effect of science writing heuristic (SWH) on 9^{th} grade students' understanding of chemistry concepts and chemistry achievement in chemical changes and mixtures unit. Four 9^{th} grade classes taught by two chemistry teachers from a public school in Turkey were selected for the study. Each teacher's one intact class was assigned as the experimental group and the other class was assigned as the control group. The experimental group had 33 males and 29 females while the control group had 30 males and 30 females. A quasi experimental design was used for a 10 -week period.

Pre-and-post-achievement tests having 22 multiple choice questions and an attitude test were administered (as well as interviews for some students). The quantitative data were analyzed using multivariate analysis of covariance (MANCOVA). The results revealed that the SWH approach was superior to the traditional approach on students understanding of the concept. The interviews results showed that students in experimental groups developed positive attitudes towards chemistry. There was no significant interaction effect between treatment and ability level on post achievement test.

A study by Arnold (2011) examined the effects of the use of the Science Writing Heuristic (SWH) on student learning in High School Chemistry in the United States. The study utilized a quasi experimental research design using a pre- post test design. The control group used a traditional directed inquiry approach and the treatment group used a guided inquiry approach based on the SWH. 67 students participated in the study with 36 students in the experimental group and 31 students in the control group. Teacher constructed test consisting of 11 multiple choice questions on gas laws and a Science Reasoning Test SRT consisting of 40 multiple choice questions were used as the research instruments. The study lasted for fifteen days. Data were analyzed using ANCOVA. Results showed that there were no significant learning gains in the treatment group (SWH) as compared to the control group with regard to either conceptual understanding of the gas laws or in student scientific reasoning ability.

Application of SWH in Different Fields of Science

A study on the effect of implementation of science writing heuristic on students' achievement and attitudes towards laboratory in introductory physics laboratory was conducted by Erkol;, Kisoglu and Buyukkasap in 2010. The study was carried out in Science Education department in a University in Eastern Turkey using 42 students with 20 in control group and 22 in experimental group. The impact of the SWH was investigated using students physics achievement in mechanical unit. The study employed 40 multiple choice questions and 3 concept questions.

The study utilized a quasi experimental design that lasted for for 8 weeks. Analysis of the data was done using independent samples t-test method. Results of the study indicated that the SWH approach significantly increased students' mechanic unit achievement, conceptual understanding of the unit and attitudes toward laboratory.

Hand, Wallace and Yang (2004) conducted a study to determine the quantitative impact of the SWH on student learning and to collect qualitative data regarding students' conceptual understanding. The study utilized a quasi-experimental design to evaluate the performance of 93 7^{th} grade students on tests of conceptual understanding of the cell. The study used 34 multi-choice questions for pre and post test and three conceptual essay questions. The data were analyzed using ANCOVA. The results showed that the experimental group outperformed the control group on the multiple choice questions.

Studies on Science Self-Efficacy

In a study on effects of inquiry-based learning on students' science literacy skills and confidence by Brickman, Gormally, Armstrong, Hallor (2009), undergraduate students of Georgia University were used for introductory biology class for non-science majors. A total of 1300 students were used in groups of 20 and data were collected over to consecutive semesters from 72 lab sections. Pre-test and Post-test scores were obtained. A science literacy assessment of 30 multiple choice questions instruments was used, with the reliability of 0.73 and 0.63 using a cronbach alpha analysis.

The inquiry and traditional lab student pre and post-test scores in science literacy assessment were analysed using ANCOVA. A self-efficacy survey created and validated by Baldwin, Ebert-May & Burns (1999) was used to measure how confident non-biology major students were in their ability to understand and do science. ANOVA was used to determine whether students in inquiry and traditional labs differed in confidence in their ability to carry out certain types of scientific activities. Significant differences between lab types were examined using Tukey's Honestly significant difference (HSD)_ means separation test while ANCOVA was additionally used to determine whether all student populations (females, males, minorities) reported similar gains in confidence in scientific abilities.

The result of the study showed greater improvement in students' science literacy and research skills using inquiry lab. instruction. It was also found that inquiry students gained self-confidence in scientific abilities, but traditional students gain was greater-likely indicating that the traditional curriculum promoted over-confidence.

Summary of related literature reviewed

In this chapter attempt was made at reviewing literature related to the study. The chapter reviewed the conceptual framework of the study where the concepts of science writing heuristic and self-efficacy were reviewed. The instructional approach of science writing heuristic was seen as a guided inquiry laboratory approach which enables students make meaning from their laboratory investigations. It was found that this heuristic approach promotes students' participation and understanding of their laboratory work when compared to the conventional (traditional) laboratory practice which often lacks opportunities for deeper students learning of science concepts.

The theoretical framework of the review was based on cognitive and social constructions in learning. The assumption of constructivism is that knowledge is not fixed, but rather is constructed by individual based on their own experiences. The constructivist learning theories by Bruner, Vygotsky and Ausubel were discussed.

Effects of the SWH on students' achievement in various fields of science were reviewed. It was found that SWH significantly increased students' achievement in the fields of chemistry, physics and Biology. Literature on self-efficacy was reviewed and it was found that self-efficacy beliefs affect educational performance through their effects on motivation, achievement and self-regulation. It was also found that males and females differed in their self-efficacy beliefs. The review showed that studies in SWH and self-efficacy are not exhaustive especially for studies conducted locally in Nigeria. It is expected that this work will provide the gap that exists with respect to Nigerian studies.

CHAPTER THREE

METHOD

This chapter presents the research design, area of study, population of the study, sample and sampling technique, instruments for data collection, validation of instruments, reliability of the instruments, method of data collection, experimental procedure and method of data analysis.

Research Design

This study adopted a quasi-experimental research design. Specifically it used the non- equivalent control group design. A quasi-experiment is an experiment where random assignment of subjects to experimental and control groups is not possible (Nworgu, 2006). A quasi experimental design was considered appropriate because the subjects were not randomly assigned to experimental or control group. While individual students were not chosen at random, the chemistry class that received the SWH treatment and the one that did not receive the treatment were chosen at random. Choosing groups at random rather than based on convenience from the relevant population helps to reduce the bias associated with Non-equivalent control group design.

Experimental design

Group	Pre-test	Treatment	Post-test
Experimental Gr 1	O_1	X_1	O_2
………………………………………………………………………...			
Control Gr 2	O_1	X_2	O_2

Where O_1 (Pre-test) = O_2 (Post-test)

X_1 = SWH treatment
X_2 =Conventional laboratory treatment

Area of the Study

The study was carried out in Anambra State. Anambra state is in the South Eastern part of Nigeria. The state's boundaries are formed by Delta state to the West, Imo state and Rivers state to the south, Enugu state to the East and Kogi state to the North. There are two Colleges of Education in Anambra State –Federal College of Education (Technical), Umunze and Nwafor Orizu College of Education Nsugbe. Umunze is a fast growing urban town in Anambra state while Nsugbe is an urban town. The two schools offer Nigeria Certificate in Education (NCE) and Degree programmes in chemistry in affiliation with Universities. The schools have a large number of students in the NCE programme where practical chemistry is taught.

Population of the study

The population of the study was all second year chemistry students in NCE programme in all Colleges of Education in South East Nigeria. The total number of second year chemistry students enrolled in the ten Colleges was six hundred and fifty (650) for the 2014/2015 academic session which made up the population of the study.

(NCCE Statistical Digest 2013)

Sample and Sampling Techniques

All the second year chemistry students numbering one hundred and twenty-five (125) constituted the sample for the study. (See sample distribution in appendix A, P. 110). In sampling Anambra state was sampled from five states in the south east Nigeria. The entire population of NCE year two chemistry students in the two Colleges of Education in Anambra state was one hundred and twenty five (125). One College was assigned to SWH treatment group and the other to the conventional laboratory (control) group using a flip of the coin.

Instrument for Data Collection

Two instruments were used to collect data namely Achievement Test on Redox Reactions (ATORR) and Questionnaire on Students' Ability to Do Science (QSADS). The ATORR comprised thirty-five (35) multiple choice questions on redox reactions with questions weighted as shown in the table of specifications (see appendix J, p. 192).

Self-efficacy in science was measured by the Questionnaire on Students Ability to do Science (QSADS) structured on a 5-point scale with 1 - Not very well 2 - partially well, 3 - undecided, 4 - moderately well and 5 - very well.

Students' belief in their ability to do science questionnaire was adapted from the task specific self-efficacy questionnaire regarding scientific inquiry developed by Webb-Williams (2006). The original instrument by Webb-Williams (2006) was modified with questions on self-efficacy in scientific inquiry reframed for students of Colleges of Education.

Validation of Instruments

Two experts in science education (chemistry) and one expert in measurement and evaluation validated the instruments ATORR and QSADS. One expert in Educational psychology validated the QSADS. This was done to ensure that the instruments had both face and construct validity. For the ATORR, the experts were specifically requested to examine:

i. The extent to which the questions on the achievement test ATORR measured students' achievement in redox reactions.

ii. The suitability of the questions in terms of coverage, versatility and students' level of study with respect to the lesson plans.

For the QSADS the experts were requested to examine the extent to which the items on the questionnaire QSADS measure students' self-efficacy with respect to science inquiry. The experts examined

i. The clarity of the questions
ii. The conformity of the questions to a task specific (science inquiry) self-efficacy.

Following the validation of the instruments, the items on the achievement test (ATORR) were reviewed and thirty-five out of the thirty-six questions were finally chosen to constitute the achievement test on redox reactions ATORR (see appendix B, P. 111). The corrections on the questionnaire on students' ability to do science QSADS were effected to give the 15-item questionnaire (see appendix C, P. 118).

The validators' comments are shown in appendix L.

Reliability of the Instruments

The instruments ATORR and QSADS were trial-tested on a sample of thirty five (35) students from Alvan Ikoku Federal College of Education (AIFCE) Owerri before the study began. The students were second year chemistry students in NCE programme. The thirty five (35) students in the college were administered the two instruments ATORR and QSADS once. The reliability of ATORR was established through the use of Kuder Richardson formula 21 (K-R 21) and found to be 0.80 as shown in appendix

F, p.156 to establish the internal consistency of the ATORR. Kuder Richardson formula 21 (K-R 21) is a measure of internal consistency for measures with dichotomous choices. K-R 21 is usually applied for items of homogenous or uniform difficulty/facility (Nworgu, 2006). For the questionnaire on student's ability to do science QSADS, Cronbach's Alpha was used to establish internal consistency of the instrument and it was found to be 0.84 as shown in appendix G, p. 158. The use of Cronbach's alpha for determining the reliability of the instrument QSADS is preferred since according to Ali (2006), Cronbach's Alpha can be used for internal consistency reliability calculation when the test items are non-dichotomous, that is no response is deemed correct or wrong.

Method of Data Collection

Data were collected using a pre-test and post test that were administered with the help of research assistants. The questionnaire was administered alongside the achievement test. The pre-test was given at the beginning of the semester. The pre-test was given to determine if there were any pre-existing differences between the experimental group and the control group. The experimental group used the SWH while the control group used the conventional mode of laboratory practical.

Experimental Procedure

Prior to the commencement of the quasi experiment, two intact classes of NCE second year chemistry in the two Colleges were randomly assigned the experimental and control groups respectively. At the beginning of the experiment, the test instruments– ATORR and QSADS were administered as pre-test to the two groups.

Between the pre and post tests, students participated in the semester course CHE 213- chemistry practical (iv) (redox titrations) with the instructional modes-Science Writing Heuristic SWH for the experimental group and the conventional laboratory practical for the control group (structured laboratory).

Laboratory practical on redox titration was done for a period of six weeks for the experimental group and control group. 1st year Cumulative Grade Point Average (CGPA) was used to establish a base line ability level for the treatment and control groups. Where CGPA of 3.50 and above was considered high ability, 2.40 - 3.49 was middle ability and from 1.00 to 2.39 is low ability.

For the experimental group, the strategy involved students brainstorming independently, participating in group discussions, designing laboratory experiences with their group members, collecting data, analyzing results, making claims based on evidence, sharing results, reflecting on their experiences in writing, and ultimately creating a written piece demonstrating their understanding. (See Appendix E, p. 144 and Appendix K, p. 193).

The control group was guided by procedure given by the teacher as contained in the lesson note in appendix D, p.121 and followed the conventional laboratory practice of reporting on the purpose (title), methods, observations, results and conclusions. Upon completion of the laboratory activities, the post test and questionnaire were administered.

Control of Extraneous Variables

1 **Experimenter bias**

This occurs when the researcher is biased when he administers treatment. To avoid experimenter bias, the regular class teachers taught their students in both the experimental and control groups. Lesson plans for the experimental and control groups were used by the teachers. See SWH grading rubric and rubric grid for instructors according to Burke, Hand, Poock & Greenbowe (2005) appendix K, p. 193.

2 **Hawthorne effect.**

Hawthorne effect arises from a study groups reaction to the special attention given rather than to the treatment itself, (Mitchell and Jolley 1988). To reduce this, the actual classroom teachers participated in the study. The practical classes were held during the actual time allocated in the school time table.

The individual students for the study were from intact NCE second year chemistry classes which were chosen because their semester work on practical chemistry dealt with redox titrations.

3 **Effect of pre-test on post-test.** The time between the pre-test and post-test was six weeks. This was considered long enough for the pre-test not to affect the post-test.

Scoring of the Instruments ATORR and QSADS

Each item answered correctly on the ATORR was scored one (1) while a wrongly answered question had no score. Total score was 35. See appendix I, p. 191. The QSADS had a five point rating scale with

Very well	-	5 points
Moderately well	-	4 points
Undecided	-	3 points
Partially well	-	2 points
Not very well	-	1 point

Method of Data Analysis

The research questions were analysed using means and standard deviations. The hypotheses were tested using (2 x 2 x 3) Analysis of Covariance ANCOVA at the 0.05 level of significance. 2 x 2 x 3 represents the variables

Treatment	-	SWH and conventional laboratory Instructional modes (2)
Gender	-	Male and female (2)
Ability level	-	Low, middle and high (3)

The statistical analysis (ANCOVA) was chosen because it is often difficult to attribute any differences in groups to any one single variable when performing educational research. It helps a researcher to partial out initial differences in the subjects and gives results based on knowledge gained. Merther and Vannatta (2002) suggested that statistical analysis of variance (ANOVA) tends to ignore the effect of other variables on the dependent variable. Based on many factors involved in student learning, the use of an ANCOVA as a statistical tool is preferred.

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

This chapter presents the results of the study. The presentation of the results is according to the research questions and hypotheses.

Research Question 1

What are the mean scores of chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes?

Table 3: The mean and standard deviations of students' scores in SWH and conventional laboratory instructional modes

	Pre-Test		Post-Test		
Group	N	Mean	SD	Mean	SD	Mean Gain

Pre-Test Post-Test Group N Mean SD Mean SD Mean Gain Control

47 7.72 3.81 14.77 3.18 7.05 Experimental

78 10.10 4.16 23.12 3.78 13.02

Pre-Test Post-Test Group N Mean SD Mean SD Mean Gain Control

47 7.72 3.81 14.77 3.18 7.05 Experimental

78 10.10 4.16 23.12 3.78 13.02

Pre-Test Post-Test Group N Mean SD Mean SD Mean Gain Control

47 7.72 3.81 14.77 3.18 7.05 Experimental

78 10.10 4.16 23.12 3.78 13.02

Post-Test Group N Mean SD Mean SD Mean Gain Control

47 7.72 3.81 14.77 3.18 7.05 Experimental

78 10.10 4.16 23.12 3.78 13.02

Group N Mean SD Mean SD Mean Gain Control

47 7.72 3.81 14.77 3.18 7.05 Experimental

78 10.10 4.16 23.12 3.78 13.02

Group N Mean SD Mean SD Mean Gain Control

47 7.72 3.81 14.77 3.18 7.05 Experimental

78 10.10 4.16 23.12 3.78 13.02

Group N Mean SD Mean SD Mean Gain Control

47 7.72 3.81 14.77 3.18 7.05 Experimental

78 10.10 4.16 23.12 3.78 13.02

N Mean SD Mean SD Mean Gain Control

47 7.72 3.81 14.77 3.18 7.05 Experimental

78 10.10 4.16 23.12 3.78 13.02

Mean SD Mean SD Mean Gain Control

47 7.72 3.81 14.77 3.18 7.05 Experimental

78 10.10 4.16 23.12 3.78 13.02

SD Mean SD Mean Gain Control
47 7.72 3.81 14.77 3.18 7.05 Experimental
78 10.10 4.16 23.12 3.78 13.02

Mean SD Mean Gain Control 47 7.72 3.81 14.77 3.18 7.05 Experimental
78 10.10 4.16 23.12 3.78 13.02
SD Mean Gain Control 47 7.72 3.81 14.77 3.18 7.05 Experimental
78 10.10 4.16 23.12 3.78 13.02
Mean Gain Control 47 7.72 3.81 14.77 3.18 7.05 Experimental
78 10.10 4.16 23.12 3.78 13.02
Control 47 7.72 3.81 14.77 3.18 7.05 Experimental
78 10.10 4.16 23.12 3.78 13.02
Control 47 7.72 3.81 14.77 3.18 7.05 Experimental
78 10.10 4.16 23.12 3.78 13.02
47 7.72 3.81 14.77 3.18 7.05 Experimental
78 10.10 4.16 23.12 3.78 13.02
7.72 3.81 14.77 3.18 7.05 Experimental
78 10.10 4.16 23.12 3.78 13.02
3.81 14.77 3.18 7.05 Experimental 78 10.10 4.16 23.12 3.78 13.02
14.77 3.18 7.05 Experimental 78 10.10 4.16 23.12 3.78 13.02
3.18 7.05 Experimental 78 10.10 4.16 23.12 3.78 13.02
7.05 Experimental 78 10.10 4.16 23.12 3.78 13.02
Experimental 78 10.10 4.16 23.12 3.78 13.02
Experimental 78 10.10 4.16 23.12 3.78 13.02
78 10.10 4.16 23.12 3.78 13.02
10.10 4.16 23.12 3.78 13.02
4.16 23.12 3.78 13.02
23.12 3.78 13.02
3.78 13.02
13.02

Table 3 shows that the mean post-test score of experimental group was 23.12 with standard deviation of 3.78 while that of control group was 14.77 with standard deviation of 3.18. It was observed that the mean gain of the experimental group was higher than that of the control group.

Research Question 2

What are the mean achievement scores of male and female chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes?

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Table 4: The mean and standard deviations of male and female students' achievement scores in SWH and conventional method

Group Gender N Pre-test Mean SD Post-test Mean SD Mean
Gain □Control Male 10 8.30 3.62 16.70 2.11 8.40 □ Female 37 7.57 3.89 14.24 3.24 6.
67 □Experimental Male 14 9.57
5.26 24.29 2.73 14.72 □ Female 64 10.22
3.92 22.86 3.95 12.64 □

Gender N Pre-test Mean SD Post-test Mean SD Mean
Gain □Control Male 10 8.30 3.62 16.70 2.11 8.40 □ Female 37 7.57 3.89 14.24 3.24 6.
67 □Experimental Male 14 9.57
5.26 24.29 2.73 14.72 □ Female 64 10.22
3.92 22.86 3.95 12.64 □

N Pre-test Mean SD Post-test Mean SD Mean
Gain □Control Male 10 8.30 3.62 16.70 2.11 8.40 □ Female 37 7.57 3.89 14.24 3.24 6.
67 □Experimental Male 14 9.57
5.26 24.29 2.73 14.72 □ Female 64 10.22
3.92 22.86 3.95 12.64 □

Pre-test Mean SD Post-test Mean SD Mean
Gain □Control Male 10 8.30 3.62 16.70 2.11 8.40 □ Female 37 7.57 3.89 14.24 3.24 6.
67 □Experimental Male 14 9.57
5.26 24.29 2.73 14.72 □ Female 64 10.22
3.92 22.86 3.95 12.64 □

SD Post-test Mean SD Mean
Gain □Control Male 10 8.30 3.62 16.70 2.11 8.40 □ Female 37 7.57 3.89 14.24 3.24 6.
67 □Experimental Male 14 9.57
5.26 24.29 2.73 14.72 □ Female 64 10.22
3.92 22.86 3.95 12.64 □

Post-test Mean SD Mean
Gain Control Male 10 8.30 3.62 16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
SD Mean
Gain Control Male 10 8.30 3.62 16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
Mean
Gain Control Male 10 8.30 3.62 16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
Control Male 10 8.30 3.62 16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
Control Male 10 8.30 3.62 16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
Male 10 8.30 3.62 16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24
10 8.30 3.62 16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67
8.30 3.62 16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57 5.26 24.29 2.73 14.72 Female 64 10.22
3.92 22.86 3.95 12.64
3.62 16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57 5.26 24.29 2.73 14.72 Female 64 10.22
3.92 22.86 3.95 12.64
16.70 2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57 5.26 24.29 2.73 14.72 Female 64 10.22
3.92 22.86 3.95 12.64
2.11 8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57 5.26 24.29 2.73 14.72 Female 64 10.22
3.92 22.86 3.95 12.64
8.40 Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57 5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
Female 37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
37 7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
7.57 3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
3.89 14.24 3.24 6.67 Experimental Male 14 9.57
5.26 24.29 2.73 14.72 Female 64 10.22 3.92 22.86 3.95 12.64
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3.24 6.67 ?Experimental Male 14 9.57
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6.67 ?Experimental Male 14 9.57
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Experimental Male 14 9.57 5.26 24.29 2.73 14.72 ? Female 64 10.22
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14 9.57 5.26 24.29 2.73 14.72 ? Female 64 10.22
3.92 22.86 3.95 12.64 ?
9.57 5.26 24.29 2.73 14.72 ? Female 64 10.22 3.92 22.86 3.95 12.64 ?
5.26 24.29 2.73 14.72 ? Female 64 10.22 3.92 22.86 3.95 12.64 ?
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? Female 64 10.22 3.92 22.86 3.95 12.64 ?
Female 64 10.22 3.92 22.86 3.95 12.64 ?
Female 64 10.22 3.92 22.86 3.95 12.64 ?
64 10.22 3.92 22.86 3.95 12.64 ?
10.22 3.92 22.86 3.95 12.64 ?
3.92 22.86 3.95 12.64 ?
22.86 3.95 12.64 ?
3.95 12.64 ?
12.64 ?
?

It was observed from table 4 that for the control group the mean post-tes score for the male was 16.70 while that of the female was 14.24. The mea gain score of the male was higher than the female mean gain score in th control group. Also, it was observed from table 4 that for the experimenta group the mean post-test score for the male was 24.29 while that of the femal was 22.86. It was observed that there is a difference between the mea achievement scores of male and female students taught redox reactions usin SWH and conventional laboratory instructional modes.

Research Question 3

What are the mean scores of students of low, middle and high ability taught redox reactions using SWH and those taught using conventional laboratory instructional modes.

Table 5: The mean and standard deviations of students' achievement scores by ability level in SWH and conventional laboratory instructional modes

Group	GPA range	N	Pre-Test	SD	Post-test	SD	Mean gain
Control	Low ability	20	4.40	2.04	13.45	3.49	9.05
	Middle ability	16	9.13	1.26	15.25	1.84	6.12
	High ability	11	11.73	3.69	16.45	3.39	4.72
Experimental	Low ability	13	9.46	3.10	20.31	2.66	10.85
	Middle ability	36	10.00	4.04	23.50	4.13	13.50
	High ability	29	10.52	4.76	23.90	3.24	13.38

GPA range N Pre-Test SD Post-test SD Mean gain Control Low
ability 20 4.40 2.04 13.45 3.49 9.05 Middle
ability 16 9.13 1.26 15.25 1.84 6.12 High
ability 11 11.73 3.69 16.45 3.39 4.72 Experimental Low
ability 13 9.46 3.10 20.31 2.66 10.85 Middle
ability 36 10.00 4.04 23.50 4.13 13.50 High
ability 29 10.52 4.76 23.90 3.24 13.38
N Pre-Test SD Post-test SD Mean gain Control Low
ability 20 4.40 2.04 13.45 3.49 9.05 Middle
ability 16 9.13 1.26 15.25 1.84 6.12 High
ability 11 11.73 3.69 16.45 3.39 4.72 Experimental Low

ability139.463.1020.312.6610.85 Middle
ability3610.004.0423.504.1313.50 High
ability2910.524.7623.903.2413.38
Pre-TestSDPost-testSDMean gain ControlLow
ability204.402.0413.453.499.05 Middle
ability169.131.2615.251.846.12 High
ability1111.733.6916.453.394.72 ExperimentalLow
ability139.463.1020.312.6610.85 Middle
ability3610.004.0423.504.1313.50 High
ability2910.524.7623.903.2413.38
SDPost-testSDMean gain ControlLow
ability204.402.0413.453.499.05 Middle
ability169.131.2615.251.846.12 High
ability1111.733.6916.453.394.72 ExperimentalLow
ability139.463.1020.312.6610.85 Middle
ability3610.004.0423.504.1313.50 High
ability2910.524.7623.903.2413.38
Post-testSDMean gain ControlLow ability204.402.0413.453.499.05 Middle
ability169.131.2615.251.846.12 High
ability1111.733.6916.453.394.72 ExperimentalLow
ability139.463.1020.312.6610.85 Middle
ability3610.004.0423.504.1313.50 High
ability2910.524.7623.903.2413.38
SDMean gain ControlLow ability204.402.0413.453.499.05 Middle
ability169.131.2615.251.846.12 High
ability1111.733.6916.453.394.72 ExperimentalLow
ability139.463.1020.312.6610.85 Middle
ability3610.004.0423.504.1313.50 High
ability2910.524.7623.903.2413.38
Mean gain ControlLow ability204.402.0413.453.499.05 Middle
ability169.131.2615.251.846.12 High
ability1111.733.6916.453.394.72 ExperimentalLow
ability139.463.1020.312.6610.85 Middle
ability3610.004.0423.504.1313.50 High
ability2910.524.7623.903.2413.38
ControlLow ability204.402.0413.453.499.05 Middle
ability169.131.2615.251.846.12 High
ability1111.733.6916.453.394.72 ExperimentalLow
ability139.463.1020.312.6610.85 Middle
ability3610.004.0423.504.1313.50 High
ability2910.524.7623.903.2413.38
ControlLow ability204.402.0413.453.499.05 Middle

ability�16�9.13�1.26�15.25�1.84�6.12� �High
ability�11�11.73�3.69�16.45�3.39�4.72� �������� Experimental�Low
ability�13�9.46�3.10�20.31�2.66�10.85� �Middle
ability�36�10.00�4.04�23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
Low ability�20�4.40�2.04�13.45�3.49�9.05� �Middle
ability�16�9.13�1.26�15.25�1.84�6.12� �High
ability�11�11.73�3.69�16.45�3.39�4.72� �������� Experimental�Low
ability�13�9.46�3.10�20.31�2.66�10.85� �Middle
ability�36�10.00�4.04�23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
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ability�11�11.73�3.69�16.45�3.39�4.72� �������� Experimental�Low
ability�13�9.46�3.10�20.31�2.66�10.85� �Middle
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ability�11�11.73�3.69�16.45�3.39�4.72� �������� Experimental�Low
ability�13�9.46�3.10�20.31�2.66�10.85� �Middle
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ability�11�11.73�3.69�16.45�3.39�4.72� �������� Experimental�Low
ability�13�9.46�3.10�20.31�2.66�10.85� �Middle
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�Middle ability�16�9.13�1.26�15.25�1.84�6.12� �High
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6.12� �High ability�11�11.73�3.69�16.45�3.39�4.72� ������� Experimental�Low
ability�13�9.46�3.10�20.31�2.66�10.85� �Middle
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ability�13�9.46�3.10�20.31�2.66�10.85� �Middle
ability�36�10.00�4.04�23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
3.39�4.72� ������� Experimental�Low
ability�13�9.46�3.10�20.31�2.66�10.85� �Middle
ability�36�10.00�4.04�23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
4.72� ������� Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle
ability�36�10.00�4.04�23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�

�������� Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

�������� Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

������� Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

������ Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

����� Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

���� Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

��� Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

�� Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

� Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

Experimental�Low ability�13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

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13�9.46�3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High ability�29�10.52�4.76�23.90�3.24�13.38�

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3.10�20.31�2.66�10.85� �Middle ability�36�10.00�4.04�23.50�4.13�13.50� �High

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ability�29�10.52�4.76�23.90�3.24�13.38�
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ability�36�10.00�4.04�23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
�Middle
ability�36�10.00�4.04�23.50�4.13�13.50� �High
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ability�36�10.00�4.04�23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
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10.00�4.04�23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
4.04�23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
23.50�4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
4.13�13.50� �High
ability�29�10.52�4.76�23.90�3.24�13.38�
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ability�29�10.52�4.76�23.90�3.24�13.38�
�High ability�29�10.52�4.76�23.90�3.24�13.38�
�High ability�29�10.52�4.76�23.90�3.24�13.38�
High ability�29�10.52�4.76�23.90�3.24�13.38�
29�10.52�4.76�23.90�3.24�13.38�
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4.76�23.90�3.24�13.38�
23.90�3.24�13.38�
3.24�13.38�
13.38�

▯ Table 5 shows that the post-test scores of low, middle and high ability students of control group were 13.45, 15.25, and 16.45 with sta deviations of 3.49, 1.84, and 3.39 respectively while the post- test scores of middle and

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Table 5 shows that the post-test scores of low, middle and high a students of control group were 13.45, 15.25, and 16.45 with standard deviatic 3.49, 1.84, and 3.39 respectively while the post- test scores of low, middle anc high ability students of experimental group were 20.31, 23.50, and 23.90

standard deviations of 2.66, 4.13, and 3.24 respectively. The mean gains c experimental group were higher than the mean gains of the control group. I therefore observed that the mean achievement scores of the low, middle and ability students in the experimental group were higher than those of the c group.

Research Question 4

What are the self-efficacy scores of chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes?

Table 6: The mean and standard deviations of students' self-efficacy scores in SWH and conventional laboratory instructional modes

Group	N	Pre-self efficacy Mean	Pre-self efficacy SD	Post-self efficacy Mean	Post-self efficacy SD	Mean Gain
Control	47	3.79	0.55	3.27	0.29	-0.52
Experimental	78	3.56	1.10	3.58	1.06	0.02

Pre-self efficacy Post-self efficacy Group N Mean SD Mean SD Mean Gain Control 47 3.79 0.55 3.27 0.29 -0.52 Experimental 78 3.56 1.10 3.58 1.06 0.02
Pre-self efficacy Post-self efficacy Group N Mean SD Mean SD Mean Gain Control 47 3.79 0.55 3.27 0.29 -0.52 Experimental 78 3.56 1.10 3.58 1.06 0.02

Post-self
efficacy Group N Mean SD Mean SD Me
an Gain Control 47 3.79 0.55 3.27 0.29 -
0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
Group N Mean SD Mean SD Mean
Gain Control 47 3.79 0.55 3.27 0.29 -
0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
Group N Mean SD Mean SD Mean
Gain Control 47 3.79 0.55 3.27 0.29 -
0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
Group N Mean SD Mean SD Mean
Gain Control 47 3.79 0.55 3.27 0.29 -
0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
N Mean SD Mean SD Mean Gain Control
47 3.79 0.55 3.27 0.29 -0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
Mean SD Mean SD Mean Gain Control
47 3.79 0.55 3.27 0.29 -0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
SD Mean SD Mean Gain Control
47 3.79 0.55 3.27 0.29 -0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
Mean SD Mean Gain Control
47 3.79 0.55 3.27 0.29 -0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
SD Mean Gain Control
47 3.79 0.55 3.27 0.29 -0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
Mean Gain Control
47 3.79 0.55 3.27 0.29 -0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
Control 47 3.79 0.55 3.27 0.29 -
0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
Control 47 3.79 0.55 3.27 0.29 -
0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
47 3.79 0.55 3.27 0.29 -0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
3.79 0.55 3.27 0.29 -0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
0.55 3.27 0.29 -0.52 Experimental
78 3.56 1.10 3.58 1.06 0.02
3.27 0.29 -0.52 Experimental

78 3.56 1.10 3.58 1.06 0.02
0.29 -0.52 Experimental 78 3.56 1.10 3.58 1.06 0.02
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Experimental 78 3.56 1.10 3.58 1.06 0.02
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1.06 0.02
0.02

Table 6 shows that the mean post self-efficacy score of experimental group was 3.58 with standard deviation of 1.06 while that of control group was 3.27 with standard deviation of 0.29. It was observed from the mean gain in self-efficacy scores that the experimental group scored higher than the control group.

Research Question 5

What are the self-efficacy scores of male and female students taught redox reactions using SWH and those taught using conventional laboratory instructional modes?

Table 7: The mean and standard deviations of male and female students' self-efficacy scores in SWH and conventional laboratory instructional modes

Group Gender N Pre-self efficacy SD Post -self efficacy SD Mean Gain Control Male 10 3.33 0.95 3.75 0.47 0.42 Female 37 3.94 0.96 3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60 1.12 0.12 Female 64 3.60

1.09 3.54 1.11 -0.06 □
Gender N Pre-self efficacy SD Post -self efficacy SD Mean
Gain □Control Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96
3.80 0.58 -
0.14 □Experimental Male 14 3.48 0.95 3.60 1.12 0.12 □ Female 64 3.60
1.09 3.54 1.11 -0.06 □
N Pre-self efficacy SD Post -self efficacy SD Mean
Gain □Control Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96
3.80 0.58 -
0.14 □Experimental Male 14 3.48 0.95 3.60 1.12 0.12 □ Female 64 3.60
1.09 3.54 1.11 -0.06 □
Pre-self efficacy SD Post -self efficacy SD Mean
Gain □Control Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96
3.80 0.58 -
0.14 □Experimental Male 14 3.48 0.95 3.60 1.12 0.12 □ Female 64 3.60
1.09 3.54 1.11 -0.06 □
SD Post -self efficacy SD Mean
Gain □Control Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96
3.80 0.58 -
0.14 □Experimental Male 14 3.48 0.95 3.60 1.12 0.12 □ Female 64 3.60
1.09 3.54 1.11 -0.06 □
Post -self efficacy SD Mean
Gain □Control Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96
3.80 0.58 -
0.14 □Experimental Male 14 3.48 0.95 3.60 1.12 0.12 □ Female 64 3.60
1.09 3.54 1.11 -0.06 □
SD Mean
Gain □Control Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96
3.80 0.58 -
0.14 □Experimental Male 14 3.48 0.95 3.60 1.12 0.12 □ Female 64 3.60
1.09 3.54 1.11 -0.06 □
Mean
Gain □Control Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96
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1.09 3.54 1.11 -0.06 □
□Control Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96 3.80
Control Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96 3.80 0
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Male 10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96 3.80 0.58 -
0.14 □Experimental Male 14 3.48 0.95 3.60 1.12 0.12 □ Female 64 3.60
1.09 3.54 1.11 -0.06 □
10 3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96 3.80 0.58 -
0.14 □Experimental Male 14 3.48 0.95 3.60 1.12 0.12 □ Female 64 3.60
1.09 3.54 1.11 -0.06 □
3.33 0.95 3.75 0.47 0.42 □ Female 37 3.94 0.96 3.80 0.58 -

0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
0.95 3.75 0.47 0.42 Female 37 3.94 0.96
3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
3.75 0.47 0.42 Female 37 3.94 0.96 3.80
0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
0.47 0.42 Female 37 3.94 0.96 3.80 0.58
-
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
0.42 Female 37 3.94 0.96 3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
Female 37 3.94 0.96 3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
Female 37 3.94 0.96 3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
Female 37 3.94 0.96 3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
37 3.94 0.96 3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
3.94 0.96 3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
0.96 3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60
1.12 0.12 Female 64 3.60 1.09 3.54 1.
11 -0.06
3.80 0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60

1.12 0.12 Female 64 3.60 1.09 3.54 1.11 -0.06
0.58 -
0.14 Experimental Male 14 3.48 0.95 3.60 1.12 0.12 Female 64 3.60
1.09 3.54 1.11 -0.06
-
0.14 Experimental Male 14 3.48 0.95 3.60 1.12 0.12 Female 64 3.60
1.09 3.54 1.11 -0.06
Experimental Male 14 3.48 0.95 3.60 1.12 0.12 Female 64 3.60 1.09
Experimental Male 14 3.48 0.95 3.60 1.12 0.12 Female 64 3.60 1.09 3.
54 1.11 -0.06
Male 14 3.48 0.95 3.60 1.12 0.12 Female 64 3.60 1.09 3.54 1.11 -
0.06
14 3.48 0.95 3.60 1.12 0.12 Female 64 3.60 1.09 3.54 1.11 -0.06
3.48 0.95 3.60 1.12 0.12 Female 64 3.60 1.09 3.54 1.11 -0.06
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3.60 1.12 0.12 Female 64 3.60 1.09 3.54 1.11 -0.06
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0.12 Female 64 3.60 1.09 3.54 1.11 -0.06
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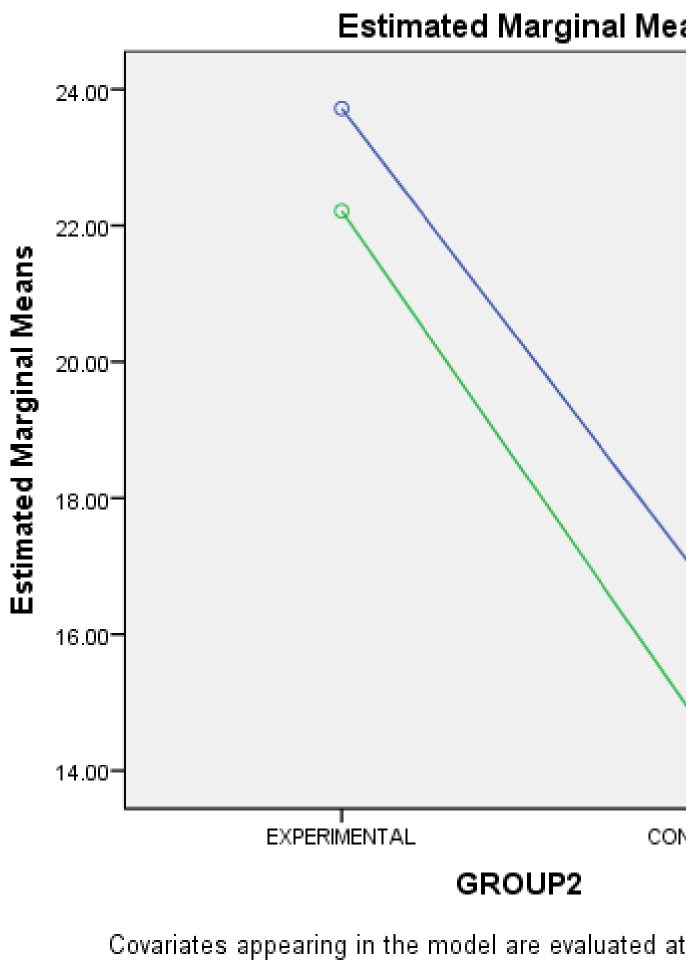
Female 64 3.60 1.09 3.54 1.11 -0.06
Female 64 3.60 1.09 3.54 1.11 -0.06
64 3.60 1.09 3.54 1.11 -0.06
3.60 1.09 3.54 1.11 -0.06
1.09 3.54 1.11 -0.06
3.54 1.11 -0.06
1.11 -0.06
-0.06

It was observed from Table 7 that for the control group the mean post self-efficacy score for the male was 3.75 while that of the female was 3.80. The mean gain for the male was higher than that of the female. Also, it was observed from Table 7 that the mean post-self-efficacy score for the male was 3.60 in experimental group which is higher than the female mean post self-efficacy score of 3.54. It was observed that there was a slight difference between the mean self-efficacy scores of male and female students taught redox reactions using SWH and conventional laboratory instructional modes.

Research Question 6

What is the interaction effect between treatment and gender on the achievement of chemistry students in redox reactions using SWH and conventional laboratory instructional modes?

Fig I: Interaction effect between treatment and gender on the achievement of NCE students' in redox reactions

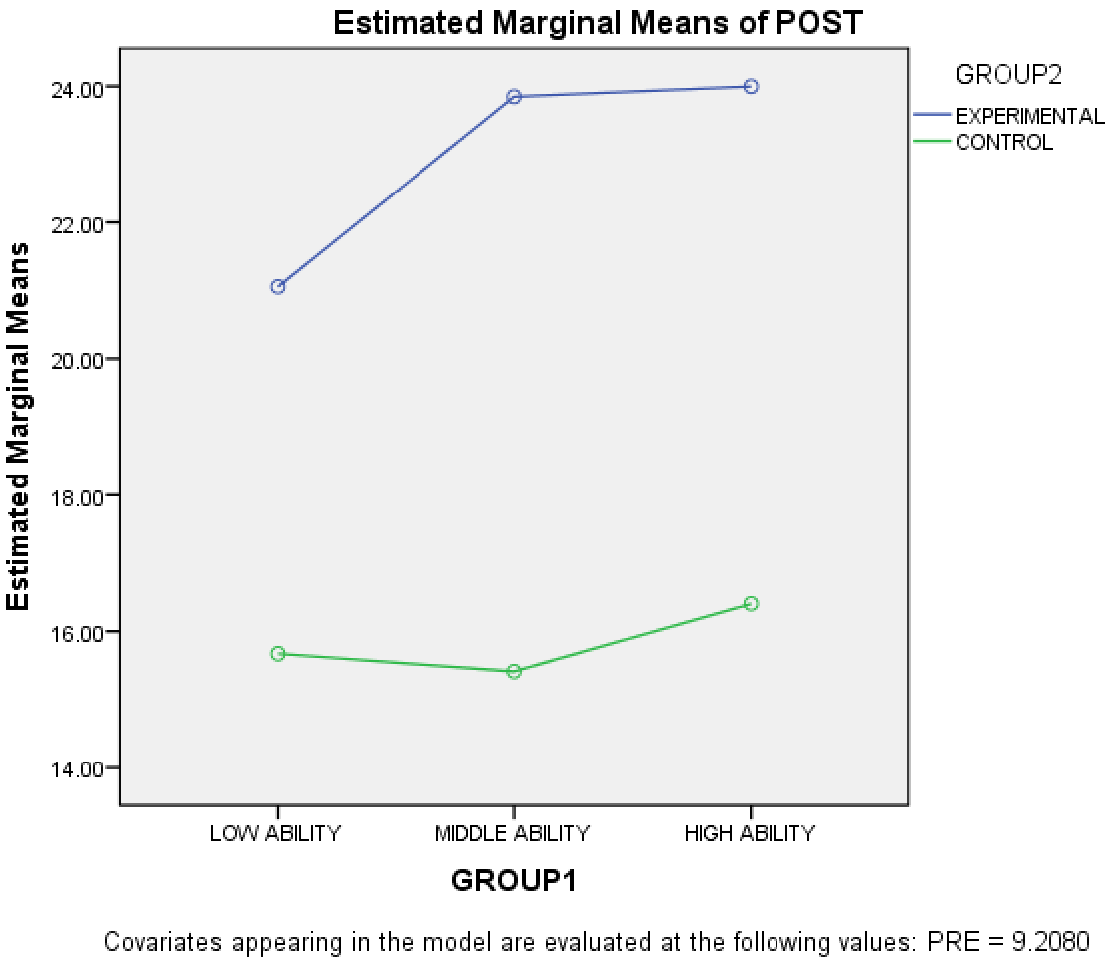


According to figure I, male and female students performed closer to each other on post-test in the experimental than control group. There was a difference between male and female students' scores in both experimental and control group. Males scored higher than females in the experimental and control group.

Research Question 7

What is the interaction effect between treatment and ability level on the achievement of students using SWH and conventional laboratory instructional modes?

Fig II: Graph showing no Interaction effect of treatment and Ability level on students achievement



According to Fig II, low, medium and high ability level students performed closer to each other on post-test in the experimental group but in the control group, there were differences among low, medium and high ability level. High ability level scored higher than medium ability level, and medium ability level scored higher than low ability level in the control group. In addition, the mean difference between experimental and control group in high ability level was the greatest and that of low ability level was the smallest.

Research Question 8

What is the interaction effect among treatment, gender and ability level on chemistry students' mean achievement scores in redox reactions?

Fig III (a):Graph showing no Interaction effect of treatment (experimental group), gender and ability level on students achievement

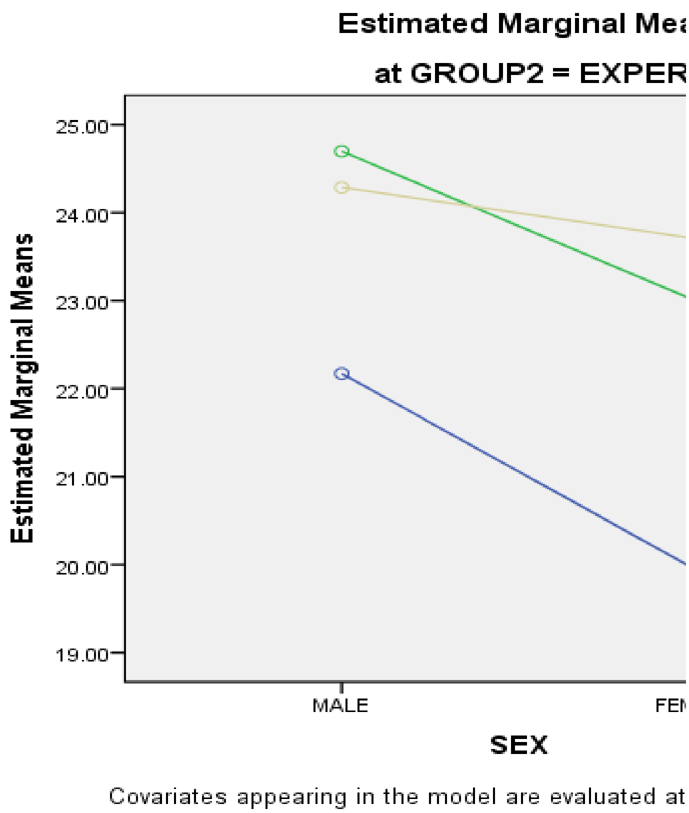
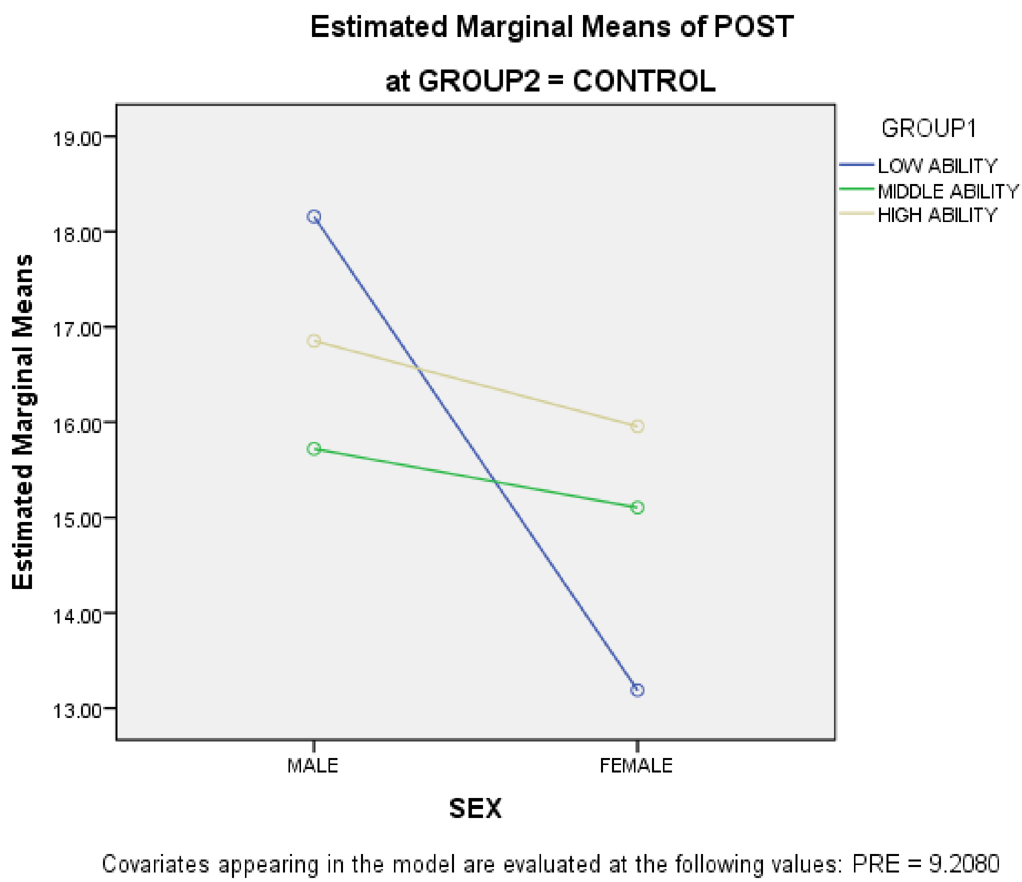


Fig III (b): Graph showing no Interaction effect of treatment (control group), gender and ability level on students achievement



According to fig III (a), there was interaction effect between middle and high ability level of students in the experimental group on gender, there was no interaction effect between low and middle ability level of students and there was no interaction effect between low and high ability level of students in the experimental group on gender. Therefore, there was no interaction effect among the treatment (experimental group), gender and ability level of NCE students on chemistry students' mean achievement scores in redox reactions.

According to fig. III (b), there was interaction effect between low and high ability level of students in the control group on gender, there was interaction effect between low and middle ability level of students and there was no interaction effect between middle and high ability level of students in the control group on gender. Therefore, there was no interaction effect among the treatment (control group), gender and ability level of NCE students on chemistry students' mean achievement scores in redox reactions.

In all, there was no interaction effect among the treatment, gender and ability level of NCE students on chemistry students' mean achievement scores in redox reactions.

Research Hypothesis 1

H_o1: There is no significant difference in the mean achievement scores of chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.

The data (scores) collected through the pre-test and post-test of the ATORR were subjected to computer analysis using the Analysis of Covariance (ANCOVA). The result is presented in table 8.

Table 8: Summary of three –way Analysis of Covariance (ANCOVA) on

the effects of the treatment, gender and ability level on students achievement

Source of Variation Sum of Squares Degree of Freedom Mean Square F Sig. of F Corrected
Model 2347.752[a] 12 195.646 17.320 0.000
Sum of Squares Degree of Freedom Mean Square F Sig. of F Corrected
Model 2347.752[a] 12 195.646 17.320 0.000
Degree of Freedom Mean Square F Sig. of F Corrected
Model 2347.752[a] 12 195.646 17.320 0.000
Mean Square F Sig. of F Corrected
Model 2347.752[a] 12 195.646 17.320 0.000
F Sig. of F Corrected
Model 2347.752[a] 12 195.646 17.320 0.000
Sig. of F Corrected
Model 2347.752[a] 12 195.646 17.320 0.000
Corrected
Model 2347.752[a] 12 195.646 17.320 0.000
Corrected
Model 2347.752[a] 12 195.646 17.320 0.000
2347.752[a] 12 195.646 17.320 0.000 Intercep
t 5014.811 1 5014.811 443.937 0.000 Pre-
Test 15.645 1 15.645 1.385 0.242 Ability
level 27.925 2 13.963 1.236 0.294 Treatme
nt 786.138 1 786.138 69.593 0.000 Gender
3.587 1 3.587 .271 .604 Treatment *
ability
level 24.917 2 12.458 1.103 0.335 Ability
level *
gender 21.440 2 10.720 0.949 0.390 Treat
ment *
gender 1.675 1 1.675 0.148 0.701 Ability
level * treatment *
gender 9.984 2 4.992 0.442 0.644 Error 1
265.176 112 11.296 Total 53493.000 12
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Table 8 shows that the F-value for treatment was found to be 69.593 with significance of F at 0.000. This means that at 0.05 level of significance the difference in the mean achievement scores of NCE chemistry students taught redox reactions is significant since 0.05>0.000 hence the null hypothesis is rejected.

Research Hypothesis 2

H_o2: There is no significant difference in the mean achievement scores of male and female chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.

Table 8 shows that the F-value for gender was found to be 0.271 with significance of F at 0.604. This means that at 0.05 level of significance the difference in the mean achievement between male and female chemistry students taught redox reactions using SWH and conventional laboratory instructional modes is not significant since 0.05 < 0.604 hence the null hypothesis is accepted.

Research Hypothesis 3

H_o3: There is no significant difference in the mean achievement scores of chemistry students of low, middle and high ability taught redox reactions using SWH and those taught using conventional laboratory instructional modes

Table 8 shows that the F-value for ability level was found to be 1.236 with significance of F at 0.294. This means that at 0.05 level of significance the difference in the mean achievement of chemistry students taught redox reactions using SWH is not significant since 0.05 < 0.294 hence the null hypothesis is accepted.

Research Hypothesis 4

H_o4: There is no significant difference in the science self-efficacy of chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.

The data (scores) collected through the pre-self efficacy and post-self efficacy of the QSADS were subjected to computer analysis using the (ANCOVA). The computer was used to statistically analyse the data for any significant difference in the mean science self-efficacy of the experimental and control groups. The result is presented in table 9.

Table 9: Summary of three –way Analysis of Covariance (ANCOVA) on the effects of the treatment and control, ability level and gender on students science self-efficacy

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F	Sig. of F
Corrected Model	51.112[a]	12	4.259	8.190	0.000
Intercept	18.489	1	18.489	35.551	0.000
Pre-self efficacy	47.016	1	47.016	90.403	0.000
Ability level	0.146	2	0.073	0.140	0.869
Treatment	0.131	1	0.131	0.253	0.616

Sum of Squares Degree of Freedom Mean Square F Sig. of F Corrected

Model 51.112[a] 12 4.259 8.190 0.000 Interc
ept 18.489 1 18.489 35.551 0.000 Pre-self
efficacy 47.016 1 47.016 90.403 0.000 Abil
ity
level 0.146 2 0.073 0.140 0.869 Treatment
0.131 1 0.131 0.253 0.616 Gender 0.667
1 0.667 1.283 0.260 Treatment * ability
level 1.547 2 0.774 1.488 0.230 Ability
level *
gender 0.568 2 0.284 0.546 0.581 Treatme
nt *
gender 0.188 1 0.188 0.361 0.549 Ability
level * treatment *
gender 0.287 2 0.144 0.276 0.759 Error 5
8.248 112 0.520 Total 1768.647 125

Degree of Freedom Mean Square F Sig. of
F Corrected

Model 51.112[a] 12 4.259 8.190 0.000 Interc
ept 18.489 1 18.489 35.551 0.000 Pre-self
efficacy 47.016 1 47.016 90.403 0.000 Abil
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level 0.146 2 0.073 0.140 0.869 Treatment
0.131 1 0.131 0.253 0.616 Gender 0.667
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level *
gender 0.568 2 0.284 0.546 0.581 Treatme
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gender 0.188 1 0.188 0.361 0.549 Ability
level * treatment *
gender 0.287 2 0.144 0.276 0.759 Error 5
8.248 112 0.520 Total 1768.647 125

Mean Square F Sig. of F Corrected

Model 51.112[a] 12 4.259 8.190 0.000 Interc
ept 18.489 1 18.489 35.551 0.000 Pre-self
efficacy 47.016 1 47.016 90.403 0.000 Abil
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0.131 1 0.131 0.253 0.616 Gender 0.667
1 0.667 1.283 0.260 Treatment * ability
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level *
gender 0.568 2 0.284 0.546 0.581 Treatme
nt *
gender 0.188 1 0.188 0.361 0.549 Ability
level * treatment *
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8.248 112 0.520 Total 1768.647 125

F Sig. of F �Corrected
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Table 9 shows that the F-value for treatment was found to be 0.253

with significance of F at 0.616. This means that at 0.05 level of significance the difference in the science self-efficacy of chemistry students taught redox reactions using SWH and conventional laboratory instructional modes is not significant since 0.05<0.616 hence the null hypothesis is accepted.

Research Hypothesis 5

H_o5: There is no significant difference in the science self-efficacy of male and female chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.

Table 9 shows that the F-value for gender was found to be 1.283 with significance of F at 0.260. This means that at 0.05 level of significance the difference in the science self-efficacy between male and female chemistry students taught redox reactions using SWH is not significant since 0.05<0.260 hence the null hypothesis is accepted.

Research Hypothesis 6

H_o6: There is no significant interaction effect between treatment and gender on the achievement of chemistry students in redox reactions.

Table 8 shows that the interaction effect between treatment and gender had an F-value of 0.148 with significance of F at 0.701. This means that at 0.05 level of significance, the interaction effect between treatment and gender was not significant since $0.05<0.701$ hence the null hypothesis is accepted.

Research Hypothesis 7

H_o7: There is no significant interaction effect between treatment and ability level on the achievement of chemistry students in redox reactions.

Table 8 shows that the interaction effect between treatment and ability level has an F-value of 1.103 with significance of F at

0.335. This means that at 0.05 level of significance, the interaction effect between treatment and ability level is not significant since 0.05<0.335 hence the null hypothesis is accepted.

Research Hypothesis 8

H_o8: There is no significant interaction effect among treatment, gender and ability level on the achievement of NCE chemistry students in redox reactions.

Table 8 shows that the interaction effect among treatment, gender and ability level had an F-value of 0.442 with significance of F at 0.644. This means that at 0.05 level of significance the interaction effect among treatment, gender and ability level was not significant since 0.05<0.644 hence the null hypothesis is accepted.

Summary of Major Findings

The findings of the study from the research questions and hypotheses are summarized as follows:

1. There is a significant difference in the mean achievement scores of

chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.

2. There is no significant difference in the self-efficacy of chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.
3. There is no significant difference in the mean achievement scores of male and female chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.
4. There is no significant difference in the mean achievement scores of chemistry students of low, middle and high ability taught redox reactions using SWH and those taught using conventional laboratory instructional modes
5. There is no significant difference in the self-efficacy of male and female chemistry students taught redox reactions using SWH and those taught using conventional laboratory instructional modes.
6. There is no significant interaction effect between treatment and gender on the achievement of chemistry students in redox reactions.
7. There is no significant interaction effect between treatment and ability level on the achievement of chemistry students in redox reactions.
8. There is no significant interaction effect among treatment, gender and ability level on the achievement of chemistry students in redox reactions.

CHAPTER FIVE

DISCUSSION OF RESULTS, CONCLUSION AND RECOMMENDATIONS

In this chapter the discussion of results, conclusion, implications of the study, recommendations, limitations of the study and suggestions for further research were presented. The discussion is done under the following sub-headings.

- the effect of science writing heuristic on chemistry students' achievement in redox reactions.
- the effect of SWH on students' self-efficacy in redox reactions.
- effect of SWH and conventional laboratory instructional modes on the achievement of male and female students.
- effect of SWH and conventional

laboratory instructional modes on the achievement of students of different ability levels.

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- the effect of SWH and conventional laboratory instructional modes on self-efficacy of male and female students.
- the interaction effect of treatment, gender and ability level on students achievement.

The educational implications of the findings, conclusions, recommendations, suggestions for further studies, limitations and summary of the work are also shown in this chapter.

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Effect of the SWH on chemistry students' achievement

The result of the analysis on table 8 revealed that students taught redox reactions using SWH significantly achieved higher than those taught with the conventional method, F = 69.593 with significance of F at 0.000. This result agrees with some earlier research findings on the relationship that exists between some instructional strategies in teaching redox reactions and achievement in redox reactions. This is in line with Schroeder and Greenbowe (2008) who discovered in their study that connection exists between effective laboratory activities and student performance.

This result also agrees with Mohammed (2007) whose study also revealed a significant difference in the mean achievement scores of students taught chemistry concepts using SWH instructional strategy and those taught using the conventional laboratory instruction in Chemistry. From these previous works and the findings of the present study, it is certain that there is a strong relationship between instructional strategy and achievement in science. Students achievement in chemistry is enhanced when teachers make use of inquiry laboratory practices. This could be due to the fact that the use of inquiry laboratory practices fosters positive classroom interaction and participation. Teachers need to identify different instructional strategies and utilize them for better achievement in Chemistry. Results of the present work also agree with the findings of Erkol, Kisoglu and Buyukkasap (2010) whose findings showed that the SWH approach significantly increased students' achievement in physics, conceptual understanding and attitudes towards laboratory.

The difference in achievement between the students taught redox reactions using SWH and conventional laboratory instructional modes may be due to the differences between the classroom activities provided in the SWH and conventional laboratory approaches. In the experimental group that used SWH, students brainstormed on their laboratory work using discussions in the argument based inquiry activities. Students were actively involved in negotiating meaning based on their laboratory results and making claims. The control group used a teacher centered instructional approach in which students were not given opportunity to be actively involved in negotiating meaning from their laboratory experiments.

Although the findings of Arnold (2011) indicated no significant learning gains in her study that investigated the impact of the SWH on student learning in high school chemistry, the reason attributed by the author was on the short duration of her study that lasted for only fifteen (15) days and the number of units she worked on, that is on the timing and duration of her study. The SWH fosters conducive classroom environment and positive classroom interaction and participation. The emphasis for the SWH approach is that it is more student centred, with teachers providing opportunity for students to be involved in building scientific arguments, debating claims and evidence, and knowledge construction through individual, small group and whole class settings. The SWH approach creates an environment such that students can use their own daily language to make connections to scientific concepts which is more meaningful to them.

Science achievement and gender

In Table 8, it can be seen that there is no significant difference in the mean achievement scores of male and female chemistry students taught redox reactions using SWH and conventional laboratory instructional modes**,** F=0.271 with significance of F at 0.604 This finding is in line with the findings of Brickman, Gormally, Armstrong & Haller (2009). They discovered in their study that there was no significant gender difference in the post test performance of the experimental group taught introductory Biology using SWH and conventional laboratory instructional modes notwithstanding the difference that existed in the pretest result in favour of the male. Caukin (2010) and Arnold (2011) also found that gender was not a significant factor on students' achievement in chemistry. These indicate that with the use of any good instructional strategy, male and female students will achieve equally. The science writing heuristic enhances the performance of both male and female students. The Science Writing Heuristic (SWH) could therefore be seen as an effective means of bridging the gender gap in chemistry achievement. Teachers should thus modify the teaching environment with the help of instructional strategies to ensure that gender differences are eliminated.

SWH and achievement of students of different ability levels

The result of the analysis in Table 8 revealed that there is no significant difference in the mean achievement scores of chemistry students of low, middle and high ability taught redox reactions using SWH and conventional laboratory instructional modes, F = 1.236 with significance of F at 0.294. This finding is in line with Adesoji (2008) who found in his study that there was no significant difference in the performance of students in the three ability levels after receiving a problem-solving instructional strategy. It could be argued that the disparity in the ability levels of students in science may be due to poor teaching technique. Adoption of inquiry-based instructional technique by teachers in chemistry teaching would go a long way in improving students' achievement in science. The finding of the study is also in line with Caukin (2010) in which students of different ability levels showed no significant difference in their achievement. However the result of the study differs from the findings of Akkus, Gunel and Hand (2010) who compared the effectiveness of the SWH on students post test scores in relation to achievement level and teachers' implementation of the approach. Results from their study showed that low ability students benefited most from the implementation of the SWH approach. This may be attributed to the level of implementation of the SWH approach as the instruction was categorized into high, middle and low implementation.

SWH and Science Self-Efficacy

In Table 9, it was revealed that there is no significant difference in the self-efficacy of chemistry students taught redox reactions using SWH and conventional laboratory instructional modes F=0.253 with significance of F at 0.616. This finding is in line with the finding of Caukin (2010) who discovered in her study that there was no statistically significant difference in science self-efficacy of students who received the SWH instructional approach and those who did not.

The SWH and the conventional

laboratory instructional mode appeared to have influenced the students' self-efficacy in science. Although students taught redox reactions using SWH appeared to have greater post self-efficacy scores the difference is not significant. It could be argued that the inquiry laboratory though it was more student centred may have been more tasking to the students and the conventional laboratory may have promoted students confidence. This assertion was seen in the study by Brickman, Gormally, Armstrong & Haller (2009) where students exposed to inquiry and conventional laboratory practices showed no significant difference in their confidence, although students in the conventional group were found to have greater confidence.

This means that the tasking nature of the inquiry laboratory may have influenced the self-efficacy of students as do physiological states like anxiety and fear in line with Britner and Pajares' (2006) assertion that perception of mastery experiences and social persuasions influence self-efficacy.

Science self-efficacy and gender

Table 9 shows that there is no significant difference in the science self-efficacy of male and female chemistry students taught redox reactions using SWH and conventional laboratory instructional modes, F = 1.283 with significance of F at 0.260. Comparing the self-efficacy scores of males and females in Table 7 resulted in no statistically significant difference. In the control group from pre to post self-efficacy score we have the males' mean score increasing from 3.33 to 3.75 and females' scores dropped from 3.94 to 3.80 while in the experimental group from pre to post self-efficacy scores, males' scores increased from 3.48 to 3.60 and females dropped from 3.60 to 3.54. Males in the control group scored a little less than males in the experimental group in the post self-efficacy scores. The females in the experimental group scored less than females in the control group. These findings are in line with Caukin (2010).This indicates that no matter the instructional strategy employed by the teacher gender is not a significant factor on the science self-efficacy of the students.

Interaction effect between treatment (instructional approach) and gender on students achievement

The results on table 8 revealed no significant interaction effect between treatment (instructional approach) and gender on students' achievement. F = 0.148 with significance of F at 0.701. This means that the effect of the instructional approach with respect to achievement is consistent across gender. This implies that male and female students equally benefit from the SWH instructional approach. This is further illustrated in figure 1 where the two lines indicating male and female did not cross. This finding is consistent with the findings of Kingir (2011), showing that with good instructional approach male and female students benefit equally.

The interaction effect between treatment and ability level on students achievement

The interaction effect of treatment and ability level on students' achievement was not significant. F = 1.103 with significance of F at 0.335 as shown on table 8. This means that with an effective instructional approach low achieving students benefit as much as medium and high achieving

students. Further illustration is seen on figure 2 where the lines did not cross for the ability levels in the experimental and control groups.

The interaction effect among treatment, gender and ability level on students achievement

The interaction effect among treatment,

gender and ability level was not significant, F=0.442 with significance of F at 0.644 as shown on table 8. This means that without the interaction, students can benefit maximally from the SWH instructional approach not influenced by gender or ability level.

Conclusion

The use of the Science Writing Heuristic (SWH) by chemistry teachers enhances students achievement in chemistry. The experimental group in the study was taught redox reactions using the science writing heuristic and they had a significantly higher achievement score than the control group taught the same topic using conventional laboratory instructional approach. The study however showed no significant difference in the mean achievement score of male and female students as well as students of different ability levels. Students in the experimental and control groups did not significantly differ in their science self-efficacy. Male and female students did not differ significantly in their science self-efficacy. The science writing heuristic is therefore an effective instructional approach in teaching science concepts and helps to bridge the gender gap in science achievement.

Educational Implications

The findings of the study have educational implications.

There is need to move students away from a cookbook approach in science laboratory practical to science as inquiry. This will help students make connections between their explanations, their evidence and their questions and between their laboratory practice in schools and science encountered in their day to day living.

Emphasis of SWH is on communication of claims made and how they compare with current scientific understandings. In the light of science achievement gap that may exist between males and females and between students of different ability levels effective teaching strategies that enhance students' achievement and self-efficacy in science are needed.

There is need to channel teacher practices from perceived traditional ways of teaching to move to inquiry-based approaches. The implication is that there is need for professional development of teachers especially in teacher education institutions.

Improving the self-efficacy through instruction implies that students have to be provided with inquiry-based science investigations that are scaffolded to help students experience mastery of science skills and thus increase their science self-efficacy.

Research has shown that self-efficacy is directly related to academic achievement. Britner & Pajares (2006), Rosen (2008), found that self-efficacy is a significant predictor of science achievement. The result of the study showed that students increased in their science self-efficacy through the SWH instructional approach. It is necessary, therefore, that teachers effectively use science instructions that are inquiry based to help students increase their self-efficacy and hence achievement in science. If teachers could develop a strong sense of efficacy in their students the students will achieve better. Teachers need to ensure that they positively influence their students' self-efficacy beliefs bearing in mind that when teachers give tasks to students one of the first things that children do is assess their capability to successfully complete the given activity. If a child believes he/she lacks the required capability and confidence to perform the task then he/she will be less motivated, less likely to sustain effort, and more likely to expect failure of the task.

Recommendations

Based on the findings of this study, the following recommendations are made.

1. Curriculum planners should emphasize inquiry science teaching and provide concrete examples and activities to be carried out in science teaching and learning.
2. Science teachers should ensure that in their laboratory practical teaching they shift from the traditional or conventional cook book practices to more student centered inquiry laboratory. They are to encourage students to experience a wide variety of practical situations in which they can apply their knowledge of the principles and concepts in science.
3. Students should be taught to express their understanding of scientific concept in language that is clear, concise and correct. This is to enhance their understanding of basic science concepts through their questions and claims in a laboratory setting.
4. Teacher Education programmes are to expose prospective science

teachers to inquiry laboratory through their methods courses and training so that they can apply such in their own classroom settings beginning from basic science teaching.

5. Equal opportunities for science should be given to male and female students for greater achievement in science.
6. Training manual on the science writing heuristic can be developed by the Science Teachers' Association of Nigeria (STAN) to assist teachers in using inquiry in their laboratory practical work.

Limitations of the Study

The study had a number of limitations

1. The study was conducted with only 125 students indicating a small proportion of NCE students. This could limit the generalization of the findings.
2. Multiple choice tests only were used to evaluate chemistry achievement. This, though limiting, was used to ensure objectivity of the scores and so does not nullify the findings.
3. An effect due to institution could have occurred since two different institutions were used.

4. Kuder- Richardson formular 20 (K-R 20) could have been used for reliability test instead of K-R21 since item analysis was not done.

Suggestions for Further Research

Further studies could be carried out to investigate

1 The effect of SWH on College of Education chemistry students' achievement and self-efficacy in electrochemistry where the knowledge of redox reaction is applied.

2 Effect of SWH on senior secondary school chemistry students' achievement and conceptual understanding in electrochemistry.

3 Effectiveness of SWH on students' achievement in other areas of science.

Summary of the study

One way that students can learn required science concepts from laboratory activities is to let them determine the result of an inquiry activity while presenting their laboratory reports by using the Science Writing Heuristic (SWH) instructional approach which is inquiry based and has a more flexible format. Students having control over their activity is likely to increase their confidence in doing science. The emphasis for the SWH approach is that it is more student centred with teachers providing opportunities for students to be involved in building scientific arguments debating claims and evidence and knowledge construction through individual, small group and whole class settings. The SWH approach creates an environment such that students can use their own daily language to make connections to scientific concepts which is more meaningful to them.

Redox reactions in chemistry is one of the most difficult topics to teach and to learn (Ojokuku & Amadi 2010, Udo 2011). Literature shows that science laboratory practical is taught by teachers in a cookbook fashion whereby students do experiments to yield expected results following the teacher's directions. The effect of SWH on College of Education chemistry students' achievement in redox reactions was investigated.

Since cognitive as well as affective factors are important in determining students achievement, effect of SWH on science self-efficacy was also investigated. The study employed eight (8) hypotheses which were tested at 0.05 level of significance.

This study was theoretically based on cognitive and social constructivism. A quasi experimental non-equivalent control group research design was adopted. One hundred and twenty-five 125 students constituted the sample for this study. Second year NCE chemistry students of two Colleges of Education in Anambra State were used for the study. The groups were chosen from two intact classes with one group randomly assigned the experimental group and the other to the control group. Redox titration was used as the laboratory practical to elucidate the concept of oxidation and reduction.

Two instruments were administered; the Achievement Test on Redox Reactions ATORR and the Questionnaire on Students Ability to Do Science QSADS. The instruments were validated by experts in Science Education(chemistry), measurement and evaluation and educational psychology. The reliability of the instrument ATORR was obtained using the Kuder Richardson formula 21 with the test administered once to NCE second year students of a non-participating school. The reliability of the QSADS was obtained using the cronbach's Alpha.

Data from the study were analysed using means, standard deviations and 2 x 2 x 3 Analysis of Covariance (ANCOVA). The result of the study showed a significant difference in achievement between the experimental group and control group. Males and females did not significantly differ in achievement and students of different ability levels did not significantly differ in their achievement. There was no significant difference in the science self-efficacy of the experimental and control group. Males and females did not significantly differ in their science self-efficacy. There was no significant interaction effectamong treatment, gender and ability level of students on their achievement. Educational implications were discussed with recommendations made. Further research was suggested and the limitations of the study stated.

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Appendix A
Sample distribution

School	**Males**	**Females**	**Total**
Federal College of Education (Tech) Umunze	14	64	78
Nwafor Orizu College of Education Nsugbe	10	37	47
Total	**24**	**101**	**125**

Source: Exams and Records Unit F.C.E. (T), Umunze &

Nwafor Orizu College of Education Nsugbe.

Appendix B

ACHIEVEMENT TEST ON REDOX REACTIONS (ATORR)

Instruction: Answer all the questions by circling the correct answer.

Time: 45mins.

1. Which of the following statements is/are true of the reaction represented by the ionic equation?

$$MnO_4^-{}_{(aq)} + 8H^+{}_{(aq)} + 5e^- \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O$$

(i) MnO_4 is oxidized

(ii) 3 moles of electrons are involved

(iii) The oxidation no of Mn changes from + 7 to +2

(iv) MnO_4 is reduced

(A) I & III only (B) III & IV only (C) II, III & IV only (D) IV only

2. In which of the following reactions are the underlined species oxidized?

(i) $2Fe^{2+} + Cl_2 \rightarrow 2Fe^{3+} + 2Cl^-$

(ii) $\underline{S_2} + Cl_2 \rightarrow S^{2+} + 2Cl^-$

(iii) $2Mg + O_2 \rightarrow 2MgO$

(iv) $2Al + \underline{6H}^+ \rightarrow 3H_2 + 2Al^{3+}$

(A) I & II only (B) II & III only (C) I, II & III only (D) II & IV only

3. In the reaction represented by the equation

$$2FeCl_3 + SO_2 + 2H_2O \rightarrow 2FeCl_2 + H_2SO_4 + 2HCl$$

The oxidation number of sulphur changes from

(A) +2 to + 6 (B) + 4 to + 6

(C) 0 to + 6 (D) – 2 to + 4

4. What happens in the redox reaction represented by the following equation: $Cu^{2+}_{(aq)} + Zn(s) \rightarrow Cu_{(s)} + Zn^{2+}_{(aq)}$

(A) The oxidation number of copper increases.

(B) Copper (ii) ions are reduced to copper atoms.

(C) Zinc atoms are reduced to zinc ions.

(D) Copper (ii) ions donate electrons to zinc atoms

5. What is the change in the oxidation number of phosphorus in the reaction represented by the following equation? $4P_{(s)} + 5O_{2(g)} \quad 2P_2O_{5(g)}$

(A) 0 to + 2 (B) 0 to + 5 (C) + 4 to+ 2 (D) + 4 to + 5

6. Oxidation is a reaction which can involve

i. loss of electrons.

ii. increase in oxidation number.

iii. gain of oxygen.

iv. loss of hydrogen

(A) I,II & III (B) I,II & IV (C) I & III (D) I,II, III & IV

7. What is the value of x in the following equation $M_no_4^{-} + 4H^{+} + x\ e$ - $MnO_2 + 2H_2O$ (a) 3 (B) 4 (C) 7 (D)8

8. How many electrons are removed from Cr^{2+} when it is oxidized to $CrO_4^{2-?}$

(A) 0 (B) 2 (C) 4 (D) 8

9. What is the value of x in the following equation?

(A) $Cr_2O_7^{2-} + 14H^{+} + xe^{-} \quad 2Cr^{3+} + 7H_2O$

(A) 1 (B)6 (C)8 ⟶ (D) 12 ⟶

10. In which of the following is the oxidation number of sulphur equal to -2?

(a) S_8 (b) H_2S (c) SO_2 (d) SO_3^{2-}

11. What is the oxidation number of nitrogen in Al $(NO_3)_3$?

(a) + 1 (b) + 3 (c) + 5 (d) + 6

12. What is oxidized in the reaction represented by the following equation?

$3Cu + 8HNO_3 \quad 3Cu(NO_3)_2 + 2NO + 4H_2O$ (a) oxygen (b) hydrogen

(c) Nitrogen (d) copper

13. In the equation $Cr2O_7^{2-}{}_{(aq)} + 14H^+ + 6e^-$ $2Cr^{3+}{}_{(aq)} + 7H_2O_{(l)}$

The oxidation number of chromium changes from

(A)– 2 to+3 (B) -2 to + 6 (C) + 6 to + 3

(D) + 7 to + 6

14. A reducing agent is expected to

(A) decolorize acidified $KMnO_4$ solution

(B) decolorize acidified $FeSO_4$ solution

(C) liberate Cl_2 from a chloride $\longrightarrow$

(D) liberate CO_2 from $NaHCO_3$ $\longrightarrow$ $\longrightarrow$

15. What is the change in the oxidation number of I^- in the reaction represented by the following equation? $5I^-_{(aq)} + 6H^+_{(aq)} + IO_3^-_{(aq)}$ $3I_{2(g)} + 3H_2O_{(l)}$

(A) – 5 to – 3 (B) -1to 0 (C) + 5 to+3 (D)-1 to+ 2

16. In which of the following reactions is sulphur (iv) oxide acting as an oxidizing agent? (A) $2HNO_{3(aq)} + SO_{2(g)}$ $H_2SO_{4(aq)} + 2NO_{2(g)}$

(B) $2KMnO_{4(aq)} + 5S0_{2(g)}$ $K_2SO_{4(aq)} + MnSO_{4(aq)} + 2H_2SO_{4(aq)}$

(C) $FeCl_{3(aq)} + SO_{2(g)} + 2H_2O_{(l)}$ $FeCl_{2(aq)} + 2HCl_{(g)} + H_2SO_{4(aq)}$

(D) $2H_2S_{(aq)} + SO_{2(g)}$ $2H_2O_{(l)} + 3S_{(s)}$

17. Which of the following equations represents a redox reaction?

(A)$Pb(NO_3)_{2(aq)} + 2HCl_{(aq)}$ $PbCl_{3(s)} + 2HNO_{3(aq)}$

(B)$H_2S_{(g)} + Cl_{2(g)}$ $2HCl_{(g)} + S_{(s)}$

(C) $AgNO_{3(aq)} + NaCl_{(aq)}$ $AgCl_{(s)} + NaNO_{3(aq)}$

(D) $BaCl_{2(aq)} + K_2SO_{4(aq)}$ $BaSO_{4(s)} + 2KCl_{(aq)}$

18. What is the reducing agent in the reaction represented by the following equation?

$Fe^{3+}_{(aq)} + H_2S_{(g)}$ $2Fe^{2+}_{(aq)} + 2H^+_{(aq)} + S_{(s)}$

(A) $Fe^{3+}_{(aq)}$ (B)$H_2S_{(g)}$ (C) $Fe^{2+}_{(aq)}$ (D) $S_{(s)}$

19. The oxidation number of iodine in the Iodate ion 10_3^- is

(A) – 5 (B) – 1 (C) + 1 (D) +5

20. What is the species reduced in the reaction represented by the equation given below

$5Fe^{2+}_{(aq)} + MnO_4^-{}_{(aq)} + 8H^+_{(aq)} \quad 5Fe^{3+}_{(aq)} + Mn^{2+}_{(aq)} + 4H_2O_{(l)}$

(A) Fe^{2+} (B) MnO_4^- (C) H^+ (D) Fe^{3+}

21. Which species undergoes reduction in the reaction represented by the equation $H_2S_{(aq)} + 2FeCl_{3(aq)} \quad S_{(s)} + 2HCl_{(aq)} + 2FeCl_{2\,(aq)}$

(A) Fe^{3+} (B) H_2S (C) Cl^- (D) S

22. Which of the following oxides of nitrogen has oxidation number of +1?

(A) NO_2 (B) N_2O (C) N_2O_3 (D) NO

23. What is the change in the oxidation number of manganese in the reaction Represented by the following equation?

$MnO_4^-{}_{(aq)} + 8H^+_{(aq)} + 5e^- \quad Mn^{2+}_{(aq)} + 4H_2O_{(l)}$

(A) + 3 to +2 (B) + 4 to + 2 (C) + 5 to + 2 (D) + 7 to +2

24. The oxidation number of Fe in $\{Fe(CN)_6\}^{3-}$ is (A) +3 (B) +2 (C) - 2 (D)-3

25. What are the values of x,y, &z respectively in the reaction represented by $xIO_3^- + yI^- + 6H^+ \quad zH_2O + 3I_2$

(A) 5, 3,1 (B)5,5,3 (C)3,1,5 (D) 1,5,3

26. The oxidation state of carbon in HCOOH is (A) – 1 (B) + 2 (C) + 3 (D)0

27. Which of the following equations represent oxidation – reduction reactions?

i. $K + O_2$ KO_2

ii. $H_2O_2 + KOH$ $KHO_2 + H_2O$

iii. $Ca(HCO_3)_2$ heat $CaCO_3 + CO_2 + H_2O$

iv. $Cr_2O_7^{2-} + 2OH^-$ $2CrO_4^{2-} + H_2O$

v. H_2O_2 $H_2O + ½ O_2$

(A) I, II & IV only (B) I, IV & V only (C) I&V only (D) I,II,IV & V only

28. What quantity of electrons (in moles) is lost when one mole of iron (II) ions is oxidized to iron (III) ions?

(A) 4 moles (B) 3moles (C) 2moles (D) 1 mole

29. Consider the reaction; $2Al_{(s)} + 6H^+_{(aq)}$ $2Al^{3+}_{(aq)} + 3H_{2(g)}$

What is the total number of moles of electrons transferred from the aluminum atoms to the hydrogen ions?

(A) 3 (B) 4 (C)5 (D) 6

30. Which of the following is a redox reaction?

(a) $CaCl_2 + 2KF \rightarrow CaF_2 + 2KCl$

(b) $CaI_2 + Cl_2$ $CaCl_2 + I_2$

(c) $NaOH + HCl$ $NaCl + H_2O$

(d) $CaCO_3 + 2HCl$ $CaCl_2 + CO_2 + H_2O$

31. Which of the following is a redox reaction?

(A) $Mg_{(s)} + H_2SO_{4(aq)}$ $MgSO_{4(aq)} + H_{2(aq)}$

(B) $Pb(NO_3)_{2(aq)} + Na_2SO_{4(aq)}$ $PbSO_{4(s)} + 2NaNO_{3(aq)}$

(C) $CuO_{(aq)} + CO_{(g)}$ $Cu_{(s)} + CO_{2(g)}$

(D) $HCl_{(aq)} + KOH_{(aq)}$ $KCl_{(aq)} + H_2O_{(l)}$

32. The oxidation number of nitrogen in N_2O, N_2O_3, N_2O_5 and N_2 respectively is

(A) 1,3,5,0 (B) 2,3,50 (C) 0,2,3,5 (D) 0,3,2,5

33. The oxidation number of carbon in the compounds CF_2Cl_2, $Na_2C_2O_4$, HCO_3^- and C_2H_6 is respectively

(A) +3,+4,+3,+4(B)+3,+3,+4,+4(C)+4,+3,+4,+3(D) +4,+4,+3,+3

34. Which one(s) of the following involve redox reactions.

i. Burning of fuel

ii. Evaporation of water

iii. Human respiration

iv. Preparation of metals from their ores

v. Reaction of H_2SO_4 with NaOH

(A) I, II & IV only (B) I & III only (C) I,III & IV only (D) I,III & V only

35. In the reaction equation given below, which of the following has taken place?

$3CuO_{(s)} + 2NH_{3\,(g)} \quad 3Cu_{(s)} + 3H_2O_{(l)} + N_{2\,(g)}$

(A) CuO is oxidized

√

(B) CuO is the reducing agent

(D) NH_3 is the reducing agent (D) NH_3 is reduced.

Appendix C

Questionnaire on Students' Ability to Do Science QSADS

Nnamdi Azikiwe University, Awka
Faculty of Education
Department Of Science Education

Dear Respondent,

The researcher is carrying out a study on the effectiveness of an inquiry laboratory approach- the Science Writing Heuristic (SWH) on NCE chemistry students' achievement and science self-efficacy. You are kindly requested to respond to the questions on the instrument tagged "Questionnaire on Students Ability to do Science" QSADS by ticking against the response c en.

Very Well

Moderately Well

Undecided

Partially Well

Not Very Well

Please note that your responses will be treated with the utmost confidentiality.

Thanks.

Jane Chinyere Madichie

Researcher

Questionnaire on Students Ability to Do Science (QSADS)

SEX: Male Female

Group Code

Indicate in the space provided how well you can do the following based on your laboratory experiences.

S/NO ITEM

ITEM

You can **VERY WELL MODERATELY**

WELL UNDECIDED PARTIALLY WELL NOT VERY WELL 1. clarify a scientific concept from the result of an experiment you carried out 2. pose probing questions to make sense of your laboratory results from a given experiment/investigation. 3. relate your laboratory investigations to everyday life 4. explain the results of your scientific investigations 5. make meaning from data collected in a laboratory experiment 6. identify the question that is being investigated from a table of results

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9. describe relationships/patterns using a table of results for any given investigation.
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13. write a conclusion for an investigation you carried out.
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Appendix D

Lesson Plan for Conventional Group

Week 1

Topic: Standardization of a given solution of potassium tetraoxomanganate (VII) $KMnO_4$ by iron (11) ammonium tetraoxosulphate (VI) hexahydrate $FeSO_4(NH_4)_2\ SO_4\ 6H_2O$

Specific Objectives

By the end of the practical class, the students should be able to

1. determine the molar concentration of the $KMnO_4$ solution
2. determine the concentration in g/dm^3 of the $KMnO_4$ solution

Entry Behaviour

Students have been taught the concepts of oxidation and reduction, balancing of redox equations, identification of oxidizing and reducing agents etc. to test their entry behaviour the teacher asks them to define

1. Oxidation in terms of electron transfer.
2. Reduction in terms of electron transfer.
3. Oxidizing agent
4. Reducing agent.

Answers

Definitions of oxidation and reduction

1. In terms of addition of Oxygen

Oxidation is a gain of oxygen

Reduction is a loss of oxygen

Example

$$2Mg_{(s)} + 0_{2\,(g)} \longrightarrow 2Mg0_{(s)}$$

2. In terms of removal of hydrogen

Oxidation is loss of hydrogen atomsReduction is gain of hydrogen atoms

Example

$$CH_3OH \xrightarrow{Cu} CH_20 + H_2$$

Methanol loses hydrogen atoms. It is oxidized.

3. In terms of electron transfer

Oxidation is the process of electron loss

Reduction is the process of electron gain

An oxidizing agent is a substance that oxidizes another species by removing electrons from it.

A reducing agent is a substance that reduces another species by donating electrons to it.

Example

$2Mg_{(s)} + 0_{2\ (g)} \longrightarrow 2Mg0_{(s)}$

Magnesium loses two electrons

$2Mg_{(s)} \longrightarrow 2Mg^{2+}{}_{(s)} + 4e^{-}$

Oxygen gains electrons

$O_{2(g)} + 4e^{-} \longrightarrow 20^{2-}{}_{(s)}$

Example 2

In the reaction

$Zn_{(s)} + CuSO_4\ (aq) \longrightarrow ZnS0_{4(aq)} + Cu_{(s)}$

The half equations

$Zn(s) \longrightarrow Zn^{2+}{}_{(aq)} + 2e^{-}$

Zinc is oxidized as a result of electron loss.

$Cu^{2+}{}_{(aq)} + 2e^{-} \longrightarrow Cu_{(s)}$

Copper(11)ions are reduced as a result of electron gain.

Combining the two equations

$Zn_{(s)} + cu^{2+}{}_{(aq)} \longrightarrow Zn^{2+}{}_{(aq)} + cu_{(s)}$

Instructional materials

Solutions of $KMnO_4$ and $FeSO_4(NH4)_2SO_4$ $6H_2O$, H_2SO_4 pipettes, burettes, conical flasks, beakers, stand and clamp etc.

Instructional Procedure

Content Development

Step 1

Theoretical background

Teacher's Activities

The teacher gives the theoretical background of the redox titration between $KMnO_4$ and $FeSO_4$ $(NH4)_2$ SO_4. $6H_2O$,.

- Potassium tetraoxomanganate (vii) $KMn0_4$ is a powerful oxidizing agent and is used for the estimation of many reducing agents especially compounds of iron. Thus
- $KMn0_4$ exhibits its oxidizing power in the presence of tetraoxosulphate (vi) acid H_2S0_4
- In solutions, iron (ii) ammonium tetraoxosulphate (vi)hexahydrate $FeS0_4$ $(NH_4)_2$ $S0_4$. $6H_20$ behaves like iron (ii) tetraoxosulphate (vi). $FeSO_4$ (NH_4) SO_4 $.6H_2O$ is a more convenient salt to use in the

preparation of standard solutions of iron (ii) tetraoxoshulphate (vi) since it is not readily oxidized by air as simple ferrous salt.

The teacher asks students to (i) calculate the molar mass of $FeSO_4$ (NH_4) SO_4 $.6H_2O$ iron (ii) ammonium tretraoxosulphate (VI) hexahydrate.

(ii) balance the half equations involved in the redox reactions.

Theory of indicator and end point

$KMnO_4$ acts as its own indicator from the above reaction. Sulphates of potassium and manganese will accumulate as the titration proceeds but at the dilution used both give colourless solution. Thus as soon as $KMnO_4$ (purple in colour) is in excess, the solution becomes pink. The first permanent pink colour is the end point

Further explanation: The solution to be titrated with $KMnO_4$ must be sufficiently acidic to prevent the formation of any precipitates of manganese (iv) oxide MnO_2 (black).

Students Activities:

(i) Calculation of molar mass of $FES0_4$ $(NH4)_2$ $S0_4$. $6H_20$

Given: Fe = 56, S = 32, 0= 16, N= 14, H=1

56 + 32 + 16 x4 + 14 x 2 + 1 x 2 + 32 + 16 x4+ 6 x18 = 392

(ii) Students are guided to balance the oxidation and reduction half equations: oxidation half equation

($Fe^{2+} = Fe^{3+} + e^-$) x 5 (Oxidation half equation.

$Mn0_4^- + 8H^+ + 5e^- = Mn^{2+} + 4H_20$ (reduction half equation)

$5Fe^{2+} + Mn0_4^- + 8H^+ = 5Fe^{3+} + Mn^{2+} + 6H_20$

Therefore 1 mole of $Kmn0_4$ = 5 moles of $FeSO_4$ $(NH_4)_2S0_4$ $6H_20$

Step II: Practical work

Teacher's Activities

The teacher gives students the procedure for the standardization of $KMn0_4$. $(NH_4)_2$. $SO_4.6H_20$:

Pipette out 25ml of the iron (ii) ammonium tetraoxosulphate (vi) $FeSO_4$ $(NH_4)_2S0_4$ solution into a conical flask and add an equal volume of tetraoxosulphate (VI) acid H_2SO_4. Titrate with the $KMnO_4$ solution from a burette until the first permanent pink coloration is observed. Record the readings and repeat the titration at least twice for constant results.

Students' activities- students carry out the practical work using the procedure given by the teacher.

Step III: Calculations

Teacher's Activities

The teacher gives students calculations to do:

Calculate (i) the molar concentration of the $KMnO_4$ solution

(ii) the concentration in g/dm^3 of $KMno_4$

The formula to be used is

$$\frac{C_{0A}V_{0A}}{C_{RA}V_{RA}} = \frac{n_{0A}}{n_{RA}}$$

Where C_{0A} = molar concentration of oxidizing agent KMn04

V_{OA} = volume of oxidizing agent $KMn0_4$

C_{RA} = molar concentration of reducing agent Fe $S0_4$ $(NH_4)_2SO_4.6H_20$

V_{RA} = Volume of reducing agent Fe $S0_4$ $(NH_4)_2SO_4.6H_20$

n_{OA} = Number of moles of oxidizing agent $KMn0_4$

n_{RA} = number of moles of reducing agent Fe $S0_4$ $(NH_4)_2SO_4.6H_20$

Students' Activities

Students do the calculations given using the formula

$$\frac{C_{0A}V_{0A}}{C_{RA}V_{RA}} = \frac{n_{0A}}{n_{RA}}$$

Take Home Assignment

How much iron (ii) ammonium tetraoxosulpahte (vi) hexahydrate Fe $S0_4$ $(NH_4)_2SO_4.6H_20$ could you weigh to make a 250ml m/50 solution?

Lesson Plan Conventional Group

Week 2

Topic: Estimation of the percentage of iron (II) ion Fe^{2+} in $FeSo_4$ $.7H_20$and purity of iron (II) tetraoxosulphate (VI) heptahydrate $FeSO_4.7H_20$

Entry Behaviour:

Students have done practical work on standardization of potassium tetraoxomanganate (VII) $KMnO_4$ using iron (II) ammonium tetraoxosulphate (VI) hexahydrate. To test their entry behaviour, the teacher asks students to state which of the solutions of $KMnO_4$ and $FeSO_4$ $(NH_4)_2SO_4$ $.6H_20$ is the oxidizing agent and the reducing agent giving reasons for their answers. The teacher also reviews students' take home assignment.

Content Development

Step I: Laboratory practical work on estimation of the percentage of Fe^{2+} ion and purity of $FeSO_4$. $7H_20$

Teacher's Activities

The teacher gives the students the procedure for the redox titration of $KMnO_4$ and $FeSO_4.7H_20$ Pipette out 25ml of the solution of commercial iron (ii) tetraoxosulphate (vi) solution into a conical flask and add about an equal amount of dilute. Tetraoxosulphate (vi) acid H_2SO_4. Titrate with $KMnO_4$ until the first permanent pink colour is observed. Repeat the titration at least twice for constant results.

Students' Activities

Students carry out the practical work using the procedure given.

Step II: Calculations

Teacher's Activities

The teacher gives the students calculations on the practical they carried out:

Calculate

i) The molar concentration of the iron (ii) tetraoxosulphate (VI) $FeS0_4.7H_20$ solution

ii) The concentration in grams/dm^3 of the iron (ii) tetraoxosulphate (vi) $FeS0_4.7H_20$ solution

iii) The percentage of iron (ii) ion in the sample of Iron (II) tetraoxosulphate (VI) $FeSO_4 . 7H_20$

iii. The percentage purity of Iron (II) tetraoxosulphate (VI) (using the strength of the commercial Iron (II) tetraoxosulphate (VI) solution given).

Answers

1.Concentration in mol/dm^3 of $FeSO_4$ H_20

$$\frac{C_{0A}V_{0A}}{C_{RA}V_{RA}} = \frac{n_{0A}}{n_{RA}}$$

Unknown is $C_{RA} = \frac{C_{OA} \times V_{OA} \times n_{RA}}{V_{RA} \times n_{OA}}$

2.Concentration in g/ dm^3 of $FeSO_4.7H_20$ = conc in moles/dm^3 x molar mass of

$FeSO_4.7H_20$ = C_{RA} x 278g

3. % of Fe^{2+} in $FeSO_4.7H_20$

$$\frac{\text{Molar concentration of } FeSO_4.7H_20 \times \text{molar mass of Fe}}{\text{Concentration of dissolved solute}} \times \frac{100}{1}$$

4. Purity of $FeSO_4$

The Commercial sample of $FeSO_4.7H_20$ contains 98% of pure $FeSO_4$ in 278.0 g/dm^3 of the sample. Then $\frac{\text{Pure}}{\text{impure}} \times \frac{100}{1}$

$$\% \text{ purity} = \frac{\text{Molar concentration of } FeSO_4.7H_20 \times 278}{\text{Concentration of commercial sample}} \times \frac{100}{1}$$

Students' Activities

Students do the calculations given as guided by the formulae shown in nos 1-4.

Lesson Plan Conventional Group

Week 3

Topic: Standardization of a given solution of sodium thiosulphate $Na_2S_2O_3 . 5H_2O$ using potassium iodate KIO_3

Specific Objectives

By the end of the practical class the students should be able to

i. determine the molar concentration of sodium thiosulphate

ii. determine the concentration in g/dm^3 of sodium thiosulphate

Entry Behaviour

Students have been taught oxidation and reduction and have done practicals on redox titration of $KMnO_4$ and Iron (ii) tetraoxosulphate (vi)heptahydrate $FeS0_4.H_20$. To test their entry behaviour the teacher will ask students to explain the meaning of oxidizing agent and reducing agent.

Content Development
Step I
Theoretical background
Teacher's Activities

The teacher gives the theoretical background explaining that crystals of sodium thiosulphate $Na_2S_2O_3 . 5H_2O$ are not sufficiently pure to be weighed out directly for the preparation of standard solution, therefore an approximately decimolar solution of sodium thiosulphate is prepared and is then standardized with potassium iodate $KI0_3$ or potassium heptaoxodichromate (VI) $K_2Cr_20_7$ solution, through the intermediate of iodine I. (I^- is a reducing agent while I_2 is an oxidizing agent).

The teacher further explains that Potassium iodate KIO_3 in acid solution oxidizes potassium iodide KI to free iodine according to the equation

$KIO_3 + 5KI + 6HCl \quad 6KCl + 3H_20 + 3I_2$ -----(1)

Or ionically

$10_3^- + 5I^- + 6H^+ \longrightarrow 3I_2 + 3H_20$ ---------------(2)

The free iodine is then estimated by its reaction with sodium thiosulphate

$2Na_2S_2O_3 + I_2 \longrightarrow Na_2S_4O_6 + 2NaI$ --------(3)

Or ionically

$2\ S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2I$ ------ (4)

By multiplying equation (4) by (3) and combining it with equation (2), we get the overall ionic equation for the redox reaction to be

$IO_3^- + 6S_2O_3^{2-} + 6H^{+ -} \rightarrow I^- + 3S_4O_6^{2-} + 3H_2O$ ---- (5)

From equation (5) one mole of iodate is equivalent to six moles of thiosulphate.

Molar mass of KIO_3

(K = 39, I = 126, O= 16)

39 + 127 + 16 x 3 = 214

Molar mass of sodium thiosulphate

$Na_2S_2O_3.5H_2O$

(Na = 23, S = 32, O=16, H=1)

23 x 2 + 32 X 2 + 16 x3 + 5 x 18 = 248

A decimolar sodium thiosulphate solution contains

1/10 of 248g of $Na_2S_2O_3.5H_2O$ = 24.8g per dm^3 and 6.2g per $250cm^3$

Students' Activities

Students balance the half equations involved in the reactions (The half equations are as shown in equations 1,2,3&4).

Step II: Laboratory Practical work

Teacher's Activities

The teacher gives students the procedure for carrying out the practical work:

Place the sodium thiosulphate $Na_2S_2O_3.5H_2O$ solution in a burette. Pipette out 25ml of the potassium iodate KIO_3 solution into a conical flask and add about 10ml of dilute hydrochloric acid HCl and 10ml of 10% potassium iodide KI solution. (Iodine will be liberated according to the equation $KIO_3 + 5KI + 6HCl \longrightarrow 6KCl + 3H_20 + 3I_2$. Shake the contents of the flask well and titrate the liberated iodine with the sodium thiosulphate solution until the iodine colour has changed to a pale yellow.

Add a few drops of starch solution and continue the titration until the blue colour just disappears.

Repeat the titration at least twice for constant results.

Students' Activities

Students carryout the practical work using the procedure given.

Step III

Calculations

Teacher's Activities

The teacher gives students the calculations to do following the practical work

Calculate

i. the molar concentration of the thiosulphate solution

ii. The concentration in g/dm^3 of the thiosulphate solution

Formula

$$\frac{C_{0A}V_{0A}}{C_{RA}V_{RA}} = \frac{n_{0A}}{n_{RA}}$$

Students' Activities

Students do the calculations given

Lesson Plan Conventional Group
Week 4
Topic: Estimation of the percentage of copper in copper tetraoxosulphate (VI) crystals $CuSO_4 .5H_20$
Specific Objectives
By the end of the practical class the students should be able to

1. determine the percentage of copper in copper (II) tetraoxosulphate (VI) crystals.

Content Development

Step I

Theoretical background

Teacher's Activities

The teacher gives students the theoretical background of the reaction: $CuSO_4$. $5H_20$ reacts with excess of potassium iodide KI to precipitate copper (II) iodide and liberate iodine according to the equation $2CuS0_4 + 4KI \rightarrow Cu_2I_2 + I_2 + 2K_2S0_4$

The copper (ii) ion oxidizes KI to free iodine and is itself reduced to the copper (i) ion. The liberated iodine is then determined by means of a standard solution of sodium thiosulphate according to the equation.

$$2Na_2S_20_3 + I_2 \rightarrow Na_2S_40_6 + 2NaI$$

Or ionically

$$2S_20_3^{2-} + I_2 \rightarrow S_40_6^{2-} + 2I^-$$

Students' Activities.

Students participate in balancing the ionic equations.

Step II Laboratory practical work on estimation of the percentage of copper in $CuSO_4 . 5H_20$ crystals.

Teacher's Activities

The teacher gives students the procedure for carrying out the practical work: Pipette out 25ml of the copper tetraoxosulphate (II) solution into a conical flask and add about 10ml of a 10% potassium iodide (KI) solution and about 20ml of distilled water and then titrate the liberated iodine with the standard sodium thiosulphate solution until the colour has changed to light-yellow.

Add 2ml of starch solution and titrate drop wise until the blue colour is just discharged. (the end point is a milky white solution because it contains the precipitated copper (II) iodide Cu_2I_2

Students' Activities

Students carry out the practical work using the procedure given.

Step III : Calculations

The teacher gives students the calculations following the practical work.

i. calculate the molar concentration of copper (II) tetraoxosulphate ($CuSO_4 . 5H_20$) in the solution given and

ii. the percentage of copper in $CuSO_4 . 5H_2O$ crystals from the weights of the $CuSO_4 . 5H_2O$ crystals dissolved in water.

Formula

$$\frac{C_{0A}V_{0A}}{C_{RA}V_{RA}} = \frac{n_{0A}}{n_{RA}}$$

Formula for determining the percentage of copper

$$\frac{\text{Molar concentration of } CuSO_4 \times \text{mass of } Cu^{2+}}{\text{Dissolved concentration of } CuSO_4} \times \frac{100}{1}$$

Students' Activities

Students do the calculations given.

Lesson Plan Conventional Group

Week 5

Topic: Standardization of a given solution of potassium tetraoxomanganate (VII) $KMnO_4$ using sodium oxalate $Na_2C_2O_4$

Specific Objectives

By the end of the practical class, the students should be able to

1. determine the molar concentration of the $KMnO_4$
2. Determine the concentration in g/dm^3 of $KMnO_4$

Entry Behaviour

Students have done practical work on estimation of iron (II) ion and determination of purity of Iron (II) salt. To test their entry behavior, the teacher asks students to write the oxidation half equation for Iron (II) ion and tetraoxomanganate (VII) ion.

Content Development

Step 1: Theoretical background

Teacher's Activities

The teacher gives the theoretical background that $KMn0_4$ is a powerful oxidizing agent and is used for the estimation of many reducing agents, especially compounds of iron and oxalic acid and its salts. $KMn0_4$ exhibits its oxidizing power in the presence of H_2S0_4. The equation for the oxidation reducing (redox) reaction between $KMn0_4$ and $Na_2C_20_4$ can be written in partial ionic forms as follows: $H_2C_20_2$ $2C0_2$ + 2H + +2e x 5 (oxidation half-equation)

$MnO_4^- + 8H^+ + 5e^- \rightarrow 2Mn^{2+} + 4H_2O \times 2$ (reduction half equation)

Overall reaction

$2MnO_4^- + 5H_2C_2O_4 + 6H^+ \rightarrow 2Mn^{2+} + 10C0_2 + 8H_2O$

The teacher further explains that an acidified solution of an oxalate is equivalent to a solution of oxalic acid itself as shown.

$Na_2C_2O_4 \longrightarrow 2Na^+ + C_2O_4^{2-}$

$C_2O_4^{2-} + 2H^+ \longrightarrow H_2C_2O_4$

Thus from the overall equation 2 moles of $KMnO_4$ = 5 moles of $H_2C_2O_4$ = 5 moles of $Na_2C_2O_4$

$KMnO_4$ acts as its own indicator from the above reaction; sulphates of potassium and manganese will accumulate as the titration proceeds but at the dilution used both give colourless solution. Thus as soon as $KMnO_4$ (purple in colour) is in excess, the solution becomes pink. The first permanent pink colour is the end point. The solution to be titrated with $KMnO_4$ must be sufficiently acidic to prevent the formation of any precipitates of MnO_2 (black)

Step II: Laboratory Practical Work

Teacher's Activities

The teacher gives students the procedure for carrying out the practical work: To 25ml of the given standard solution of $Na_2C_20_4$ in a conical flask, add about 15 ml of bench H_2S0_2 and heat the mixture to above 60^oC (or just too hot to be held by bare hands). Titrate with $KMn0_4$ heating again as the liquid cools till a permanent pink colouration is observed. Repeat the titration at least twice to obtain constant results.

Students Activities

Students carry out the practical work using the procedure given.

Step III Calculations

Teacher's Activities

The teacher gives students the calculations to do following practical work:

Calculate

a) the molar concentration of the $KMn0_4$ solution
b) the concentration in g/dm^3 of the $KMn0_4$ solution

$$\frac{C_{0A}V_{0A}}{C_{RA}V_{RA}} = \frac{n_{0A}}{n_{RA}}$$

Students' Activities
Students do the calculations given.

Assignment
How much sodium oxalate $Na_2C_2O_4$ would a 500ml m/15 Na_2C2O_4contain?

Lesson Plan Conventional Group

Week 6

In this week's work, the concentrations of the solutions of $KMnO_4$ and $Na_2C_2O_4$ change and the students are required to determine the concentration of the oxalate.

Topic: Standardization of sodium oxalate $Na_2C_2O_4$ using potassium tetraoxomanganate (VII) $KMnO_4$

Specific Objectives

By the end of the practical class, the students should be able to:

i) determine the molar concentration of the sodium oxalate solution

ii) determine the concentration in g/dm^3 of the sodium oxalate.

iii) Entry Behaviour

iv) Students have standardized $KMnO_4$ using sodium oxalate. To test their entry behaviour, the teacher asks students to write the oxidation and reduction half equations for $KMnO_4$ and the oxalate.

Content Development

Step I

Theoretical background

Teacher's Activities

The teacher gives the theoretical background that $KMnO_4$ is a powerful oxidizing agent and is used for the estimation of many reducing agents, especially compounds of iron and oxalic acid and its salts. $KMnO_4$ exhibits its oxidizing power in the presence of H_2SO_4. The equation for the oxidation reduction (redox) reaction between $KMnO_4$ and $Na_2C_2O_4$ can be written in partial ionic form as follows: $H_2C_2O_2 \rightarrow 2CO_2 + 2H + +2e^- \times 5$ (oxidation half-equation)

$MnO_4^- + 8H^+ + 5e^- \rightarrow 2Mn^{2+} + 4H_2O$ x 2 (reduction half equation)

Overall reaction

$2MnO_4^- + 5H_2C_2O_4 + 6H^+ \rightarrow 2Mn^{2+} + 10C0_2 + 8H_2O$

Note:

An acidified solution of an oxalate is equivalent to a solution of oxalic acid itself as shown.

$Na_2C_2O_4 \rightarrow 2Na^+ + C_2O_4^{2-}$

$C_2O_4^{2-} + 2H^+ \longrightarrow H_2C_2O_4$

Thus from the overall equation 2 moles of $KMnO_4$ = 5 moles of $H_2C_2O_4$ = 5 moles of $Na_2C_2O_4$

$KMnO_4$ acts as its own indicator from the above reaction; sulphates of potassium and manganese will accumulate as the titration proceeds but at the dilution used both give colourless solution. Thus as soon as $KMnO_4$ (purple in colour) is in excess, the solution becomes pink. The first permanent pink colour is the end point

Note: The solution to be titrated with $KMnO_4$ must be sufficiently acidic to prevent the formation of any precipitates of MnO_2 (black)

Step II

Laboratory Practical work

Teacher's Activities

The teacher gives students the procedure for carrying out the practical work.

To 25ml of the given standard solution of $Na_2C_2O_4$ in a conical flask, add about 15 ml of bench H_2SO_4 and heat the mixture to above 60^0C (or just too hot to be held by bare hands). Titrate with $KMnO_4$ heating again as the liquid cools till a permanent pink colouration is observed. Repeat the titration at least twice to obtain constant results.

Students Activities

Students carry out the practicals using the procedure given.

Step III Calculations

Teacher's Activities

The teacher asks students to calculate

a) the molar concentration of the oxalate

b) The concentration in g/dm^3 of the oxalate

Answer

To calculate the molar concentration of the KMn04 and the concentration in g/dm^3 of the oxalate.

Overall ionic equation for the reaction

$2Mn0_4^- + 5H_2C_20_4 + 16H^+ \longrightarrow 2Mn^{2+} + 10C0_2 + 8H_20$

Molar concentration of the $KMn0_4$

$\underline{C_{oA}\ V_{oA}} = \underline{N_{oA}}$

C_{RA} V_{RA} N_{RA} Where C_{oA} V_{oA} are the concentration and volume of the

$Kmn0_4$– the oxidizing agent and C_{RA} V_{RA} are the

concentration and volume of the oxalate respectively.

N_{oA} and N_{RA} are the mole ratio of the $KMn0_4$ and oxalate.

Students Activities

Students do the calculations given.

Appendix E

Science Writing Heuristic (SWH) Lesson Plan for the treatment group

WEEK 1

Science Writing Heuristic

Topic: Redox Titrations

The challenge

A sample of impure iron (II) salt $FeS0_4$ is provided. Using a solution of Kmn04 determine the percentage by mass of Iron in the impure iron (II) salt.

Templates

1. Exploration of Pre-instruction understanding of redox reactions. Students brainstorm terms related to what is known about oxidation and reduction.
   - i) What is oxidation?
   - ii) What is reduction?
   - iii) What is an oxidizing agent?
   - iv) What is a reducing agent?

Definitions of oxidation and reduction: Teacher's guide

4. <u>In terms of addition of Oxygen</u>

   Oxidation is a gain of oxygen

   Reduction is a loss of oxygen

Example

$2Mg_{(s)} + 0_{2\ (g)} \longrightarrow 2Mg0_{(s)}$

5. <u>In terms of removal of hydrogen</u>

Oxidation is loss of hydrogen atoms

Reduction is gain of hydrogen atoms

Example

$CH_3OH \xrightarrow{Cu} CH_20 + H_2$

Methanol loses hydrogen atoms. It is oxidized.

6. <u>In terms of electron transfer</u>

Oxidation is the process of electron loss

Reduction is the process of electron gain

An oxidizing agent is a substance that oxidizes another species by removing electrons from it.

A reducing agent is a substance that reduces another species by donating electrons to it.

Example

$2Mg_{(s)} + 0_{2\ (g)} \longrightarrow 2Mg0_{(s)}$

Magnesium loses two electrons

$2Mg_{(s)} \longrightarrow 2Mg^{2+}{}_{(s)} + 4e^{-}$

Oxygen gains electrons

$O_{2(g)} + 4e^{-} \longrightarrow 20^{2-}{}_{(s)}$

Example 2

In the reaction

$Zn_{(s)} + CuSO_4\ (aq) \longrightarrow ZnS0_{4(aq)} + Cu_{(s)}$

The half equations

$Zn(s) \longrightarrow Zn^{2+}_{(aq)} + 2e^{-}$

Zinc is oxidized as a result of electron loss.

$Cu^{2+}_{(aq)} + 2e^{-} \longrightarrow Cu_{(s)}$

Copper(11)ions are reduced as a result of electron gain

Combining the two equations

$Zn_{(s)} + cu^{2+}_{(aq)} \longrightarrow Zn^{2+}_{(aq)} + cu_{(s)}$

While brainstorming, students are asked to make a **concept map** of oxidation and reduction terms

2. **Pre-Lab Activities**

Students in small groups are given redox equations between $FeSO_4$ and $KMn0_4$ to balance by writing the oxidation half equation and the reduction half equation.

(i) Students are guided to balance the oxidation and reduction half equations: oxidation half equation

$(Fe^{2+} = Fe^{3+} + e^{-})$ x 5 (Oxidation half equation).

$Mn0_4^{-} + 8H^{+} + 5e^{-} = Mn^{2+} + 4H_20$ (reduction half equation)

$5Fe^{2+} + Mn0_4^{-} + 8H^{+} = 5Fe^{3+} + Mn^{2+} + 6H_20$

Therefore 1 mole of $Kmn0_4$ = 5 moles of $FeSO_4\ (NH_4)_2S0_4\ \ 6H_20$

iii. Class guide toward their possible beginning questions like:

i What is the concentration of the $FeSO_4$?

ii How does the concentration of the iron salts determine the percentage of iron?

3. **Participation in Lab-activities:** The teacher serves as a facilitator during the laboratory activities when students:

   a. take measurements of samples

   b. take readings from their titration

4. **Negotiation phase I:** Writing personal meanings

   The teacher engages students to write personal meanings from the investigation they are carrying out. This could be in the form of posing questions that center on the chemical concept of oxidation and reduction. E.g. why do you consider the reaction a redox reaction?

   Guide: Recognizing redox reactions using change in oxidation numbers.

   The half equations previously stated may be used to explain changes in oxidation numbers.

5. **Negotiation phase II:** Sharing and comparing data interpretation in small groups.

    Students group together based on their investigations and make a group chart/report.

6. **Negotiation phase III:** Comparing students' ideas to text books or other reliable sources.

    Students compare their work with ideas from text books.

7. **Negotiation phase IV:** Individual reflection and writing –

    Students reflect in their note books explanations of what they have learned.

Science Writing Heuristic (SWH) Lesson Plan for the treatment group

WEEK II

The lab-activities for week 1 spill over to week II. The class gathers and writes their data for class discussions.

Exploration of post-instruction understanding. The class reviews the laboratory analysis done by the groups.

Science Writing Heuristic (SWH) Lesson Plan for the treatment group

Week III

Topic: Redox Titrations

The challenge

A 3.00g sample of copper (II) tetraoxosulphate (VI) CuS04 crystals was dissolved in water and the solution made up to 250cm3. You are required to determine the percentage of copper in the crystals.

1. Exploration of Pre-instruction understanding.

   Exploration of iodometric titrations.

i. In their note books students respond to the following questions and statements: How is free iodine I_2 formed from the oxidation of potassium iodide KI by potassium iodate KIO_3.?

Guide

ii. Formation of free iodine from the oxidation of potassium iodide by potassium iodate.

$$KI\,0_3 + 5KI + 6HCl \longrightarrow 6KCl + 3H_20 + 3I_2$$

$$\text{i.e. } 10_3^- + 5I^- + 6H^+ \longrightarrow 3I_2 + 3H_20$$

Potassium iodate KIO_3 in acid solution oxidizes potassium iodide KI to free iodine according to the equation

$KIO_3 + 5KI + 6HCl \rightarrow 6KCl + 3H_20 + 3I_2$ -----(1)

Or ionically
$10_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_20$ ---------------(2)

The free iodine is then estimated by its reaction with sodium thiosulphate

$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI$ --------(3)

Or ionically

$2 S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I$ ------ (4)

By multiplying equation (4) by (3) and combining it with equation (2), we get the overall ionic equation for the redox reaction to be

$IO_3^- + 6S_2O_3^{2-} + 6H^+ \rightarrow I^- + 3S_4O_6^{2-} + 3H_2O$ ---- (5)

From equation (5) one mole of iodate is equivalent to six moles of thiosulphate.

2. Pre-laboratory activities

Students in small groups brainstorm on the redox processes taking place in standardization of $CuS0_4$ with thiosulphate. Half equations involving copper and thiosulphate.

$$2Cu^{2+}(aq) + 4 I^-(aq) \longrightarrow 2CuI(s)^+ I_2(aq)$$

$$2S_20_3^{2-}(aq) + I_2(aq) \longrightarrow S_40_6^{2-}(aq) + 2I^-(aq)$$

Moles of $S_20_3^{2-}$ = moles of Cu^{2+}

2b. class guide toward their possible beginning questions like how does the mass of copper dissolved determine the percentage of copper?

3. Participation in laboratory activity

Students in small groups carry out measurements of samples and do titrations. Note: Place the sodium thiosulphate $Na_2S_2O_3.5H_2O$ solution in a burette. Pipette out 25ml of the potassium iodate KIO_3 solution into a conical flask and add about 10ml of dilute hydrochloric acid HCl and 10ml of 10% potassium iodide KI solution. (Iodine will be liberated according to the equation $KIO_3 + 5KI + 6HCl \longrightarrow 6KCl + 3H_20 + 3I_2$. Shake the contents of the flask well and titrate the liberated iodine with the sodium thiosulphate solution until the iodine colour has changed to a pale yellow.

Add a few drops of starch solution and continue the titration until the blue colour just disappears.

Repeat the titration at least twice for constant results.

Further titration

Pipette out 25ml of the copper tetraoxosulphate (II) solution into a conical flask and add about 10ml of a 10% potassium iodide (KI) solution and about 20ml of distilled water and then titrate the liberated iodine with the standard sodium thiosulphate solution until the colour has changed to light-yellow.

Add 2ml of starch solution and titrate drop wise until the blue colour is just discharged. (the end point is a milky white solution because it contains the precipitated copper (II) iodide Cu_2I_2

4. **Phase I:** Writing personal meanings.

   Students record them in their note books answers to questions like, how can you distinguish between the role of the iodide ion I^- and the iodine formed? Note: I^- is a reducing agent while I_2 is an oxidizing agent.

5. **Negotiation phase II:** Sharing and comparing data in small groups.

   Students make a good record of the results and compare their results in small groups.

6. **Negotiation Phase III:** Comparing science ideas to textbooks and other resources.

   Students compare their work to scientific accepted knowledge.

7. **Negotiation phase IV:** Individual reflection and writing (creating presentations)

   Students write explanations of what they have learned.

Science Writing Heuristic (SWH) Lesson Plan for the treatment group

Week IV

Exploration of post-instruction understanding:

The class activities spill over to week IV. Students gather to hold group discussions on the laboratory determination of the percentage of copper.

Science Writing Heuristic (SWH) Lesson Plan for the treatment group

Week V

Topic: Redox Titrations

The challenge

The oxalate content of a sample dissolved in the flask is unknown. Determine the oxalate content of this sample.

The templates to be used by the teacher and the students.

1. **Exploration of pre-instruction understanding:**

   The students review what is known about redox reactions. Students create group concept maps about oxidation and reduction in terms of electron transfer.

2. **Pre-laboratory activities :**

i. Students discuss reactions of oxalates including reaction conditions.

Teacher's note: mixture of the oxalate and acid is heated to about 60 °C (or just too hot to be held by bare hands)

ii. Students write the oxidation and reduction half equations of oxalate and tetraoxomanganates (VII). **Teacher's note:** The equation for the oxidation reducing (redox) reaction between $KMn0_4$ and $Na_2C_20_4$ can be written in partial ionic forms as follows: $H_2C_20_2 \longrightarrow 2C0_2 + 2H +$ $+2e^- \times 5$ (oxidation half-equation)

$MnO_4^- + 8H^+ + 5e^- \rightarrow 2Mn^{2+} + 4H_2O$ x 2 (reduction half equation)

Overall reaction

$2MnO_4^- + 5H_2C_2O_4 + 6H^+ \rightarrow 2Mn^{2+} + 10C0_2 + 8H_2O$

An acidified solution of an oxalate is equivalent to a solution of oxalic acid itself as shown.

$Na_2C_2O_4 \rightarrow 2Na^+ + C_2O_4^{2-}$

$C_2O_4^{2-} + 2H^+ \rightarrow H_2C_2O_4$

Thus from the overall equation 2 moles of $KMnO_4$ = 5 moles of $H_2C_2O_4$ = 5 moles of $Na_2C_2O_4$.

iii. Class guide toward their possible beginning question like (a) what is the molar concentration of the oxalic acid and the concentration in g/dm^3?

3. **Participation in laboratory activity**: Students in groups are engaged in the laboratory activities involving measurements and titrations.

Teacher's note: The procedure for carrying out the practical work: To 25ml of the given standard solution of $Na_2C_20_4$ in a conical flask, add about 15 ml of bench H_2S0_2 and heat the mixture to above 60^oC (or just too hot to be held by bare hands). Titrate with $KMn0_4$ heating again as the liquid cools till a permanent pink colouration is observed. Repeat the titration at least twice to obtain constant results.

4. **Negotiation phase I** : Students record in their note books answers to questions like why does the solution need to be sufficiently acidic? Or if you carried out the titration without acidifying, what is likely to result? Teacher's note: The solution to be titrated must be sufficiently acidic to prevent the formation of any precipitates of manganese (iv) oxide MnO_2 (black).
5. **Negotiation phase II :** Sharing and comparing data in small groups Students make a group record of the results and compare in small groups.
6. **Negotiation phase III:** Students compare their work to scientific accepted knowledge.
7. **Negotiation phase IV:** Students reflect in their note books explanations of what they have learned.

Science Writing Heuristic (SWH) Lesson Plan for the treatment group

Week VI

Exploration of post – instruction understanding –

Students gather to review their activities by writing their data for group discussions.

Appendix F

Reliability test for Achievement test on Redox reactions (ATORR)

S/N	SCORES
1	9
2	8
3	15
4	11
5	10
6	9
7	9
8	10
9	14
10	10
11	5
12	11
13	15
14	14
15	13
16	17
17	11
18	12
19	10
20	9
21	15
22	12
23	11
24	13
25	10
26	12
27	16
28	8
29	10
30	13
Mean	11.4
SD	2.711406

USING K-R 21

K-R 21 n/n-1[1-{1(n-x)}/nSx]

Where n= no of items

x = the mean of the test scores

Sx^2= Variance of the test scores

K-R 21= 30 [1-1(30-11.4)

30-1 30×2.71

= 30 (1-18.6)

29 81.3

=30/29 [1-0.2288)

=30/29(0.7712)

=0.7977

Appendix G

Reliability test on Questionnaire on students' Ability to do Science QSADS using Cronbach's Alpha

Case Processing Summary

		N	%
Cases	Valid	35	100.0
	Excluded[a]	0	.0
	Total	35	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.837	15

Item Statistics

	Mean	Std. Deviation	N
Item1	4.1429	.91210	35
item2	3.6286	1.11370	35
Item3	3.5429	.98048	35
Item4	3.8000	.83314	35
Item5	3.9714	.66358	35
Item6	3.9429	1.02736	35
Item7	3.6857	1.32335	35
Item8	3.5714	1.19523	35
Item9	3.6286	1.08697	35
item10	3.2571	1.33599	35
item11	3.5429	1.03875	35
Item12	3.7429	1.12047	35
Item13	3.7714	.87735	35
Item14	3.2286	1.08697	35
Item15	3.8286	1.38236	35

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
55.2857	80.210	8.95601	15

Appendix H

COMPUTATION ANALYSIS FOR THE TWO INSTRUMENTS

Univariate Analysis of Variance

DataSet1] C:\Users\Walex\Documents\Madichie RH1.sav

Between-Subjects Factors

		Value Label	N
GROUP1	1.00	LOW ABILITY	33
	2.00	MIDDLE ABILITY	52
	3.00	HIGH ABILITY	40
GROUP2	1.00	EXPERIMENTAL	78
	2.00	CONTROL	47
SEX	1.00	MALE	24
	2.00	FEMALE	101

Descriptive Statistics

Dependent Variable: POST

GROUP1	GROUP2	SEX	Mean	Std. Deviation	N
LOW ABILITY	EXPERIMENTAL	MALE	22.0000	.00000	2
		FEMALE	20.0000	2.79285	11
		Total	20.3077	2.65784	13
	CONTROL	MALE	17.6667	1.52753	3
		FEMALE	12.7059	3.19697	17
		Total	13.4500	3.48644	20
	Total	MALE	19.4000	2.60768	5
		FEMALE	15.5714	4.70168	28
		Total	16.1515	4.63088	33
MIDDLE ABILITY	EXPERIMENTAL	MALE	24.7778	2.99073	9
		FEMALE	23.0741	4.41088	27
		Total	23.5000	4.13003	36
	CONTROL	MALE	15.7500	2.21736	4

		FEMALE	15.0833	1.78164	12
		Total	15.2500	1.84391	16
		MALE	22.0000	5.09902	13
	Total	FEMALE	20.6154	5.30945	39
		Total	20.9615	5.24297	52
		MALE	24.3333	2.51661	3
	EXPERIMENTAL	FEMALE	23.8462	3.35490	26
		Total	23.8966	3.24417	29
		MALE	17.0000	2.64575	3
HIGH ABILITY	CONTROL	FEMALE	16.2500	3.77018	8
		Total	16.4545	3.38714	11
		MALE	20.6667	4.63321	6
	Total	FEMALE	22.0588	4.71581	34
		Total	21.8500	4.67152	40
		MALE	24.2857	2.72957	14
	EXPERIMENTAL	FEMALE	22.8594	3.94754	64
		Total	23.1154	3.78301	78
		MALE	16.7000	2.11082	10
Total	CONTROL	FEMALE	14.2432	3.24384	37
		Total	14.7660	3.18429	47
		MALE	21.1250	4.53309	24
	Total	FEMALE	19.7030	5.56874	101
		Total	19.9760	5.39783	125

Tests of Between-Subjects Effects

Dependent Variable: POST

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2347.752[a]	12	195.646	17.320	.000
Intercept	5014.811	1	5014.811	443.937	.000
	15.645	1	15.645	1.385	.242
PRE					
GROUP1	27.925	2	13.963	1.236	.294
GROUP2	786.138	1	786.138	69.593	.000
SEX	3.587	1	3.587	.271	.604
GROUP1 * GROUP2	24.917	2	12.458	1.103	.335
GROUP1 * SEX	21.440	2	10.720	.949	.390
GROUP2 * SEX	1.675	1	1.675	.148	.701
GROUP1 * GROUP2 * SEX	9.984	2	4.992	.442	.644
Error	1265.176	112	11.296		
Total	53493.000	125			
Corrected Total	3612.928	124			

a. R Squared = .650 (Adjusted R Squared = .612)

Custom Hypothesis Tests Index

1	Contrast Coefficients (L' Matrix)	Simple Contrast (reference category = 1) for GROUP1
	Transformation Coefficients (M Matrix)	Identity Matrix
	Contrast Results (K Matrix)	Zero Matrix
2	Contrast Coefficients (L' Matrix)	Simple Contrast (reference category = 1) for GROUP2
	Transformation Coefficients (M Matrix)	Identity Matrix
	Contrast Results (K Matrix)	Zero Matrix
3	Contrast Coefficients (L' Matrix)	Simple Contrast (reference category = 1) for SEX
	Transformation Coefficients (M Matrix)	Identity Matrix
	Contrast Results (K Matrix)	Zero Matrix

Custom Hypothesis Tests #1

Contrast Results (K Matrix)

GROUP1 Simple Contrast[a]			Dependent Variable
			POST
Level 2 vs. Level 1	Contrast Estimate		1.265
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		1.265
	Std. Error		1.051
	Sig.		.231
	95% Confidence Interval for Difference	Lower Bound	-.817
		Upper Bound	3.348
Level 3 vs. Level 1	Contrast Estimate		1.836
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		1.836

	Std. Error		1.188
	Sig.		.125
	95% Confidence Interval for Difference	Lower Bound	-.519
		Upper Bound	4.191

a. Reference category = 1

Test Results

Dependent Variable: POST

Source	Sum of Squares	Df	Mean Square	F	Sig.
Contrast	27.925	2	13.963	1.236	.294
Error	1265.176	112	11.296		

Custom Hypothesis Tests #2

Contrast Results (K Matrix)

GROUP2 Simple Contrast[a]			Dependent Variable
			POST
Level 2 vs. Level 1	Contrast Estimate		-7.136
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-7.136
	Std. Error		.855
	Sig.		.000
	95% Confidence Interval for Difference	Lower Bound	-8.830
		Upper Bound	-5.441

a. Reference category = 1

Test Results

Dependent Variable: POST

Source	Sum of Squares	Df	Mean Square	F	Sig.
Contrast	786.138	1	786.138	69.593	.000
Error	1265.176	112	11.296		

Custom Hypothesis Tests #3

Contrast Results (K Matrix)

SEX Simple Contrast[a]			Dependent Variable POST
Level 2 vs. Level 1	Contrast Estimate		-1.834
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-1.834
	Std. Error		.851
	Sig.		.033
	95% Confidence Interval for Difference	Lower Bound	-3.519
		Upper Bound	-.148

a. Reference category = 1

Test Results

Dependent Variable: POST

Source	Sum of Squares	Df	Mean Square	F	Sig.
Contrast	52.471	1	52.471	4.645	.033
Error	1265.176	112	11.296		

Estimated Marginal Means

1. GROUP1

Estimates

Dependent Variable: POST

GROUP1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
LOW ABILITY	18.364[a]	.864	16.652	20.077
MIDDLE ABILITY	19.629[a]	.584	18.472	20.787
HIGH ABILITY	20.200[a]	.777	18.661	21.740

a. Covariates appearing in the model are evaluated at the following values: PRE = 9.2080.

Pairwise Comparisons

Dependent Variable: POST

(I) GROUP1	(J) GROUP1	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]
					Lower Bound
LOW ABILITY	MIDDLE ABILITY	-1.265	1.051	.231	-3.348
	HIGH ABILITY	-1.836	1.188	.125	-4.191
MIDDLE ABILITY	LOW ABILITY	1.265	1.051	.231	-.817
	HIGH ABILITY	-.571	.967	.556	-2.487
HIGH ABILITY	LOW ABILITY	1.836	1.188	.125	-.519
	MIDDLE ABILITY	.571	.967	.556	-1.346

Pairwise Comparisons

Dependent Variable: POST

(I) GROUP1	(J) GROUP1	95% Confidence Interval for Difference
		Upper Bound
LOW ABILITY	MIDDLE ABILITY	.817
	HIGH ABILITY	.519
MIDDLE ABILITY	LOW ABILITY	3.348
	HIGH ABILITY	1.346
HIGH ABILITY	LOW ABILITY	4.191
	MIDDLE ABILITY	2.487

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: POST

	Sum of Squares	Df	Mean Square	F	Sig.
Contrast	27.925	2	13.963	1.236	.294
Error	1265.176	112	11.296		

The F tests the effect of GROUP1. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

2. GROUP2

Estimates

Dependent Variable: POST

GROUP2	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
EXPERIMENTAL	22.966[a]	.591	21.794	24.137
CONTROL	15.830[a]	.614	14.614	17.047

a. Covariates appearing in the model are evaluated at the following values: PRE = 9.2080.

Pairwise Comparisons

Dependent Variable: POST

(I) GROUP2	(J) GROUP2	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]
					Lower Bound
EXPERIMENTAL	CONTROL	7.136*	.855	.000	5.441
CONTROL	EXPERIMENTAL	-7.136*	.855	.000	-8.830

Pairwise Comparisons

Dependent Variable: POST

(I) GROUP2	(J) GROUP2	95% Confidence Interval for Difference
		Upper Bound
EXPERIMENTAL	CONTROL	8.830*
CONTROL	EXPERIMENTAL	-5.441*

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: POST

	Sum of Squares	Df	Mean Square	F	Sig.
Contrast	786.138	1	786.138	69.593	.000
Error	1265.176	112	11.296		

The F tests the effect of GROUP2. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

3. SEX

Estimates

Dependent Variable: POST

SEX	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
MALE	20.315[a]	.766	18.797	21.832
FEMALE	18.481[a]	.369	17.750	19.212

a. Covariates appearing in the model are evaluated at the following values: PRE = 9.2080.

Pairwise Comparisons

Dependent Variable: POST

(I) SEX	(J) SEX	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
MALE	FEMALE	1.834*	.851	.604	.148	3.519
FEMALE	MALE	-1.834*	.851	.604	-3.519	-.148

Based on estimated marginal means

*. The mean difference is not significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: POST

	Sum of Squares	Df	Mean Square	F	Sig.
Contrast	3.587	1	3.587	.271	.604
Error	1265.176	112	11.296		

The F tests the effect of SEX. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

4. GROUP1 * GROUP2

Dependent Variable: POST

GROUP1	GROUP2	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
LOW ABILITY	EXPERIMENTAL	21.055[a]	1.293	18.494	23.616
	CONTROL	15.673[a]	1.131	13.433	17.913
MIDDLE ABILITY	EXPERIMENTAL	23.846[a]	.650	22.558	25.135
	CONTROL	15.412[a]	.970	13.490	17.335
HIGH ABILITY	EXPERIMENTAL	23.996[a]	1.028	21.959	26.032
	CONTROL	16.405[a]	1.153	14.120	18.689

a. Covariates appearing in the model are evaluated at the following values: PRE = 9.2080.

5. GROUP1 * SEX

Dependent Variable: POST

GROUP1	SEX	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
LOW ABILITY	MALE	20.165[a]	1.560	17.074	23.255
	FEMALE	16.564[a]	.674	15.227	17.900
MIDDLE ABILITY	MALE	20.209[a]	1.011	18.206	22.212
	FEMALE	19.049[a]	.584	17.893	20.206
HIGH ABILITY	MALE	20.570[a]	1.375	17.847	23.294
	FEMALE	19.830[a]	.704	18.435	21.226

a. Covariates appearing in the model are evaluated at the following values: PRE = 9.2080.

6. GROUP2 * SEX

Dependent Variable: POST

GROUP2	SEX	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
EXPERIMENTAL	MALE	23.719[a]	1.089	21.562	25.876
	FEMALE	22.212[a]	.464	21.293	23.132
CONTROL	MALE	16.910[a]	1.076	14.778	19.043
	FEMALE	14.750[a]	.582	13.596	15.903

a. Covariates appearing in the model are evaluated at the following values: PRE = 9.2080.

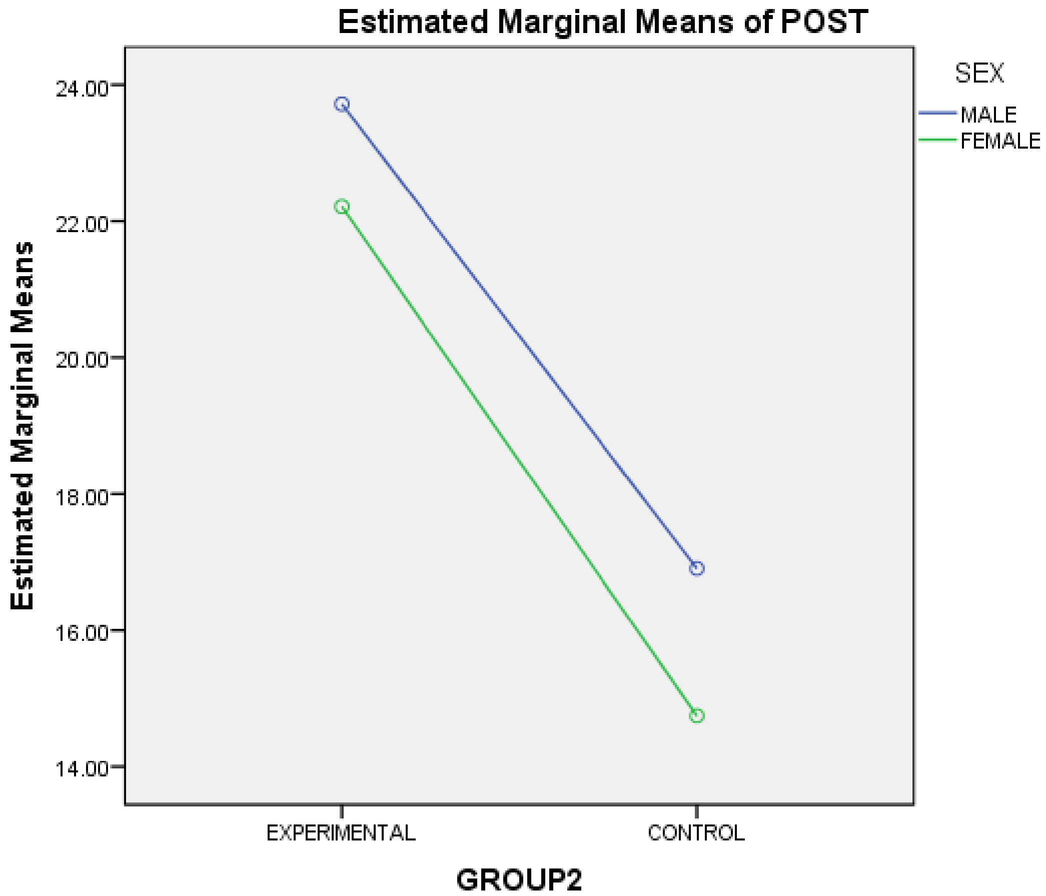
7. GROUP1 * GROUP2 * SEX

Dependent Variable: POST

GROUP1	GROUP2	SEX	Mean	Std. Error	95% Confidence Interval

					Lower Bound	Upper Bound
LOW ABILITY	EXPERIMENTAL	MALE	22.172[a]	2.381	17.454	26.890
		FEMALE	19.939[a]	1.015	17.928	21.949
	CONTROL	MALE	18.157[a]	1.985	14.225	22.090
		FEMALE	13.189[a]	.913	11.381	14.997
MIDDLE ABILITY	EXPERIMENTAL	MALE	24.698[a]	1.122	22.474	26.922
		FEMALE	22.994[a]	.650	21.706	24.283
	CONTROL	MALE	15.721[a]	1.681	12.391	19.051
		FEMALE	15.104[a]	.970	13.182	17.027
HIGH ABILITY	EXPERIMENTAL	MALE	24.287[a]	1.941	20.442	28.133
		FEMALE	23.704[a]	.670	22.377	25.032
	CONTROL	MALE	16.853[a]	1.944	13.000	20.706
		FEMALE	15.956[a]	1.214	13.551	18.362

a. Covariates appearing in the model are evaluated at the following values: PRE = 9.2080.

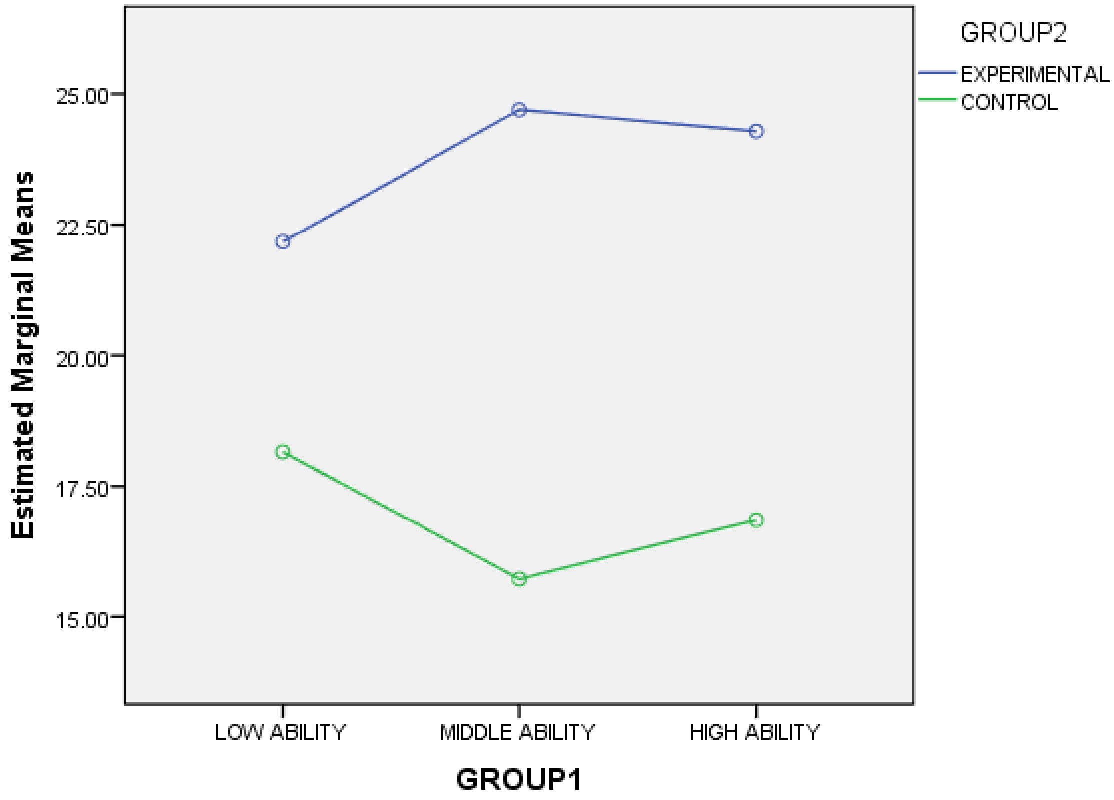


Covariates appearing in the model are evaluated at the following values: PRE = 9.2080

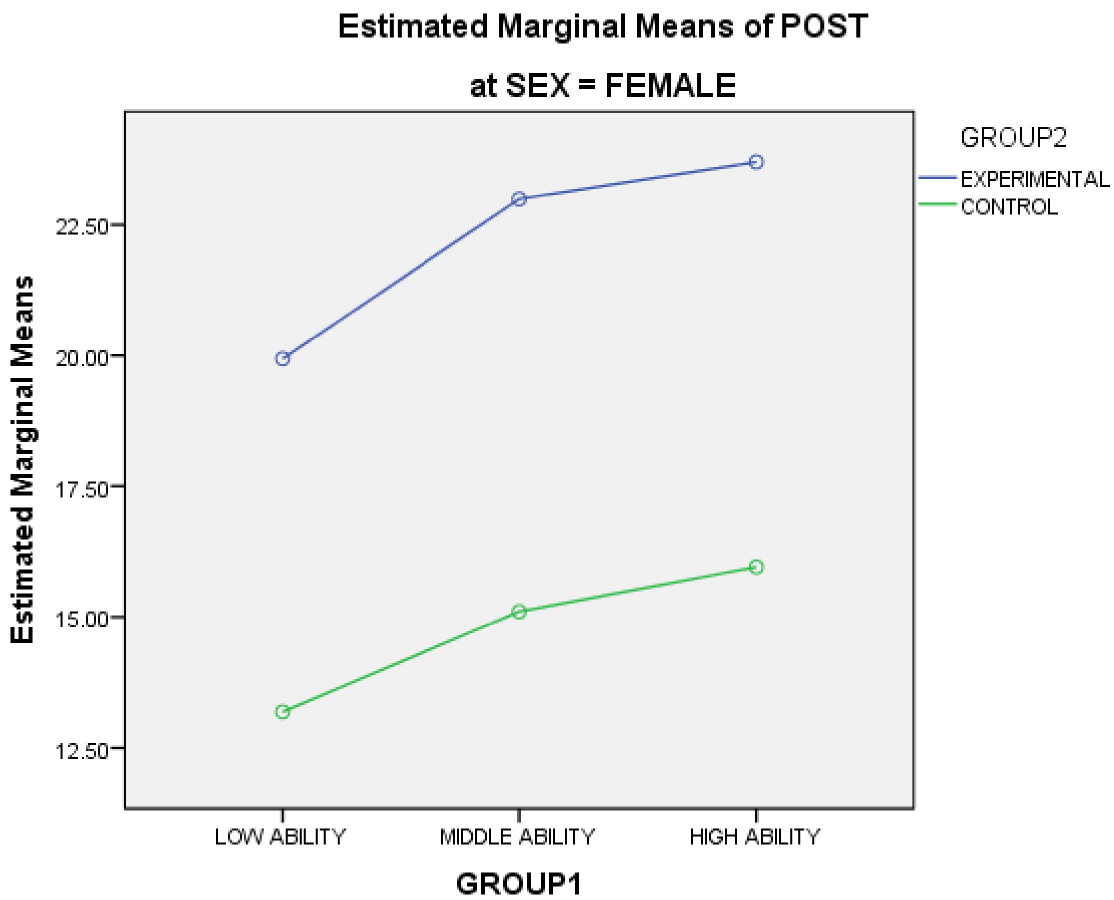
GROUP1 * GROUP2 * SEX

Estimated Marginal Means of POST

at SEX = MALE

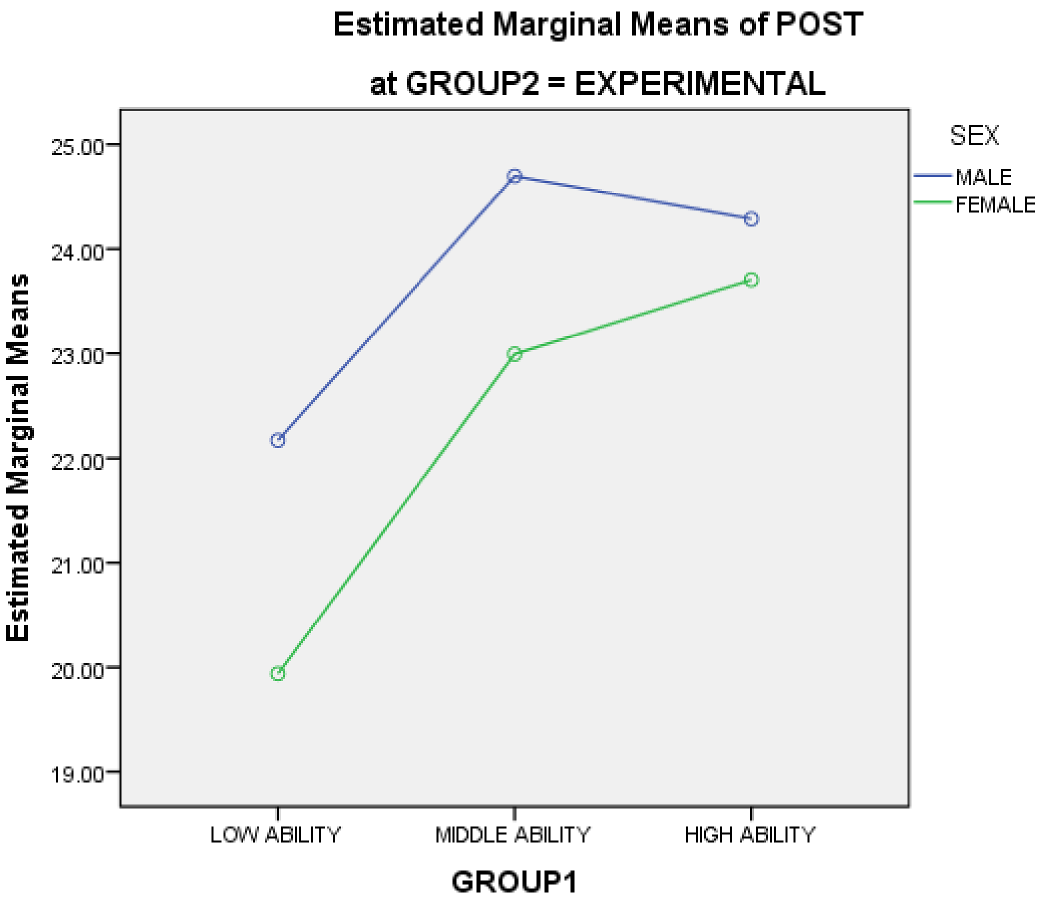


Covariates appearing in the model are evaluated at the following values: PRE = 9.2080

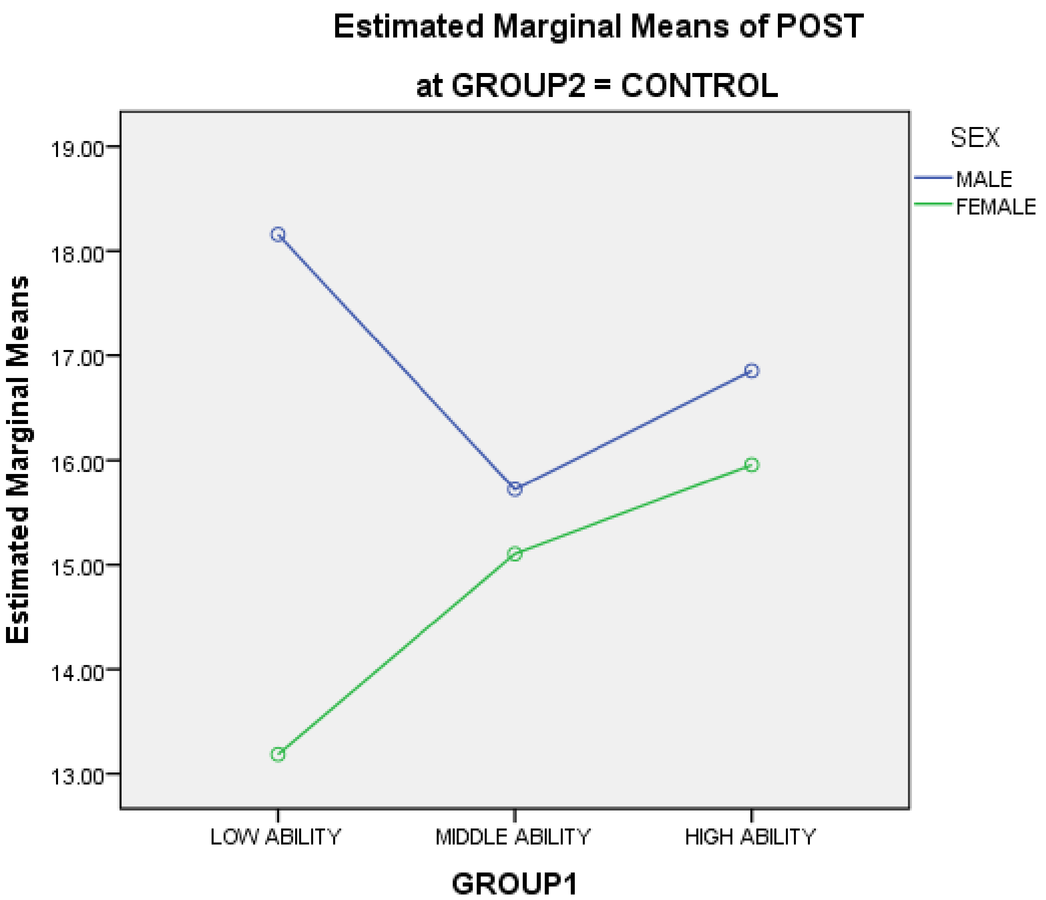


Covariates appearing in the model are evaluated at the following values: PRE = 9.2080

GROUP1 * SEX * GROUP2

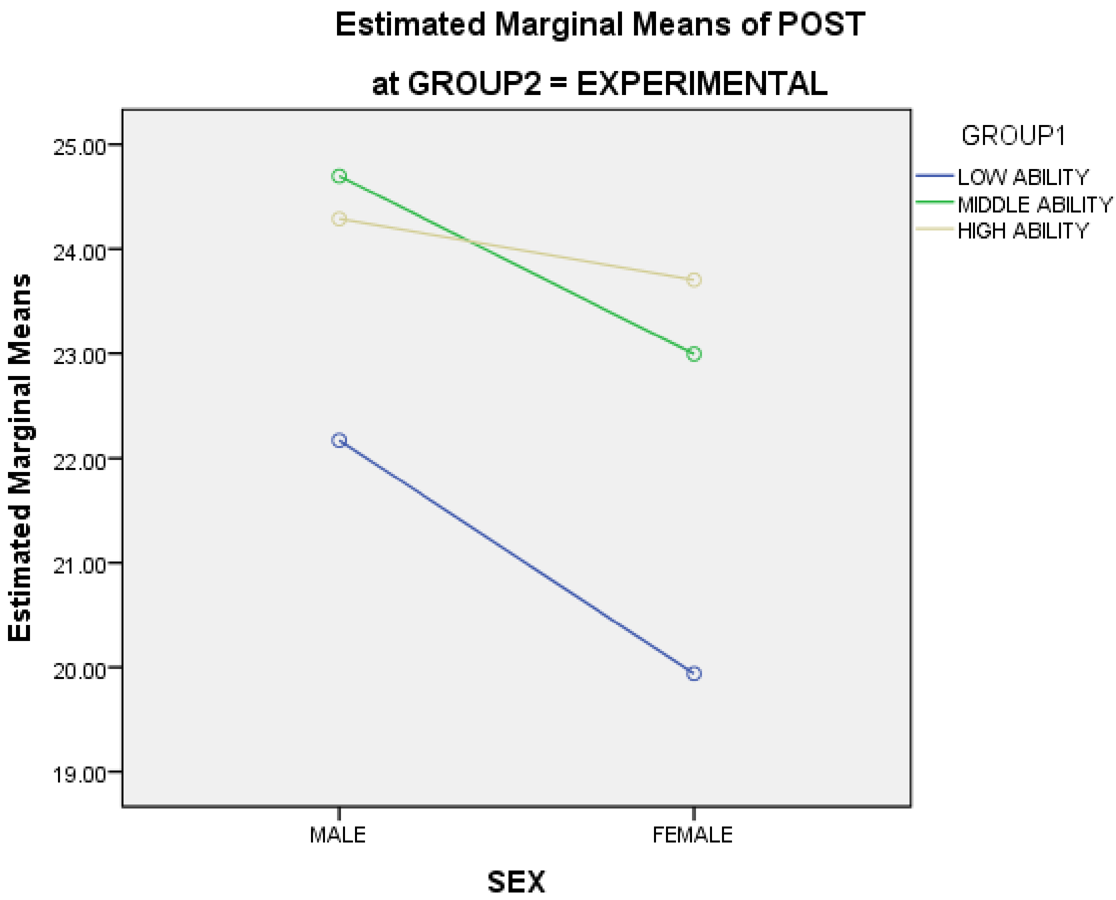


Covariates appearing in the model are evaluated at the following values: PRE = 9.2080

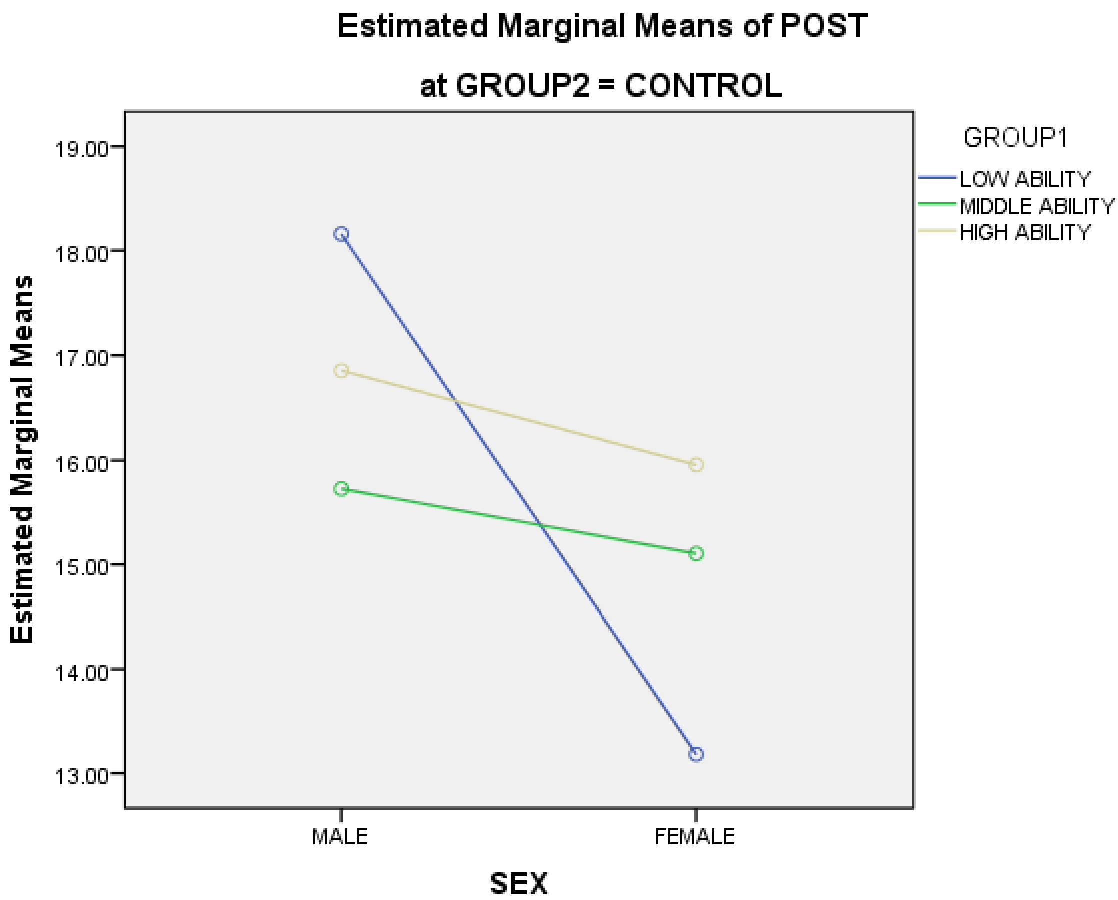


Covariates appearing in the model are evaluated at the following values: PRE = 9.2080

SEX * GROUP1 * GROUP2

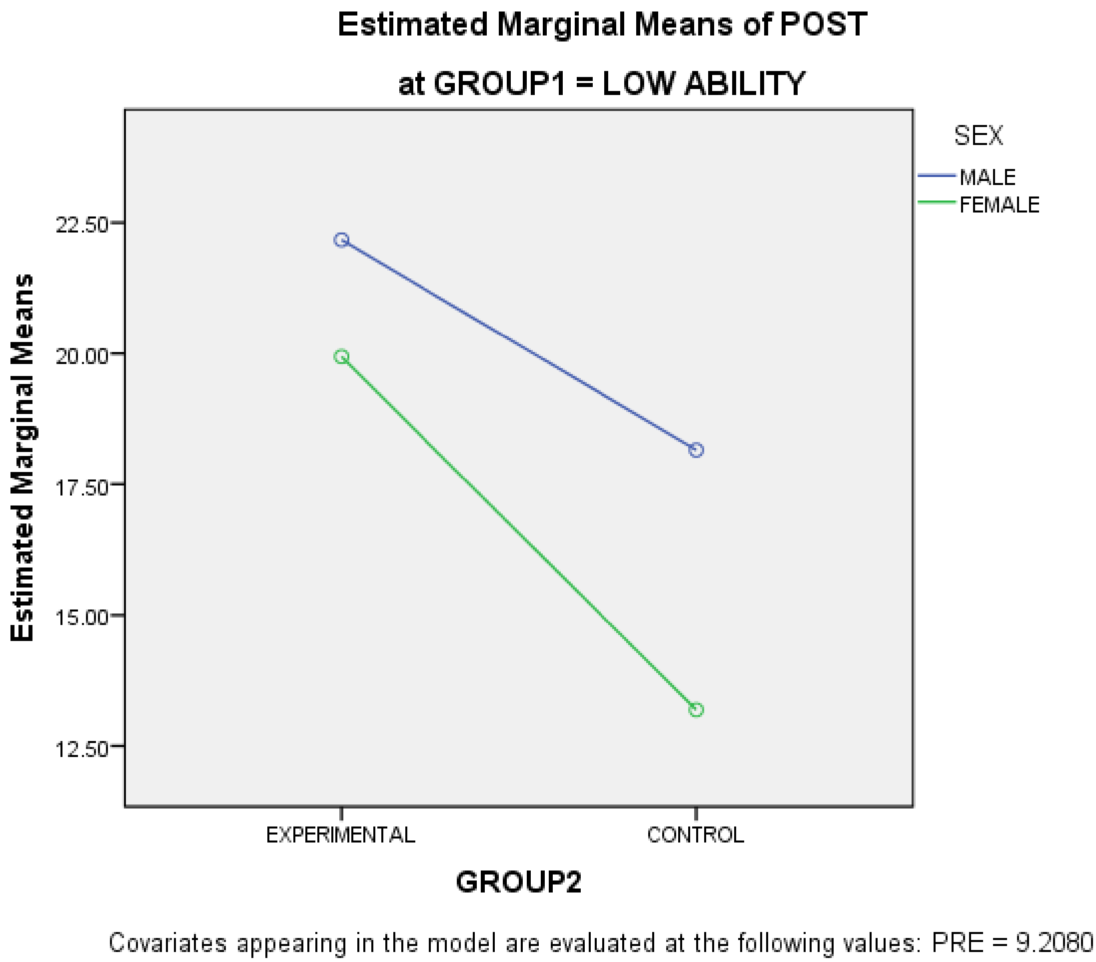


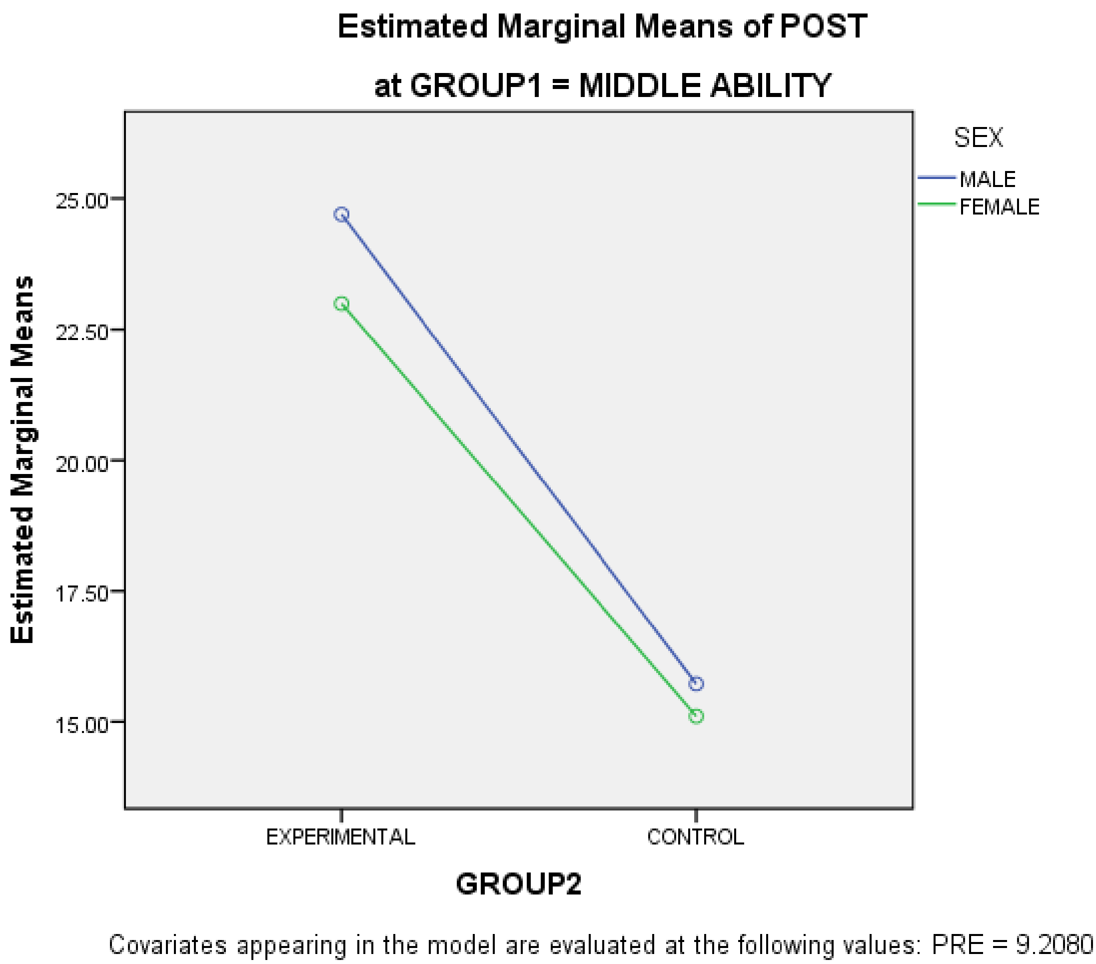
Covariates appearing in the model are evaluated at the following values: PRE = 9.2080

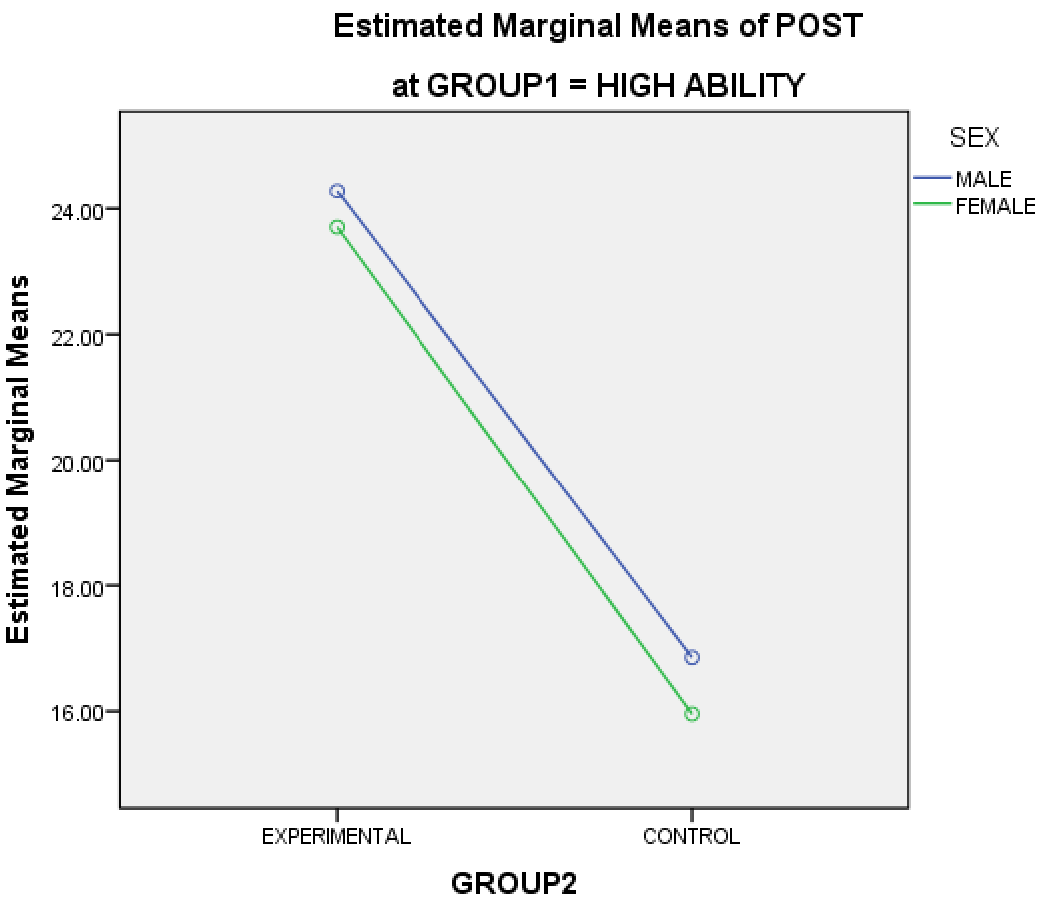


Covariates appearing in the model are evaluated at the following values: PRE = 9.2080

GROUP2 * SEX * GROUP1




Estimated Marginal Means of POST
at GROUP1 = MIDDLE ABILITY
SEX
MALE
FEMALE
Estimated Marginal Means
25.00
22.50
20.00
17.50
15.00
EXPERIMENTAL
CONTROL
GROUP2
Covariates appearing in the model are evaluated at the following values: PRE = 9.2080



Covariates appearing in the model are evaluated at the following values: PRE = 9.2080

Univariate Analysis of Variance

[DataSet9] C:\Users\Walex\Documents\Mrs Madichie JC RH 2.sav

Between-Subjects Factors

		Value Label	N
GROUP1	1.00	LOW ABILITY	33
	2.00	MIDDLE ABILITY	52
	3.00	HIGH ABILITY	40
GROUP2	1.00	EXPERIMENTAL	78
	2.00	CONTROL	47
SEX	1.00	MALE	24
	2.00	FEMALE	101

Descriptive Statistics

Dependent Variable: POST

GROUP1	GROUP2	SEX	Mean	Std. Deviation	N
LOW ABILITY	EXPERIMENTAL	MALE	3.8333	.89567	2
		FEMALE	3.6485	1.24010	11
		Total	3.6769	1.16328	13
	CONTROL	MALE	3.2222	.21430	3
		FEMALE	3.8235	.55073	17
		Total	3.7333	.55567	20
	Total	MALE	3.4667	.57927	5
		FEMALE	3.7548	.86999	28
		Total	3.7111	.83161	33
MIDDLE ABILITY	EXPERIMENTAL	MALE	3.6074	1.34058	9
		FEMALE	3.4543	1.16061	27
		Total	3.4926	1.18993	36
	CONTROL	MALE	3.8726	.39081	4
		FEMALE	3.9056	.60800	12
		Total	3.8973	.54941	16
	Total	MALE	3.6890	1.11916	13
		FEMALE	3.5932	1.03594	39
		Total	3.6171	1.04694	52
HIGH ABILITY	EXPERIMENTAL	MALE	3.4444	.65433	3
		FEMALE	3.5923	1.03354	26
		Total	3.5770	.99320	29
	CONTROL	MALE	4.1333	.26667	3
		FEMALE	3.5917	.59887	8
		Total	3.7394	.57384	11
	Total	MALE	3.7889	.58487	6
		FEMALE	3.5922	.94092	34
		Total	3.6217	.89333	40
Total	EXPERIMENTAL	MALE	3.6048	1.11691	14

			3.5438	1.10916	64
		FEMALE			
		Total	3.5547	1.10350	78
		MALE	3.7557	.47476	10
	CONTROL	FEMALE	3.8000	.57542	37
		Total	3.7906	.55097	47
		MALE	3.6677	.89392	24
	Total	FEMALE	3.6376	.95375	101
		Total	3.6434	.93911	125

Tests of Between-Subjects Effects

Dependent Variable: POST

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	51.112[a]	12	4.259	8.190	.000
Intercept	18.489	1	18.489	35.551	.000
PRE	47.016	1	47.016	90.403	.000
GROUP1	.146	2	.073	.140	.869
GROUP2	.131	1	.131	.253	.616
SEX	.667	1	.667	1.283	.260
GROUP1 * GROUP2	1.547	2	.774	1.488	.230
GROUP1 * SEX	.568	2	.284	.546	.581
GROUP2 * SEX	.188	1	.188	.361	.549
GROUP1 * GROUP2 * SEX	.287	2	.144	.276	.759
Error	58.248	112	.520		
Total	1768.647	125			
Corrected Total	109.360	124			

a. R Squared = .467 (Adjusted R Squared = .410)

Custom Hypothesis Tests Index

1	Contrast Coefficients (L' Matrix)	Simple Contrast (reference category = 1) for GROUP1
	Transformation Coefficients (M Matrix)	Identity Matrix
	Contrast Results (K Matrix)	Zero Matrix
2	Contrast Coefficients (L' Matrix)	Simple Contrast (reference category = 1) for GROUP2
	Transformation Coefficients (M Matrix)	Identity Matrix
	Contrast Results (K Matrix)	Zero Matrix
3	Contrast Coefficients (L' Matrix)	Simple Contrast (reference category = 1) for SEX
	Transformation Coefficients (M Matrix)	Identity Matrix
	Contrast Results (K Matrix)	Zero Matrix

Custom Hypothesis Tests #1

Contrast Results (K Matrix)

GROUP1 Simple Contrast[a]			Dependent Variable
			POST
Level 2 vs. Level 1	Contrast Estimate		-.040
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-.040
	Std. Error		.219
	Sig.		.856
	95% Confidence Interval for	Lower Bound	-.473

	Difference	Upper Bound	.393
Level 3 vs. Level 1	Contrast Estimate		.070
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		.070
	Std. Error		.243
	Sig.		.774
	95% Confidence Interval for Difference	Lower Bound	-.411
		Upper Bound	.551

a. Reference category = 1

Test Results

Dependent Variable: POST

Source	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.146	2	.073	.140	.869
Error	58.248	112	.520		

Custom Hypothesis Tests #2

Contrast Results (K Matrix)

GROUP2 Simple Contrast[a]			Dependent Variable POST
Level 2 vs. Level 1	Contrast Estimate		.092
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		.092
	Std. Error		.182
	Sig.		.616
	95% Confidence Interval for Difference	Lower Bound	-.269
		Upper Bound	.453

a. Reference category = 1

Test Results

Dependent Variable: POST

Source	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.131	1	.131	.253	.616
Error	58.248	112	.520		

Custom Hypothesis Tests #3

Contrast Results (K Matrix)

SEX Simple Contrast[a]			Dependent Variable
			POST
Level 2 vs. Level 1	Contrast Estimate		-.207
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-.207
	Std. Error		.183
	Sig.		.260
	95% Confidence Interval for Difference	Lower Bound	-.570
		Upper Bound	.155

a. Reference category = 1

Test Results

Dependent Variable: POST

Source	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.667	1	.667	1.283	.260
Error	58.248	112	.520		

Estimated Marginal Means

1. GROUP1

Estimates

Dependent Variable: POST

GROUP1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
LOW ABILITY	3.740[a]	.179	3.386	4.095
MIDDLE ABILITY	3.701[a]	.125	3.453	3.948
HIGH ABILITY	3.810[a]	.165	3.484	4.137

a. Covariates appearing in the model are evaluated at the following values: PRE = 3.6688.

Pairwise Comparisons

Dependent Variable: POST

(I) GROUP1	(J) GROUP1	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]
					Lower Bound
LOW ABILITY	MIDDLE ABILITY	.040	.219	.856	-.393
	HIGH ABILITY	-.070	.243	.774	-.551
MIDDLE ABILITY	LOW ABILITY	-.040	.219	.856	-.473
	HIGH ABILITY	-.110	.207	.598	-.520
HIGH ABILITY	LOW ABILITY	.070	.243	.774	-.411
	MIDDLE ABILITY	.110	.207	.598	-.300

Pairwise Comparisons

Dependent Variable: POST

(I) GROUP1	(J) GROUP1	95% Confidence Interval for Difference
		Upper Bound
LOW ABILITY	MIDDLE ABILITY	.473
	HIGH ABILITY	.411
MIDDLE ABILITY	LOW ABILITY	.393
	HIGH ABILITY	.300
HIGH ABILITY	LOW ABILITY	.551
	MIDDLE ABILITY	.520

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: POST

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.146	2	.073	.140	.869
Error	58.248	112	.520		

The F tests the effect of GROUP1. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

2. GROUP2

Estimates

Dependent Variable: POST

GROUP2	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
EXPERIMENTAL	3.705[a]	.127	3.453	3.957
CONTROL	3.796[a]	.131	3.537	4.055

a. Covariates appearing in the model are evaluated at the following values: PRE = 3.6688.

Pairwise Comparisons

Dependent Variable: POST

(I) GROUP2	(J) GROUP2	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]
					Lower Bound
EXPERIMENTAL	CONTROL	-.092	.182	.616	-.453
CONTROL	EXPERIMENTAL	.092	.182	.616	-.269

Pairwise Comparisons

Dependent Variable: POST

(I) GROUP2	(J) GROUP2	95% Confidence Interval for Difference
		Upper Bound
EXPERIMENTAL	CONTROL	.269
CONTROL	EXPERIMENTAL	.453

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: POST

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.131	1	.131	.253	.616
Error	58.248	112	.520		

The F tests the effect of GROUP2. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

3. SEX

Estimates

Dependent Variable: POST

SEX	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
MALE	3.854[a]	.165	3.527	4.181
FEMALE	3.647[a]	.079	3.490	3.804

a. Covariates appearing in the model are evaluated at the following values: PRE = 3.6688.

Pairwise Comparisons

Dependent Variable: POST

(I) SEX	(J) SEX	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
MALE	FEMALE	.207	.183	.260	-.155	.570
FEMALE	MALE	-.207	.183	.260	-.570	.155

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: POST

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.667	1	.667	1.283	.260
Error	58.248	112	.520		

The F tests the effect of SEX. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Appendix I
Marking Scheme for Achievement Test on Redox Reactions (ATORR)

1	B	21	A
2	B	22	B
3	B	23	A
4	B	24	A
5	B	25	D
6	D	26	B
7	A	27	C
8	D	28	D
9	B	29	D
10	B	30	B
11	C	31	C
12	C	32	A
13	C	33	C
14	A	35	D
15	B		
16	D		
17	B		
18	B		
19	D		

APPENDIX J

Table of Specification for Achievement Test on Redox Reactions ATTORR

%Content	10	10	15	30	20	15	Total
Redox	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	35
Reactions	4	4	5	10	7	5	

Appendix K
SWH Grading-Rubric and Rubric Grid

Students reports are graded using a ten-category, 40 point grading rubric. This could be modified to meet the needs of any grading scheme. Students are provided a thorough verbal and written explanation of how the points are awarded so that they are well-informed about how detailed their reports should be. An abbreviated version of the rubric and a grading grid follow this session.

1. Can the beginning questions be potentially answered by the results of the laboratory experiment?
   0-Questions cannot be answered by doing experimental work or the questions are not related to the lab
   1-One or two inappropriate, trivial, or factoid questions (ex. Why questions: Why are there buffers? What questions: What color is my product?)
   2-One directed question that can be answered by doing experimental work.
   3-More than one or two questions that demonstrate understanding of what the lab could result in.
   4-One or two questions that demonstrate understanding of independent and dependent variables, a generalization, or an appropriate application of what the lab could result in.
   Or, the student improves his or her questions (makes a significant change) as the purpose of the lab becomes clearer or the class agrees to take the experiment in a different direction.

2. What is the quality of the data and observation?
   0-Does not display any understanding or shows no data.
   1-Only limited portions of data are recorded.
   2-Listed all data.
   3-Lists all data, observations and appropriate calculations. Good organization of the data and observation. Correct use of significant figures and units.
   4-Lists all data, observations and appropriate calculations and notes additional chemical information such as potential tends, likely reactions, balanced equations, etc. Good information such as potential tends, likely reactions, balanced equations, etc,. Good organization of the data and observation. Showed all appropriate steps in the calculation. Correct use of significant figures and units. Displays an understanding of how and why the data was collected.

3. Are the claims a direct result of the data and observations?
   0-No, missed the point or showed a misunderstanding of the lab or a lack of understanding of the lab
   1-Has claims for only a portion or sections of the data.
   2-Has claims for all data but only has numeric answers and doesn't grasp bigger picture (ex. trends)
   3-Has claims for all data-numeric and concepts. Writes using proper English.

4-Several claims for all data, numeric and concepts.

4. How well are your data and observations used in the evidence statements?
   0-Not used in evidence statements.
   1-Referred to some of the data.
   2-Restates data or observation, which would support the claim.
   3-Interprets graphs, calculations and balanced equations. Correct use of significant figures and units.
   4-Interprets graphs, calculations, and balanced equations and explains how the interpretations relate to claims. Correct use of significant figures and units. Write a paragraph using proper English with clear logical statements.

5. Are the claims backed up in the evidence?
   0-Evidence does not support claims made.
   1-Claims and procedures are simply restated, but not explained.
   2-Refers to chemical equations, calculations, and graphs.
   3-Explains the chemical equations, calculations, and graphs. Correct use of significant figures and units. Writes using proper English.
   4-Explains and interprets chemical equations, calculations, and graphs. Restates claims and clearly defends them. Mathematic calculations, all steps, are clearly written and explained. Correct use of significant figures and units. Writes a paragraph using proper English with clear logical statements. Inferences drawn.

6. How well does the student answer all of the questions that were asked in the laboratory write-up for this particular experiment?
   0-No questions were answered or the questions were answered but 80% were incorrect.
   1-Some questions answered, but the majority were not answered or answered incorrectly.
   2-50% of the questions were answered correctly.
   3-80% of the questions were answered correctly.
   4-All questions answered correctly.

7. How well does the students analyze the data and observation to make the experimental measurements or observations meaningful?
   0-No or very little attempt at doing everything necessary for the analysis.
   1-Did less than 50% of the analysis.
   2-Did 60% of the analysis.
   3-Did 80% of the analysis.
   4-Everythibng necessary for the analysis was done and done well.

8. Do the results of the experiment come close to the accepted values, or identify an unknown compound correctly, or show an accepted comparison, trend, etc?
   0-Results are so far off as to be meaningless.
   1-The results are within the ballpark, but not on the playing field.
   2-Within 40% of the accepted value.
   3-Within 60% of the accepted value.
   4-Within 80% of the accepted value.

9. In the reflection and readings how many sources are used and how are they connected?
   0-No sources.
   1-One source but linked poorly to experiment.
   2-One source and linked well.
   3-More than one source and linked well to evidence, very helpful to explain data.
   4-More than one source, and refers to place of found knowledge (ex. Graphs, comparisons, a reference to a textbook or handbook with the “literature value’). Linked directly to claims and evidence,. Defines meaning behind graph slopes, pH levels, and other explainable elements. Relates all of science content back to the experiments results and or discusses the results in terms of commercial, medical, household, etc. applications.

10. Does your readings and reflection discuss your initial questions? Does your reading and reflections aid your claims and evidence?
    0-No, not related
    1-Only discuss some of your questions (maybe indirectly). Does explain and define parts of your evidence.
    2-Yes, the questions are answered based on the results of your experiment. Explains and defines all or most of your evidence.
    3-Yes, the questions are answered based on the results of your experiment and have stated new questions or have discussed how ideas/concepts have changed or how ideas/concepts are now better understood. Explains and defines all or most of your evidence, plus discuss initial questions and changing ideas, new questions and one outside source.
    4-Initial questions are answered by an analysis of the results, new questions and changed ideas/concepts(or better understood ideas/concepts) have been stated, and results have been compared to other groups, teachers, textbooks, and other sources. Writes a paragraph using proper English with clear logical statements, explains and defines all or most of your evidence, including terminology that would aid the readers understanding plus discusses initial questions and changing ideas. Refers to place of found knowledge (e.g, graph). Also includes the use of several outside sources including textbooks (page numbers), other groups’ results, literature (e.g, handbook values), class lecture notes (date), teacher, etc.

SWH Grading grid for Instructors – 40 points total for each lab

Rubric categories	0	1	2	3	4
1. Can the beginning questions be potentially answered by the results of the lab?					
2. What is the quality of the data and observation?					
3. Are the claims a direct result of the data and observation?					
4. How well are your data and observation used in your evidence?					
5. Are the claims backed up in the evidence?					
6. How well does the student answer all of the questions that were asked in the laboratory write-up for this particular experiment?					
7. How well does the student analyze that data and observations to make the experimental measurements or observations meaningful?					
8. Do the results of the experiment come close to the accepted values, or identify an unknown compound correctly, or show an accepted comparison, trend, etc?					
9. In the reflection and readings how many sources are used and how are they connected?					
10. Does your reading and reflection discuss your initial questions? Does your reading and reflections aid your claims and evidence?					