UNIVERSITY OF EDUCATION, WINNEBA

COMPARING THE EFFECTS OF MNEMONIC, PRIOR KNOWLEDGE AND MODIFIED LECTURE-BASED INSTRUCTIONAL STRATEGIES ON STUDENTS' LEARNING OUTCOMES OF ION-IDENTIFICATION IN ACCRA GIRLS' SENIOR HIGH SCHOOL

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A dissertation in the Department of Science Education, Faculty of Science Education, Submitted to the School of Graduate studies in partial fulfilment

of the requirements for the award of the degree of Master of Education (Science Education) in the University of Education, Winneba.

MARCH, 2022

DECLARATION

Student's Declaration

I, LAWRENCE KORANKYE-MENSAH, declare that this project, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE……………………………………………

DATE …………………………………………………

Supervisor's Declaration

I, hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of project as laid down by the University of Education, Winneba.

DR. EMMANUEL OPPONG

Signature………………………………….

Date ………………………………………

DEDICATION

To my sweet grandmother, Nana Adjoa Kesewaa.

ACKNOWLEDGEMENTS

I am thankful to all who in diverse ways helped in producing this work. My special gratitude to Dr. Laurel Mends for the immense help. I also appreciate all the technical advice and guidance from Dr. Emmanuel Oppong, my supervisor. Finally, the cooperation and assistance from the students and staff of Accra Girls' Senior High School are duly acknowledged.

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ABBREVIATIONS

MBIS	**:**	Mnemonic-based instructional strategy.
RPKBIS	**:**	Relevant prior knowledge-based instructional strategy.
MLM	**:**	Modified lecture method.
GES	**:**	Ghana Education Service.
NaCCA	**:**	National Council for Curriculum and Assessment.
SHS	**:**	Senior High School.
MLT	**:**	Meaningful learning theory.
ST	**:**	Schema theory.
$SS3_{T1}$	**:**	Group representing form 3 Science students that received mnemonic treatment.
$SS3_{T2}$	**:**	Group representing form 3 Science students that received Prior knowledge treatment.
SS3C	**:**	Group of form 3 Science students who were given Standard treatment representing control.
WASSCE	**:**	West African Senior School Certificate Examinations.
WAEC	**:**	West African Examinations Council.
NVR	**:**	No visible reaction.
IGCSE	**:**	International General Certificate of Secondary Education.
FSHSP	**:**	Free Senior High School Policy.
AGISS	**:**	Accra Girls' Senior High School.

ABSTRACT

The type of instructional strategies adopted by students and teachers affect learners' educational outcomes such as students'test scores or attitude to the topic after instruction, whether favourably or otherwise. The purpose of this study was to determine the most effective teaching method for the instruction of ion identification, during ion-qualitative analysis in Accra Girls' Senior School by adopting the pretest-posttest control true experimental design. Twelve students each from a randomly selected intact class were randomly assigned to three independent groups. Treatment lasted for two weeks. Instruments used were achievement test, self-administered questionnaire (Cronbach reliability=0.84) and an interview schedule. Three hypotheses were tested at 0.05 level of significance and, data analysed using the one way analysis of covariance followed by Bonferroni post hoc pairwise comparison test .The participants were relatively young (M = 17.33, SD = 0.89) and residential status split between day (50%) and boarding (50%).The respective mean achievement scores for MBIS, RPKBIS and MLM groups, controlling for covariate were 27.69 (SD=0.61), 20.78 (SD=0.60) and 16.37 (SD=0.62). Pairwise comparison indicated statistically significant contributions by all three levels of the independent variable. On all five measures of attitude, students in the mnemonic group scored highest after treatment, with that of prior knowledge trailing. All twelve students in the mnemonic group reported an improved performance due to option to select one's own mnemonic type for analysis. All three null hypotheses were thus rejected since differences in means were statistically significant ($F_{(2, 32)} = 67.39$, $P < 0.05$) . Overall, the study revealed that learners' test scores and attitude to ion qualitative analysis improved by the largest margin when mnemonic-based instructional method was adopted compared with the prior-knowledge or modified lecture method of instruction. It is recommended that curriculum designers include mnemonics for the ion analysis and students should be encouraged to create and use their own mnemonics especially acronyms for the ion-qualitative analysis and periodically study it using "doing practice problems" since these ranked first among other strategies for effectiveness.

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter forms the introductory part of the study. It starts with background to the study and ends with the general layout of the entire study. The background is followed by problem statement and problem identification. The purpose and study hypotheses are then stated. The significance, delimitation, assumption, definition of terms and objectives of the study then follow in that order.

1.2 Background to the Study

Beginning from the time of ancient Greek, various neuroscience studies have proven that people with outstanding memory abilities do not have significant innate cognitive dispositions better than others, but rather applied dedicated rehearsal of a few mnemonic techniques that everyone can learn to use. Competitive mnemonists use these memory strategies to improve recall and organise information efficiently. (Ericsson & Crutcher, 2003) .

According to Ho (2021), in the absence of mnemonic with meaningful learning basis, students learn by rote. This information so learnt is only stored in the short term memory and creates a vicious cycle where time is wasted by repeatedly returning to the learning material for recall, and for a short time forgetting.

Yara (2009) posits that students' beliefs and attitudes as well as the attitudes and teaching methods of their teachers have the potential to either facilitate or inhibit learning. The West African Examinations Council (2010) lists the following inorganic ions expected to be analysed and identified: NH_4^+, Ca^{2+}, Pb^{2+}, Zn^{2+}, Al^{3+}, Fe^{2+}, Fe^{3+}, Cu^{2+}, S^{2-}, SO_3^{2-}, CO_3^{2-}, Cl^-, SO_4^{2-}, NO_3^-.

Qualitative analysis of these ions finds application in the following topics, found in the rest of the syllabus: Solubility of precipitates, rate of reaction, dynamic equilibrium, crystallisation, recrystallization, electrolysis and electrochemistry. Therefore, the mnemonic to help encode and recall the ion reaction patterns is invaluable to students' learning outcomes especially in these topics. A vicious cycle ensues between these topics and identification of ions , thus impacting negatively on students' attitude to the study of chemistry.

Though some authors have created mnemonic devices to assist students memorise precipitation reaction patterns, this is only for some of the cations as shown in Table 1 using the mnemonic "LAZCuZCuFeCaLAFe"

Table 1: Solubilty of precipitates on addition of NaOH(aq) or NH3(aq)

Observation with excess	Reagents	
Reagent	Dilute NaOH	Dilute NH_3
Soluble in excess	LAZ	CuZ
Insoluble in excess	Cu Fe Ca	LA Fe

Note. L, A, Z, Cu, Ca, Fe represent the metallic radicals Lead, Aluminium, Zinc, Copper, Calcium, and iron respectively.

Source: Essel (1997)

Table 2: Mnemonic, colour and nature of precipitates with NaOH

Symbol	Cation	Colour
L	Pb^{2+}	White chalky precipitate
A	Al^{3+}	White gelatinous precipitate
Z	Zn^{2+}	White gelatinous precipitate
Cu	Cu^{2+}	Blue gelatinous precipitate
Fe	Fe^{2+}	Green gelatinous precipitate
Fe	Fe^{3+}	Brown gelatinous precipitate
Ca	Ca^{2+}	White chalky precipitate

Source: Essel (1997)

Table 2 shows the colours of the cations in Table 1. However ammonium ion is missing in this mnemonic though required by the syllabus. Cations which give no visible reaction and their behaviour when heated are also absent in the mnemonic device. (The West African Examinations Council, 2010).

Further, the memory device is not meaningful, making it difficult for students to relate to previous knowledge. Lastly there is no mnemonic for the anions.

Sunshine Educational Resource (2017) also used the mnemonic device in Table 3 to help students memorise eight of the ions prescribed.

Table 3:Mnemonics for Solubility of precipitates containing metallic radicals on addition of excess $NaOH_{(aq)}$ and $NH_{3(aq)}$ respectively.

Cations	Solubility
Ca^{2+}	Ca – In - -
Pb^{2+}	Pb – S – In
Al^{3+}	Al – S – In
Zn^{2+}	Z – S – S
Fe^{2+}	Fe – In – In
Fe^{3+}	Fe – In – In
Cu^{2+}	Cu – In – S
NH_4^+	NH_4 - - -

Source: Sunshine Educational Resource (2017)

"S" means precipitate is soluble, "In" means precipitate is insoluble and an extra dash means no visible reaction. The first "S" or "In" refers to solubility of the precipitate in aqueous ammonia and the second refers to solubility of precipitate in aqueous sodium hydroxide. However where there is no visible reaction another dash is used.

Though this device, unlike the previous, includes cations that show no visible reaction, getting a recall cue for all these separate mnemonics is difficult. Further, this memory device does not provide any cue for recalling the anions. Odeyemi and Akinsola (2014) on the effects of instructional strategies at different levels and the learning outcomes of students in mathematics, discovered that mnemonic and prior knowledge-based instructional strategies improved students' achievement and attitude to instruction regardless of gender: Specifically, the mnemonic based instructional strategy group had a higher achievement mean score (x=13.07) than the control group (x=12.0). Further, there was significant main effect of treatment on students' attitude to instruction. In this study, the three levels of instructional strategies-mnemonic, prior knowledge and modified lecture method-are compared for their effectiveness when applied to qualitative analysis. Coverdale & Nairne (2019) found out that participants' memory was improved compared with a yoked control group when the experimental group was given choices in their learning session to select the words to be remembered. This study extends the finding by applying it to the memorisation of the ions and providing different mnemonic options to students.

1.3 Statement of the Problem

Many Students have difficulty understanding the formation of precipitate complex salts and the reactions of acids and alkalis in qualitative analysis because the topic is conceptually difficult to understand and there is inadequate time for comprehensive experimental work. (Goh, Tan, Chia, & Treagust, 2004)

Thirty-three percent of chemistry contact hours is intended to be used for practical lessons for form one to three to help students understand ion-identification which in turn will increase learning outcomes. This is relevant because performing well in many other topics in chemistry is hinged on grasping ion-qualitative analysis according to the ministry of education education syllabus. (2010).

Over the years, from author's personal observation, students in AGISS have increasingly resorted to rote learning and cramming of the reaction patterns of the ions, in order to make time to exhaust all the theoretical aspect of the syllabus. In this study, the effects of mnemonic, prior knowledge, and adjusted lecture -based instructional strategies on learning outcomes of ion-identification in AGISS are determined, together with students' attitudes to instruction at different levels of the independent variable. The most effective method for recalling the reaction patterns of these ions is also determined.

1.4 Problem Identification

1. Low interest and poor attitude of SHS students to qualitative analysis due partly to the complex nature of cation-anion reactions with reagent in both wet and dry reactions.
2. Lack of a comprehensive and tailor-made set of learning strategies such as mnemonic to memorise and recall ion-identification processes.
3. Inadequate data on how the following instructional strategies correlate with learning outcomes as applied to inorganic qualitative analysis: Mnemonic based instructional strategy, Prior knowledge strategy and modified Lecture method.
4. SHS chemistry students do not have access to any known mnemonic choices in ion-identification learning episodes to select from during encoding and recall.

1.5 Purpose of Study

The study was to determine and compare the effects of mnemonic, prior knowledge, and modified lecture method based-instructional strategies on students' learning outcomes of ion-identification in AGISS to determine the most effective method.

1.6 Objectives of the Study

The objectives of the study were to:

1. To identify the most effective instructional strategy to ion-identification experiments.
2. To assess the attitudes of students to qualitative analysis after treatment with different types of learning strategies: Modified lecture, Prior knowledge and Mnemonic.
3. To replicate (or refute) and extend knowledge on the connection between providing students with different mnemonic types to choose from, and their learning outcomes.

1.7 Research Questions

The following research questions were formulated to guide the study

1 How does the test scores of students in the MBIS, RPKBIS, and MLM groups compare after respective treatments with mnemonic, prior knowledge and modified lecture methods.

2 How does the attitude of students in the MBIS, RPKBIS, and MLM groups compare after respective treatments with mnemonic, prior knowledge and modified lecture methods.

3 What is the association between providing students with different mnemonic types to choose from, and their learning outcomes.

1.8 Study Hypotheses

a) Null Hypothesis

The following null hypothesis was tested at 0.05 significance levels

H_0: There is no statistically significant difference in the effects of mnemonic, prior-knowledge or modified lecture instructional methods on students' learning outcomes .

b) Alternative hypothesis

H_A: There is statistically significant difference in the effects of mnemonic, prior-knowledge or modified lecture instructional methods on students' learning outcomes .

1.9 Significance of the Study

It is expected that the results of this study would provide a new body of knowledge to existing literature about instructional strategies of ion-qualitative experiments. This study would assist students in AGISS with a mnemonic template to improve memory on ion-identification and provide a metacognitive understanding that will aid in creating their own memory aids and improve attitude to the study of reaction patterns of inorganic ions. Teachers will be equipped to teach learning material appropriately for meaningful memorisation.

Further, the science department of Accra Girls' Senior High School will be more informed about the resources available to teachers and students so they can specify and order content as suggested in the recommendation section.

1.10 Delimitation

The following delimitations were chosen to, in part minimise the stated limitations.

1. The period for collection of data was minimised to one week in order to reduce diffusion by students in the treatment groups which could potentially affect the validity and reliability of results. Further, data about the lecture group was taken first, ending with the mnemonic group to avoid students in the modified lecture method group from getting the mnemonic used from the mnemonic group.
2. Lesson disruptions were avoided by using cluster sampling of intact classes. Probability random sampling of participants in lieu would have interfered with smooth running of normal classes.
3. Although mnemonic instruction is not a common strategy in most SHS, prior knowledge and modified lecture method are common hence to increase knowledge in ion-identification, mnemonic, prior knowledge and modified lecture method instructional methods were compared to allow for a larger target population for application.

1.11 Assumptions

Participants were expected to answer the questionnaire items and examination questions truthfully, since anonymity and confidentiality were both assured. Further, it was assumed that the sample was representative of the accessible population because the intact class was both randomly selected from four general science classes and also randomly assigned to the treatment and control groups.The mnemonics for memorising the eight cations and six anions are applicable to all schools offering the WASSCE Syllabus of 2010.

1.12 Definition of terms

Learning outcomes: these are the output of achievement test and attitude questionnaire of SHS 3 Science students after being exposed to some selected inorganic qualitative analysis using modified lecture method, prior knowledge instructional method and mnemonic instructional method.

Students Achievement in qualitative analysis: This refers to the scores of SHS 3 Science students in ion-identification using the standard achievement test.

Students' attitudes to qualitative analysis: These are feelings, beliefs, interests or predispositions to respond in a favourable or unfavourable manner with respect to ion-identification during qualitative analysis.

Instructional strategies: These are the strategies adopted by the author in teaching SHS 3 Science students ion identification to ensure effective achievement and improve attitude towards chemistry.

Qualitative Ion-identification: This is the process of using specific reagents to make out the presence or absence of cations (NH_4^+, Ca^{2+}, Pb^{2+}, Zn^{2+}, Al^{3+}, Fe^{2+}, Fe^{3+} and Cu^{2+}) and anions (NO_3^-, SO_4^{2-}, SO_3^-, Cl^-, CO_3^{2-} ,S^{-2}) based on their particular reaction pattern.

Prior knowledge-based instructional strategy: This is a teaching strategy that is based on the existing information students acquired before the chemistry class.

Mnemonic-based instructional strategy: This is a process of teaching that uses memory enhancing techniques to assist students recall new and already stored chemistry information.

Modified Lecture method: This is the teacher dominated plan of teaching where, notes about chemistry are dictated to students to write and chemistry questions solved on the chalkboard without mnemonics nor prior knowledge.

Solubility: The ability of a solid precipitate formed from the addition of a reagent to dissolve in solution.

1.13 Organisation of the study

The study was organised into five chapters: chapter one covered the introductory part of the research. The second chapter reviewed relevant literature, chronologically categorised into theoretical and conceptual frameworks, students' attitude to chemistry, memory, mnemonic strategy, prior knowledge and modified lecture methods. The methodology in chapter three entails the population, research design, data collection instrument, sampling method, and data analysis. Chapter four presents and discusses the analysed data and its limitation. The general organisation ends with summary of findings, its conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This details the theoretical and conceptual frameworks which provide a foundation to this study. Students' attitude, memory, mnemonics, prior knowledge and lecture methods of teaching are then explained to give a foundation to any results that may be obtained in the study.

2.2 Theoretical framework

The theoretical frameworks that provide structure for mnemonic-based and modified lecture method-based instructional strategies is schema theory whilst that for prior knowledge-based instructional strategy is Ausubel's receptive meaningful learning. In the former a particular schema for acquiring knowledge is formed without a prior interaction between learner and the object or knowledge to be acquired and the schema is more generic. However in the latter there is usually a prior interaction between student and the object or a similar object or the knowledge to be acquired. In meaningful learning there is a less generic prior knowledge.

2.2.1 Schema Theory: The theory in its current state according to Dixon (2020) is a culmination of diverse contributions from Barlett, Piaget and Vygowsky. This is unlike meaningful learning theory, which was by and large, authored by Ausubel alone. It is posited that, schemata can represent knowledge at all levels from ideologies and cultural truths , knowledge about the meaning of a particular word to knowledge about what patterns of excitations are associated with the letters of the alphabets. We have schemata to represent all levels of abstraction. (Rumelhart as cited in Lekshmi, 2020)

Schemas are units of understanding that can be hierarchically categorised as well as webbed into complex relationships with one another. Our schemata are our knowledge. All of our generic knowledge is embedded in schema. Schema theory describes how knowledge is acquired, processed and organised. The schemata a person already possess are a principal determiner of what will be learned from a new text therefore, the more we learn the easier it is to learn more. This is so because we rely on our previous schema to make sense of new information. Schema theory was partly influenced by unsuccessful attempts in the area of artificial intelligence: Teaching a computer to read natural text or display other human-like behaviour was rather unsuccessful because it is impossible to do so without a preinstalled amount of information as is inherently present in humans. However, Minsky (1975) developed machines that would have human-like abilities. Building on Barlett's work he created a frame construct to represent the preinstalled knowledge in machines. This was seen as an extension and elaboration of the schema construct.

According to Anderson, Spiro and Anderson (1978) it is very important to note that schemata which are the building blocks of cognition, represent our personal simplified view of reality derived from our experience and prior knowledge. Schema enables us to recall, modify, concentrate attention on key information or try to predict most likely outcomes of events. It indicates that knowledge is a network of mental frame or cognitive construct called schema. It organises knowledge stored in the long term memory. It is a hypothetical mental structure for representing generic concepts stored in the long term memory. It is an internal representation of the world: an organisation of concepts and actions that can be revised by new information about the world.

Schema, from Greek schema means a plan, a product of the imagination and intermediate between an image and a concept. Driscoll (2005) suggests that a schema is analogous to computer programme in that, it helps us to understand and evaluate incoming information. It is a theory because it helps to make predictions even from incomplete information by filling in the missing details with default values.

2.2.1.1 Implications of schema theory on education

In educational processes the task of a teacher is to help learners to develop new schemata and establish connections between them.students should be asked questions and encouraged to read titles and headings to determine already existing schema. Teachers should pay attention to answers and remarks from students about how they are organising information to create their schemata. Focus on students' processes, structures and decisions and not just on answers.

2.2.1.2 Principles of Schema Theory

According to Dixon (2020)

- The theory is analogous to a filling cabinet representing the mental thought- the various drawers represent different schema about different subjects. The individual file folders represent the organised memory, information or knowledge about a given subject.
- Schemata are composed of generic or abstract knowledge used to guide encoding, organisation and retrieval of information.
- They could be formed and used without the individuals' conscious awareness.
- They also reflect prototypical properties of experiences encountered by an individual, integrated over many instances.
- Although the theory is assured to reflect an individual's experiences, they are also shared across a given culture.

- People's schemata have a tendency to remain unchanged, even in the face of contradictory information, thus they prefer to live with inconsistency rather than changing a deeply rooted mental structure.

2.2.1.3 Creation of Schema Theory

Schemas are created through experience with people, objects and events in the world. We develop an abstracted, generic expectation for the future when we encounter an experience. Although schema is stable over time, it can sometimes be modified by the following processes.

1. Accretion: New information is remembered in the context of an existing schema without altering the existing schema. The new information meets the students' expectation: this is analogous to Ausubel's derivative subsumption.
2. Tuning: New information or experience cannot be fully accommodated under an existing schema, so the schema evolves to become more consistent with the new experience: it is analogous to Ausubel's correlative subsumption.
3. Restructuring: When new information cannot be accommodated by merely tuning on existing schema, it results in the creation of new schema: it may be similar to Ausubel's Superordinate learning or combination learning depending on the situation.

2.2.1.4 Benefits of Schema Theory

The following advantages of schema theory accrue to learners

- When learners build schemata and make connections between ideas, learning is maximally facilitated and is optimally made more meaningful.
- Students can quickly organise new perceptions into schemata and act effectively with little effort.

- The use of schemata makes automatic processing an effortless task because they are an effective tool for understanding the world.
- Our role schema helps to explain why some learners have behaviour that are social or antisocial (Brewer & Treyens, 1981)
- Cognitive energy is conserved when schemas are used.

2.2.1.5 The Effects of Mnemonic-based and Modified Lecture Method-Based Instructional Strategies on Learning Outcomes using Schema Theory

This theory describes how learners acquire, process and organise information. The theory represents knowledge at all levels including knowledge about and attitude towards ion-identification analysis, since students have schemata to represent all levels of abstraction. (Rumelhart as cited in Lekshmi, 2020) .The way a learner has generally organised knowledge in their long term memory, determines whether they understand ion-identification analysis or not. The learners' schema for accommodating ion-identification analysis is made up of units of understanding about generic concept about ions webbed into units of understanding about other concepts in students' cognitive structure in the long term memory. According to Anderson, Spiro and Anderson (1978) the learner's ability to recall encoded material, retain concentration and score high marks in their achievement test depends on the particular schema they applied during ion-identification analysis.

When information about ion-identification enters the cognitive field of the learner, their schema about ion-identification analysis and its structural connection to other topics guides the lesson to encode, organise and retrieve the information even without the conscious awareness of the student. There is accommodation through accretion to absorb the new information about the ions if students' prediction using the schema meets the actual lesson, otherwise tuning is done by learner where the schema is evolved to fit the lesson . An entirely new schema is however created before the concept is absorbed. Using schema is quick and conserves cognitive energy during lessons. Teachers should aid students in identifying faulty schemas to maximise its effects during ion-identification analysis.

2.2.2 Ausubel's Meaningful Receptive Learning Theory

According to Ausubel, the most important single factor influencing learning is what the learner already knows for mnemonic application (Novak, 1998).In meaningful learning, learned information is fully understood by relating specific fact to already stored fact, and it can be easily retained and applied (Novak & Canas, 2006). Learning occurs, as potentially meaningful material enters the cognitive field and interacts with, and is appropriately subsumed under a relevant and a more inclusive and general conceptual system (Ausubel, 1963)

According to this theory meaning is not an implicit response but, an expressed and distinguished conscious experience that takes place when meaningful signs, symbols, concepts or propositions are related to a given individual's cognitive structure.

Though Ausubel believes that one should start with general ideas which will be gradually differentiated to specific ideas, he also appreciates the existence of another mechanism with an upward direction called the integrative reconciliation. Hence the learner who learns meaningfully applies both routes, in relating new information to already existing knowledge in the cognitive structure.

The preconditions for meaningful learning to be fulfilled are;

- the offering of a potentially meaningful content by teacher to learner. This implies that the content must have a logical meaning and conceptually consistent to the point of being potentially linkable to the cognitive structure of the learner in a substantive and non-arbitrary process. Further, there must be appropriate subsumers in the learner's cognitive structure that allows interaction with the new information. Where no preinstalled relevant knowledge exists it must be created before the new information is introduced.
- that the learner has a potentially meaningful attitude that makes them willing to learn meaningfully.

Component of meaningful learning:

Meaningful learning requires learner's prior knowledge, meaningful material and learner's choice to use it. Learner's prior knowledge is stored in network of neurons which produces constructive changes to link new information which is relevant to prior knowledge. Further, the prior knowledge and meaningful material are assessed by the teacher who encourages learner to performer the linking and discourages from rote learning. The learner however has the choice to both use meaningful material and link new information with prior knowledge but not to rote learn.

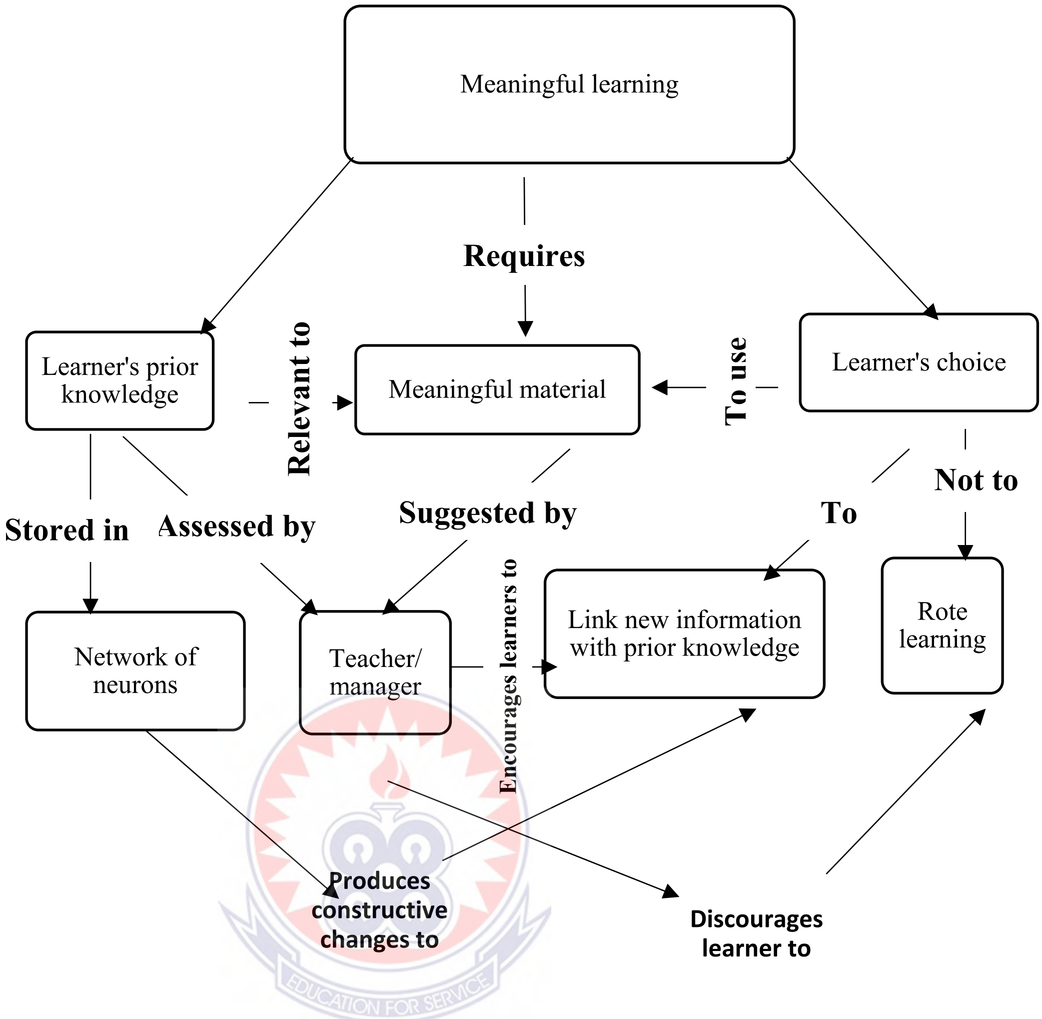


Figure 1: Flow chart showing the relationship between meaningful learning and its various components.
Source: Researcher Construct, (2021).

In figure 1, meaningful learning occurs when meaningful material is presented, to a learner who is willing not to learn by rote and is ready to link new information to prior knowledge , by the teacher. Learner's prior knowledge which is assessed by the teacher is stored in network of neurons which produces constructive changes to in order to link new information to a subsumers. The teacher must also discourage rote learning and encourage meaningful learning.

2.2.2.1 The Process of Meaningful Learning

The learning theory is built around the concept of subsumption, which was later replaced with assimilation. When a new idea enters consciousness, it is processed and classified under one or more of inclusive concepts called subsumers already existing in the learners' cognitive structure. Thus new meaningful material becomes incorporated into the cognitive structure in so far as it is subsumable under relevant existing concepts. Schema is created based on an initial experience with a specific or similar object whereas meaningful learning is achieved based on an already existing concept in the cognitive structure before the experience without an initial familiarity with the object.

When a new concept can be categorised under a more general and broad pre-existing subsumer at the apex of the pyramid for assimilation then subordinate subsumption has occurred. Example: learning of a neem tree as new concept subsumed under the pre-existing broad concept of "tree", when tree is defined as having green leaves, trunk, branches, having fruits and about twelve feet when fully grown.

In correlation subsumption during assimilation, the pre-existing concept is altered to accommodate the new otherwise unfitting concept. Example: when learner meets a tree with red leaves they change the properties of the concept "tree" to include red leaves. Superordinate learning occurs when the new concept is more general than the pre-existing subsumer. Learner during assimilation realises that the pre-existing subsumers are categorised under the new broad concept instead. Example: learner categorise pre-existing different trees as examples of the rather new concept of "tree".

Finally, analogy is used to assimilate a new concept when it does not have relationship to the pre-existing subsumer. This is called combinatorial learning. Example: if a learner has no subsumer to learn about a flag, analogy could be drawn between the flag and the tree since both are "planted" in the ground with the flag end serving as "leaves".Shuell (1992) outlined the principles of meaningful learning process:

1. Active: The learner must cognitively engage with the presented information using appropriate learning styles.
2. Constructive: When information is incorporated into a cognitive structure, it is recreated as a new form showing the learner's own understanding.
3. Cumulative: New information building upon old information, rather than being replaced or stored independently.
4. Self-regulated: Meaningful learning is an independent process, the learner must conduct and regulate their own learning process. The learner as well makes decisions on how to organise mental model.
5. Goal-oriented: An outcome or expectation should be worked towards by the learner. Moreover, the goal must be devised individually.

2.2.2.2 Meaningful learning and Rote learning

Ausubel made a distinction between rote learning and meaningful learning with the former not linking new information with pre-existing concept in the cognitive structure. It is memorisation based on repetition. Rote learning has information which is discrete and stored in an isolated compartment and is unintegrated into the person's larger cognitive structure. This makes forgetting quick.

Although rote learning has its own place in the process of instruction for memorising facts, periodic table, alphabets and multiplication table, it has its rather numerous disadvantages:

1. easy to lose focus
2. repetitive and boring
3. little or no deeper understanding
4. no connection between new and previous knowledge
5. may result in impression of wrong understanding of concepts
6. does not allow for the use of social skills through interaction with teacher, other learners or learning material.

It may however help with the ability to quickly recall basic facts and help to develop foundational knowledge.

Meaningful learning on the other hand:

1. encourages understanding and not memorisation only.
2. encourages active learning techniques.
3. focus on outcome of learning process.
4. relates new information to prior knowledge therefore, information gained can be applied to new situations and it stays with student for a longer time.

Meaningful learning however takes longer to achieve and is tailor made for different learners.

2.2.2.3 The Effects of Prior Knowledge-Based Instructional Strategies on Learning Outcomes using Ausubel's Receptive Meaningful Learning Theory

The facts presented during ion-identification analysis are connected by learners to previous relevant facts to make connection, understand and apply to other situations

(Novak & Canas, 2006). When students are taught ion-identification, the facts interacts with and is subsumed under a relevant conceptual system. (Novak, 1998).

However the ion-identification lesson should be meaningful-logical and conceptually consistent to the relevant prior knowledge so as to make linkage. The teacher should create a relevant prior knowledge where upon assessment it is discovered that learner lacks relevant knowledge. The learner on the other hand should have a potentially meaningful attitude to learn meaningfully. The learner obtains the relevant prior knowledge by interacting with a similar topic or reading the topic before the lesson.

When ion-identification is taught the student assimilate by consciously classifying the incoming information under a relevant subsume already in the cognitive structure using subordinate subsumption .However where the ion-identification information is broader than any available subsumer then superordinate subsumption is applied by student to assimilate. Analogy is used by learner where there is no relevant prior knowledge in order to learn the ion-identification.

2.3 Conceptual framework

The concepts below (see Figure 2) is a proposed research framework after a thorough assessment of the literature reviewed. It provides a summary of linkage between key concepts and variables. In figure 2, instruction by learner and teacher is performed using mnemonic-based, prior knowledge-based, and modified lecture method based strategies on learning material. The effects of these strategies on learning outcomes are indicated by the test scores and attitude scores.

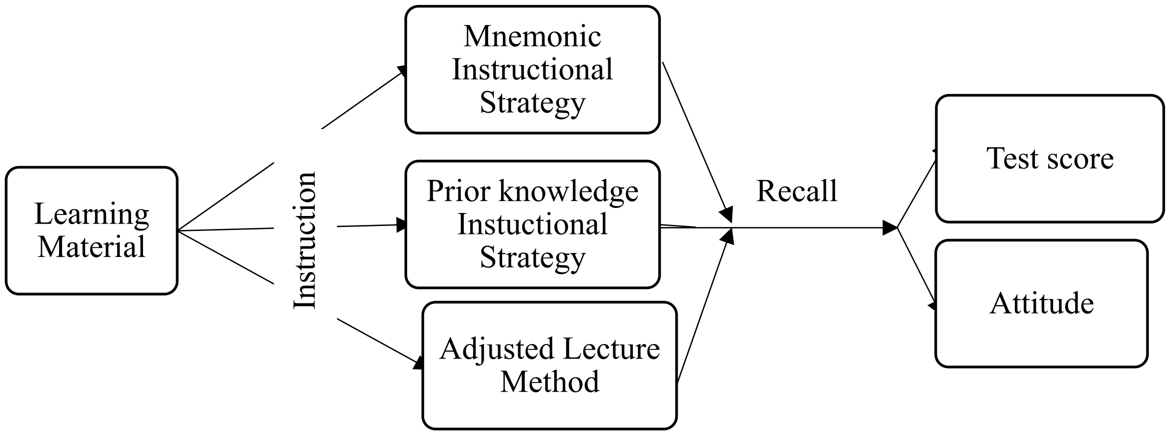


Figure 2: Conceptual framework showing how the individual concepts in this study are interconnected.

Source: Researcher Construct (2021)

2.4 Principles of Simple ion identification

As part of their summative assessment, final year SHS candidates are expected to sit for a practical examination to demonstrate skills acquired during experimental lessons. Chemistry experiments are performed to either verify a scientific fact or test a hypothesis whilst the practical examinations or sessions are to test for competencies acquired during the experiments.

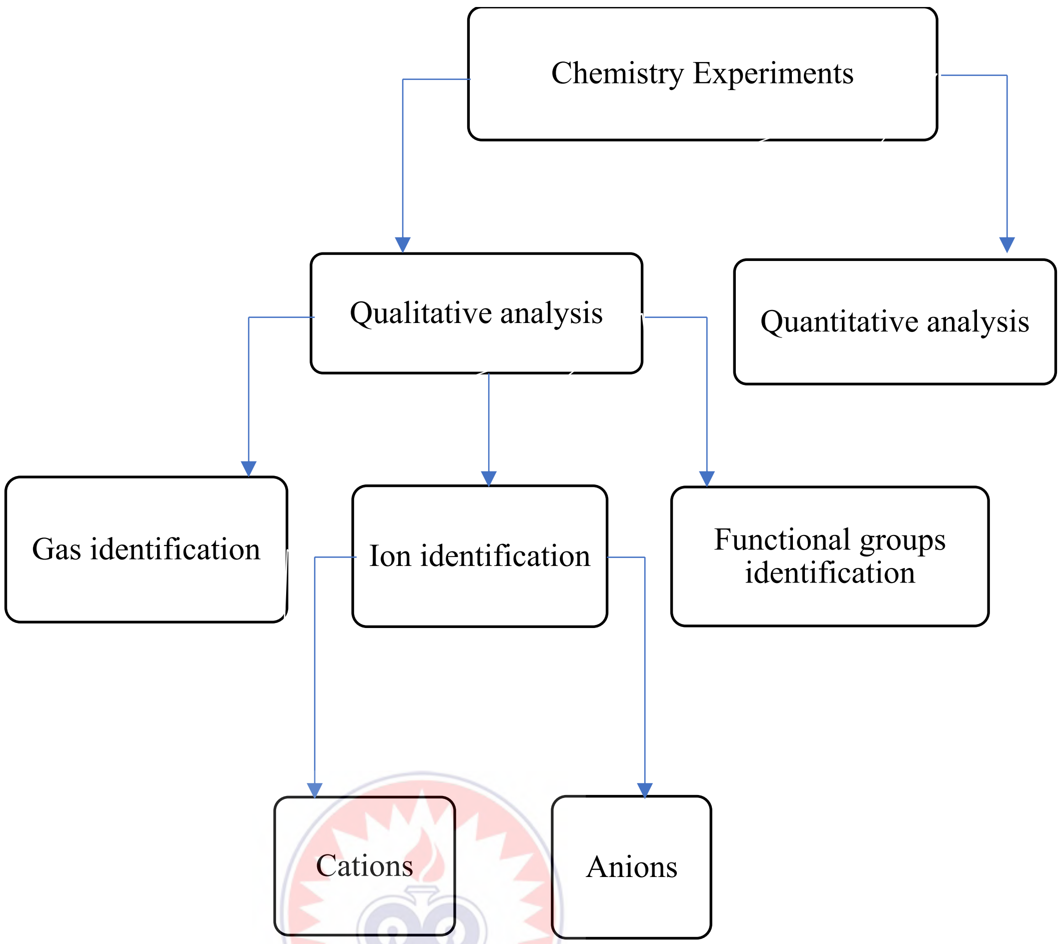


Figure 3: Flow chart showing contents of chemistry experiments for SHS.
Source: Researcher Construct (2021).

Ion-identification is a process where the nature and identify of an anion or cation in an inorganic compound is determine using a reagent and/or by physical examination.

The amount of sample used varies depending on whether analysis is micro or macro. Typically, 0.1g of salt in 1-2cm^3 of distilled water is used for WASSCE.

Systematic analysis of an inorganic salt involves the following steps:

1. Physical examination of salt and its solution during dry tests: General appearance and physical properties such as colour, smell, solubility, melting point are determined.

2. Preliminary determination of cations and anions by reactions carried out in solution using selected reagents. This is wet tests. Common reactions used are precipitation and evolution of gas.
3. Confirmatory determination of cations and anions using reagents. This is also a wet test. (see Figure 3)

2.4.1 Solubility rules

Yoder (2020) states the following rules for which cation-anion combination will produce precipitate or solubility.

1. All nitrates are soluble
2. Practically all Na^+, K^+, NH_4^+, H^+ salts are soluble.
3. All halogens are soluble except those of Ag^+, Hg^+, Pb^{2+}.
4. All sulphates are soluble except Sr^{2+}, Ba^{2+}, Pb^{2+} which are insoluble and those of Ca^{2+} and Ag^+ which are moderately soluble.
5. All carbonates, sulphites, phosphates, sulphides are insoluble.
6. All oxides and hydroxides are insoluble except those of the alkali metals, alkaline earth metals and NH_4^+. Those of Ca^{2+}, Sr^{2+}, Ba^{2+} are moderately soluble.

The solubility of Ag_2SO_4 is 0.014M and the solubility of $CaSO_4$ is 0.007M hence for WASSCE qualitative analysis Ag_2SO_4 is considered practically soluble but $CaSO_4$ is insoluble. This is the case because solubility value less than 0.01M is insoluble and more than 0.01M is soluble.(see Table 5)

2.4.2 Principles of Precipitation

Precipitation is achieved by addition of proper reagents and under correct conditions. Common chemical reagents used for cations according to WAEC (2010) are hydroxides and sulphides precipitation.

Cations and anions will precipitate out of supernatant as salts if their ionic products are greater than the solubility product.

Factors affecting chemical precipitation are

- Type and concentration of metal ion
- Precipitant used
- Reaction conditions. Example: pH, temperature, redox potential, common ion effect
- Presence of other complexing agents that may influence the precipitation reaction.

Table 4: Showing Concentration and Solubility values.

Solubility

	Insoluble	Slightly soluble	Soluble	Highly soluble
Concentration	0.001M	0.01M[a]	0.10M	1.0M[b]
	Sparingly soluble			

Note

[a] Concentration equal to or less than 0.01moldm^{-3} is sparingly soluble, between 0.01 moldm^{-3} and 0.001 moldm^{-3} is insoluble. Concentration greater than 0.01 moldm^{-3} is soluble but between 0.01 moldm^{-3} and 0.1 moldm^{-3} it is slightly soluble.

[b] Concentrations greater than 1.0 moldm^{-3} is highly soluble but between 0.10 moldm^{-3} and 1.0 moldm^{-3} it is soluble.

Source: Researcher Construct (2021)

Chemical precipitation is used for removal of both impurities and metals from leaching solutions and to remove impurities from waste waters called solution precipitation or metal recovery. When the desired metal is precipitated, it is usually treated further before a desired product, metal or metal salt is obtained.

According to WAEC Syllabus (2010) the cations and anions and the respective reagents to be used for preliminary tests are as follows:

Table 5 : Ions and their respective reagents.

Cations	Reagents	Anions	Reagents
NH_4^+ Ca^{2+} Pb^{2+} Al^{3+} Zn^{2+} Fe^{2+} Fe^{3+} Cu^{2+}	$NaOH_{(aq)}$, $H_2S_{(aq)}$ and $NH_{3(aq)}$	NO_3^- SO_4^{2-} SO_3^{2-} CO_3^{2-} Cl^- S^{2-}	– $NH_{3(aq)}$, $HNO_{3(aq)}$ or $HCl_{(aq)}$ on aqueous solutions or precipitates – Concentrated H_2SO_4 on solid or liquid samples – $Pb(NO_3)_2$, $Ba(NO_3)_2$ or $BaCl_2$

Source: Researcher Construct (2021)

Qualitative Analysis involves the identity of the chemical species in a sample. Chemical Precipitation leads to the formation of a heavier solid in a lighter liquid: The precipitate so formed being more densed, sinks in the precipitant. Sometimes a solid precipitate forms inside another solid during a chemical reaction or diffusion in a solid. In wet tests, aqueous solutions of the unknown sample are treated with various reagents to test for reactions characteristic of certain ions, which may cause gas evolution with characteristic smell and other visible changes. During the preliminary wet tests of the cations two or three consistent drops are added to $2cm^3$ of the aqueous sample. After observing the formation of a precipitate, excess amount of reagent in the ratio 1:1 of the sample to reagent is added, to observe whether the precipitate would dissolve or not.(see Tables 7 and 8)

Table 6: Addition of $NH_{3(aq)}$ to metallic radicals in drops and then in excess

Cation	$2cm^3$ sample + 2 drops of $NH_{3(aq)}$	Resulting solution + Excess $NH_{3(aq)}$
NH_4^+	$NH_4^+{}_{(aq)} + NH_{3(aq)} \longrightarrow$ NVR	-
Ca^{2+}	$Ca^{2+}{}_{(aq)} + NH_{3(aq)} \longrightarrow$ NVR	-
Pb^{2+}	$Pb^{2+}{}_{(aq)} + NH_{3(aq)} \longrightarrow Pb(OH)_{2(s)}$	$Pb(OH)_{2(s)}$ + excess $NH_{3(aq)} \longrightarrow$ NVR
Zn^{2+}	$Zn^{2+}{}_{(aq)} + NH_{3(aq)} \longrightarrow Zn(OH)_{2(s)}$	$Zn(OH)_{2(s)}$ + excess $NH_{3(aq)} \longrightarrow (NH_4)_2Zn(OH)_{2(aq)}$
Al^{3+}	$Al^{3+}{}_{(aq)} + NH_{3(aq)} \longrightarrow Al(OH)_{3(s)}$	$Al(OH)_{3(s)}$ + excess $NH_{3(aq)} \longrightarrow$ NVR
Cu^{2+}	$Cu^{2+}{}_{(aq)} + NH_{3(aq)} \longrightarrow Cu(OH)_{2(s)}$	$Cu(OH)_{2(s)}$ + excess $NH_{3(aq)} \longrightarrow Cu[NH_3]_4(OH)_{2(aq)}$
Fe^{2+}	$Fe^{2+}{}_{(aq)} + NH_{3(aq)} \longrightarrow Fe(OH)_{2(s)}$	$Fe(OH)_{2(s)}$ + excess $NH_{3(aq)} \longrightarrow$ NVR
Fe^{3+}	$Fe^{3+}{}_{(aq)} + NH_{3(aq)} \longrightarrow Fe(OH)_{3(s)}$	$Fe(OH)_{3(s)}$ + excess $NH_{3(aq)} \longrightarrow$ NVR

Source: Researcher Construct (2021)

Table 7: Addition of NaOH to metallic radicals in drops and then in excess

Cation	$2cm^3$ sample + 2 drops of $NaOH_{(aq)}$	Resulting solution + Excess $NaOH_{(aq)}$
NH_4^+	$NH_4^+{}_{(aq)} + NaOH_{(aq)} \longrightarrow$ NVR	-
	$NH_4^+{}_{(aq)} + NaOH_{(aq)} \xrightarrow{\Delta} NH_{3(g)}$	
Ca^{2+}	$Ca^{2+}{}_{(aq)} + NaOH_{(aq)} \longrightarrow Ca(OH)_{2(s)}$	$Ca(OH)_{2(s)}$ + excess $NaOH_{(aq)} \longrightarrow$ NVR
Pb^{2+}	$Pb^{2+}{}_{(aq)} + NaOH_{(aq)} \longrightarrow Pb(OH)_{2(s)}$	$Pb(OH)_{2(s)}$ + excess $NaOH_{(aq)} \longrightarrow Na_2Pb(OH)_{4(aq)}$
Zn^{2+}	$Zn^{2+}{}_{(aq)} + NaOH_{(aq)} \longrightarrow Zn(OH)_{2(s)}$	$Zn(OH)_{2(s)}$ + excess $NaOH_{(aq)} \longrightarrow Na_2Zn(OH)_{4(aq)}$
Al^{3+}	$Al^{3+}{}_{(aq)} + NaOH_{(aq)} \longrightarrow Al(OH)_{3(s)}$	$Al(OH)_{3(s)}$ + excess $NaOH_{(aq)} \longrightarrow NaAl(OH)_{4(aq)}$
Cu^{2+}	$Cu^{2+}{}_{(aq)} + NaOH_{(aq)} \longrightarrow Cu(OH)_{2(s)}$	$Cu(OH)_{2(s)}$ + excess $NaOH_{(aq)} \longrightarrow$ NVR
Fe^{2+}	$Fe^{2+}{}_{(aq)} + NaOH_{(aq)} \longrightarrow Fe(OH)_{2(s)}$	$Fe(OH)_{2(s)}$ + excess $NaOH_{(aq)} \longrightarrow$ NVR
Fe^{3+}	$Fe^{3+}{}_{(aq)} + NaOH_{(aq)} \longrightarrow Fe(OH)_{3(s)}$	$Fe(OH)_{3(s)}$ + excess $NaOH_{(aq)} \longrightarrow$ NVR

Source: Researcher Construct (2021)

Table 8: Addition of hydrogen sulphide to the cations

Cation Type	Precipitate
1. NH_4^+	NVR
2. Ca^{2+}	NVR
3. Zn^{2+}	White precipitate
4. Al^{3+}	Yellow precipitate
5. Fe^{2+}	Black precipitate
6. Cu^{2+}	Black precipitate
7. Pb^{2+}	Black precipitate
8. Fe^{3+}	Green precipitate

Source: Researcher Construct (2021)

Tables 7, 8 and 9 show reaction patterns when the metal cations react respectively with aqueous ammonia, aqueous sodium hydroxide and hydrogen sulphide.

Reaction of anions with reagents

i) $HNO_{3(aq)}/HCl_{(aq)}$ Reagent

a) $NO_3^- + HCl_{(aq)} \longrightarrow$ NVR

b) $SO_4^{2-} + HCl_{(aq)} \longrightarrow$ NVR

c) $Cl^- + HNO_{3(aq)} \longrightarrow$ NVR

d) $SO_3^{2-} + HCl_{(aq)} \longrightarrow SO_{2(g)}$

e) $CO_3^{2-} + HNO_{3(aq)} \longrightarrow CO_{2(g)}$

f) $S^{2-} + HCl_{(aq)} \longrightarrow H_2S_{(g)}$

ii) $Pb(NO_3)_{2\ (aq)}$ Reagent

a) $Pb^{2+} + NO_3^- \longrightarrow$ No precipitate

b) $Pb^{2+} + Cl^- \longrightarrow$ White precipitate

c) $Pb^{2+} + SO_3^{2-} \longrightarrow$ White precipitate of $PbSO_3$

d) $Pb^{2+} + SO_4^{2-} \longrightarrow$ White precipitate of $PbSO_4$

e) $Pb^{2+} + CO_3^{2-} \longrightarrow$ Precipitate of $PbCO_3$

f) $Pb^{2+} + S^{2-} \longrightarrow$ Black precipitate of PbS

iii) $Ba(NO_3)_2$ (aq) or $BaCl_2$ (aq) reagent

a) $Ba^{2+} + NO_3^- \rightarrow$ No precipitate

b) $Ba^{2+} + Cl^- \rightarrow$ No precipitate

c) $Ba^{2+} + SO_3^{2-} \rightarrow$ Precipitate of $BaSO_3$

d) $Ba^{2+} + SO_4^{2-} \rightarrow$ No precipitate of $BaSO_4$

e) $Ba^{2+} + CO_3^{2-} \rightarrow$ Precipitate of $BaCO_3$

f) $Ba^{2+} + S^{2-} \rightarrow$ Precipitate of BaS

iv) $AgNO_3$ (aq) reagent to anions

a) $Ag^+ + NO_3^- \rightarrow$ No precipitate

b) $Ag^+ + Cl^- \rightarrow$ Precipitate of AgCl

c) $Ag^+ + SO_3^{2-} \rightarrow$ Precipitate of Ag_2SO_3

d) $Ag^+ + SO_4^{2-} \rightarrow$ No precipitate

e) $Ag^+ + CO_3^{2-} \rightarrow$ Precipitate of Ag_2CO_3

f) $Ag^{2+} + S^{2-} \rightarrow$ Precipitate of Ag_2S

2.5 Students' attitude to chemistry

Cheung (2009) states that attitudes about academic achievement are important outcomes of science education in secondary school. The development of students' positive attitudes regarding science as a school subject is one of the major responsibilities of every science teacher. Unfortunately, research has revealed that much of what goes on in science classrooms is not particularly attractive to students across all ages. Oskamp & Schultz (2005) say an attitude is a predisposition to respond in a favourable or unfavourable manner with respect to an attitude object. The focus here is students' attitude towards chemistry qualitative experiments, taught in secondary school classrooms.

Attitudes towards chemistry denotes interests or feelings towards liking or disliking chemistry. Students beliefs and attitudes have the potential to either facilitate or inhibit instruction (Yara, 2009), and studies including Berg (2005) and Adesoji (2008) report that students' positive attitude towards the basic sciences decreases in the order: Biology, Chemistry, Physics and Mathematics.

Adesoji (2008) has concluded that a number of factors have been identified as influencing students' attitude to chemistry: teaching methods, teacher's general attitude to instruction of the subject, influence of parents, gender of students, age of students, cognitive style of students, career interest of students, social view of science and scientist, and, social implication of science and achievement for the particular society. Generally, studies posit that there is a relationship between attitude and methods of instruction and also between attitudes and achievement and that students' achievement can be predicted from attitude scores.

2.6 Memory

Martin (2005) defines memory as the process of maintaining information over time. Generally, memory comprises both structures and processes involved in storage and subsequent retrieval of information. Memory is an indispensable mental capacity.

Tulving (1985) states that there are at least three basic types of memory: episodic, semantic and procedural. Episodic memory involves specific events drawn from personal experiences where an individual was present.

Procedural memory is that part of memory which allows task to be performed without conscious awareness.

Semantic memory deals with the portion of long term memory that processes general ideas and concepts not obtained from personal experience as shown in figure 4.

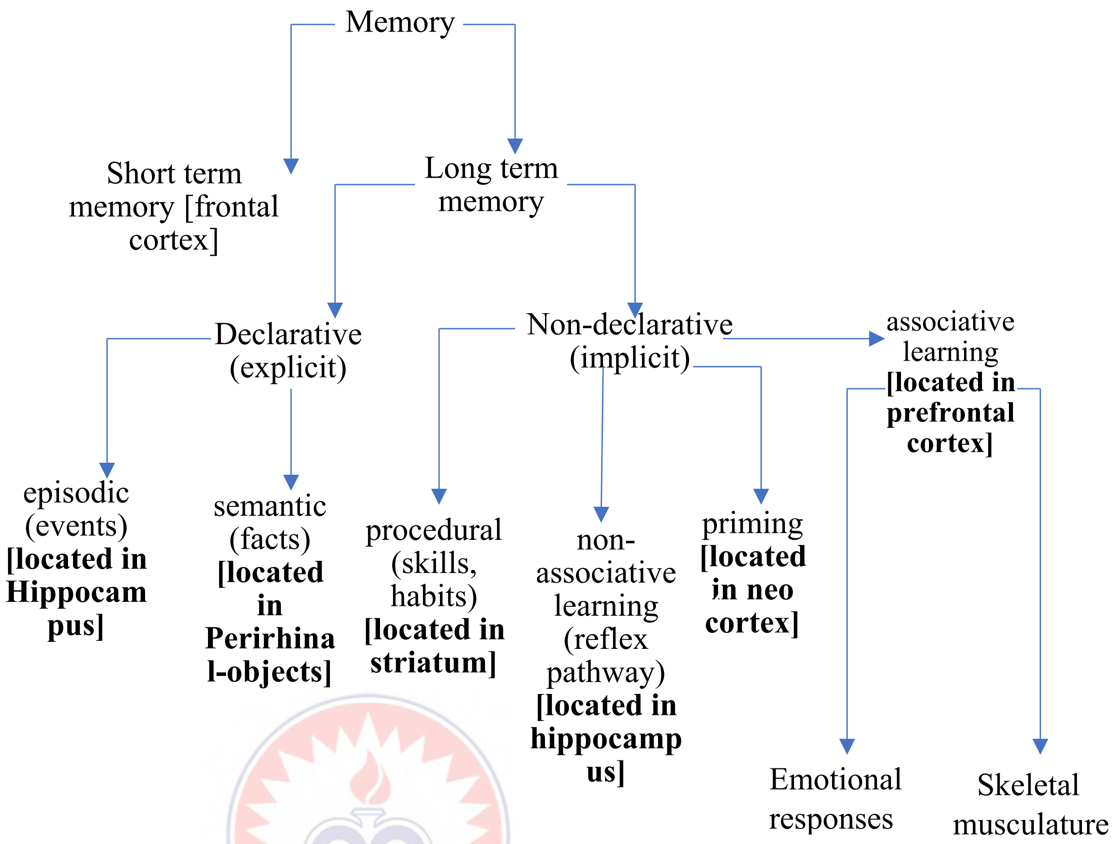


Figure 4: Types of memory with the part of the brain for a specific memory in square brackets.

Source: Researcher Construct (2021)

2.6.1 Cognitive Information Processing Theory

This is a generic theory which describes all the perspectives that focus on how our cognitive processes such as attention, perception, encoding, storage and retrieval of knowledge are performed.

Typical of such theories are

- Information Processing Theory
- Piaget's cognitive development theory
- Lev Vygotsky's socio-cultural theory of cognitive development

This theory uses a two store model where

1) Stimuli enters the sensory register
2) From there to short term memory
3) Where they get stored if encoded and or rehearsed into the long term memory
4) Retrieval is done from the long term memory into the working memory.

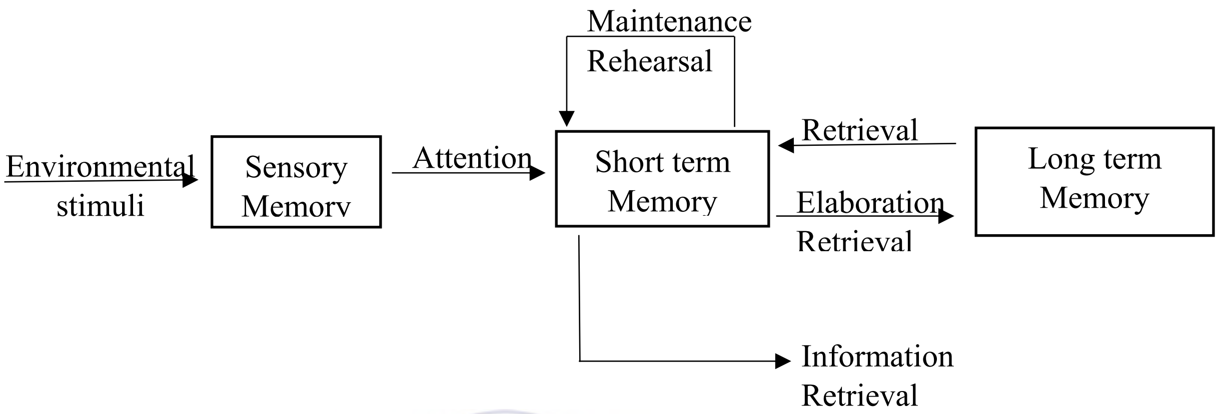


Figure 5: Information Processing Theory

Note. Adapted from *Human Memory :A proposed system and its control processes (p. 89)* by R. C. Atkinson and R. M. Shaffrin. 1989 . New York: Academic Press(1963)

In order for information to become firmly embedded into memory, it must pass through three stages of processing: sensory memory, short term memory and long term memory. The sensory register hosts information from the senses- sight and sound for a fraction of a second. This information may be attended to, analysed and encoded as a meaningful pattern. This process is known as perception. The perceived information then enters the short term memory and if nothing happens then the information is lost in about 20 seconds in the short term memory. However, if it is processed in the short term memory, it may remain indefinitely. In order for the brain to recognise incoming stimuli, it must compare it with already stored stimuli in the long term memory as shown in figure 5. This improves retention during storage

A good memory is characterised by

1. Rapidity: How quickly the learner recalls his experiences.
2. Accuracy: The exactness with which past experiences are recalled.
3. Length of time: How long information is stored before loss if ever.
4. Promptness: Recall of the right experience at the right time, at the right place and in the right manner.
5. Quantity of recall.

2.6.2 Improving Memory

1. Flavell and Wellman (1977) state that memory can be improved by Metacognition knowledge which comprises three types of knowledge:

a. The mechanism of our memory process, its strengths and limitations (Friedrichs, Flavell, & Hoyt, 1970)

b. Knowledge about different types of memory tasks also improve recall, for instance multiple choice or short answer task. (Horowitz & Samuels, 1985) .

c. Flavell and Wellman (1977) posit that knowledge about the most effective method of remembering information enhances recall.

2. Interest: Student's interest in the topic or subject. (Fabricius & Wellman, 1983)
3. Will: Will to learn a topic or subject enhances interest and motivation hence leading to retention.
4. Association: the law of association helps with memory enhancement.
5. Repetition: High number of repetitions implies more memorisation, but repetition with understanding causes more memorisation. Spaced repetition improves memory further: the material to be committed to memory is repeated at intervals with periods of rest. This will save the learner from fatigue. Thus, effort-rest-effort will lead to better memorisation.

6. Modern technology: A variety of aids is used during instruction process to make students motivated in the lesson to increase memory.
7. Recitation: Repeating the material loudly to self without looking at material but checking from time to time improves memory (Gates, 1917).
8. Mnemonic use: Information is deliberately transformed into meaningful system to improve memory.
9. Meaningful organisation: When learning material is psychologically and logically arranged it aids memory.
10. Principle of learning by doing: Learning experiences acquired through practicals and hands-on activities are retained longer.
11. Overall Classroom Environment: This includes the physical conditions and the teacher's attitude.
12. Self-testing: Learners set own questions answer and mark.
13. Use of multiple sensory modalities enhance memory.

2.6.3 Memory and Forgetting

Retention is influenced by the following factors:

- Availability in cognitive structure of relevant subsuming concepts at an appropriate level of inclusiveness;
- The stability and clarity of these concepts and
- Their discriminability from the learning task.

Subsumption both explains how information is retained and forgotten. New information is stored when it becomes anchored to a larger subsuming concept. Reciprocally, the same information is forgotten as it becomes progressively absorbed into its cognitive host. Forgetting is complete when the information can no longer be separated from its subsuming concept. Ausubel refers to this as "obliterative subsumption". Further, remembering is inhibited when learning task is rote learnt: discrete information is stored in an isolated compartment and is not integrated into the student's larger cognitive structure.

There are many ways in which memory might fail to be retrieved.

i. Trace decay theory: all memories fade automatically as a function of time. Decay can however be slowed with elaborate rehearsal.

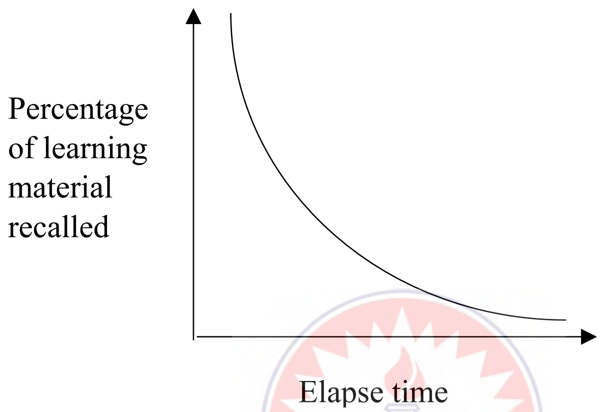


Figure 6 : Diagram showing variation of recall with time

ii. All memories interfere with the ability to recall other memories:

Proactive damage: new knowledge is damaged by old memories.

Retroactive damage: old knowledge is damaged by recent memories.

iii.Cue-dependent forgetting: this is the failure to retrieve information in the absence of memory cues. The learning task is memorised together with the environmental state, emotional and mental state of the learner. In the absence of these cues retrieval becomes difficult.

a) Semantic cues are used when a memory is retrieved because of its association with another memory.

b) State-dependent cues are governed by emotional or mental state of the learner at the time of encoding

c) Context-dependent cues: the weather, school location, the smell of a particular odour, or having a particular taste can cue the recall of a memory if the context is replicated at the time of recall.

iv. Forced forgetting: when learning material involves trauma during encoding, the mind suppresses and/or represses the memory unconsciously. When a learner experiences a major accident during a chemistry experiment, retrieval becomes difficult later. Hyperthymesia occurs when the memory cannot be forgotten even with effort. However, this causes the learner distress.

v. Absentmindedness: occurs when at the time of encoding, sufficient attention was not paid to what would later need to be recalled.

vi. Blocking: this is the cause of Tip of the tongue; it is failure to retrieve a word from memory combined with partial recall and a feeling that retrieval is imminent.

2.7 Mnemonic Strategy

Mnemonics allow for classification, organisation and recollection of information into and out of the long term memory. Since items in the long term memory are maintained longer, with better organisation, mnemonic devices ensure that the memoriser is paying attention to the material.

According to Metivier (2022), mnemonics are processes not devices while Berglass (2022) states that mnemonics are not a unitary mechanism or a “thing” but a behaviour. Therefore, any process, behaviour or activity that improves learning memory is a mnemonic.

According to the Oxford English Dictionary (2002), "mnemonic" is a system or device such as pattern of letters, ideas, or associations which assists in remembering something. It was first used as part of the English Language in 1662 , and has Greek roots- mnemonikos, from mnemon meaning "mindful". The word is connected to Mnemosyne, the Greek god of memory, sleep and dreams.

Higbee (2001) concludes that mnemonics are of two forms:

- Process mnemonic: it is rather uncommon and used to remember rules and procedures in science, spelling and mathematics.
- Fact mnemonic; this is more common and it is for remembering facts. Each is remembered by one mnemonic associations.

Many mnemonists and researchers have strongly advocated for the use of mnemonics in education. (Levin, 1993; Lorayne, 1990)

Empirical studies show that mnemonics are highly effective in the right circumstances (Worthen & Hunt, 2011)

However, some reviews reached different conclusions about whether mnemonics should be used in the classroom: some have been supportive (Manalo, 2002), others have been critical of the use of mnemonics in the classroom (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013).

Modern memory research has shown clearly that mnemonics can be powerful learning tools in certain contexts such as remembering a list of concrete objects (Bower, 1970).

Most researchers believe that mnemonics improve memory by capitalising on naturally occurring memory processes such as visual imaging, organisation and elaborative encoding (Worthen & Hunt, 2011; Higbee, 2001).

Pavio (1971) lists the following classical principles about the psychological foundations for mnemonics:

- Things we experience as “real” (examples are objects, places and other people), have size, colour, mass as attributes, are assumed to carry over to our memory. Therefore, thoughts and perceptions are continuous.
- Memory is like a “wax tablet” and each of the mental rooms can have images or facts stored in much the same way as one will write letters on a wax tablet. The facts and images stay there until are erased or overwritten.
- Sight is the strongest of all senses. The most durable impression placed on our minds are those placed by the sense of sight. As a result, information perceived through other senses are best retained if it is converted into visual images.
- Words can be converted into symbol and vice versa. Using sophisticated systems even a large text can be converted into a series of images. This can be stored using a location mnemonic and then be converted into text without loss.
- Mnemonic organises information irrespective of the type used, into chunks and ordered form.
- The users’ interaction with the learning task through rote learning rehearsal, processing and reprocessing to make the information fit into complex mnemonic system helps refresh the images used.
- Mnemonics provide retrieval cues which enhance recall of new information.
- It prevents interference between pieces of information. By storing bits of information in distinct form hence mnemonic prevent confusion between similar concepts.

- It makes use of novelty or distinctiveness: though mnemonic system do not inherently require users to create bizarre or unusual mental images. Learners tend to recall that which is extraordinary more easily than that which is ordinary, thus most writers rightly place emphasis on the need for images that are active, exceptionally beautiful or ugly, disfigured or comical.

In addition to the above, Higbee (1987) states that process mnemonics utilises the five principles of learning and memory: meaningfulness, organisation, association, attention and visualisation.

Mastropieri and Scruggs (1998) state that mnemonics are transfer material processes, such as a formula or a rhyme used as an aid in remembering. Therefore, even tutors who claim not to use this strategy inadvertently apply it. It uses equations or organise notes or logically present learning material. They are not comprehension strategy nor a comprehensive teaching method but a memory device.

2.7.1 Principles of Mnemonics

Though it is a memory and not comprehension strategy, students who are trained mnemonically also perform better on comprehension tests of the same content because they remember more information that can be applied on comprehension tests (Fulk & Ryu, 1990).

Mnemonics do not inhibit comprehension (Kilpatrick, 1985). It becomes more important because learners sometimes achieve adequate comprehension but forget the facts associated with it.

It is common place for authors of many popular literature on mnemonic techniques to assert that the focal information in the integrated science needs to be greatly exaggerated or be in some way bizarre. This is not corroborated by scientific research, which rather asserts that what seem to be critical for mnemonic to work are the effort and attention devoted by the learner to the task at hand in selecting the most effective mnemonic cue and the formation of a vivid image of the integrated mnemonic information scene.

Atkinson and Rough (1975) state that mnemonics work on the principle that, the human mind much more easily remembers data attached to spatial, personal and meaningful information than that occurring in meaningless sequence.

2.7.2 Advantages of Mnemonics

- It has been found that mnemonic strategies can be used to enhance science learning when the curriculum involves a lecture or textbook format or when it involves hands-on inquiry learning format. (Sruggs & Mastropieri, 1992)
- General mnemonics can be modified to fit a variety of learning format.
- Intervention using mnemonic instruction have produce some of the largest instructional gains recorded in the special education literature (Swanson, 1999).
- They serve as a bridge to other required information according to Yoder (2020).
- According to Yoder (2020) mnemonics can be applied to a multitude of content information: involving behaviour, academic career and hobbies.
- Carney and Levin (2000) found out that mnemonics benefit both short term and long-term memories in laboratory studies.
- The mnemonist becomes an active learner because mnemonic involves rearranging or reorganising information hence the learning material is personalised.
- Mnemonics add interest to studying because there are new ways to study.
- When used correctly, they enable learners to spend less time retrieving information from the long-term memory.

2.7.3 Disadvantages of Mnemonics

Scruggs and Mastropieri (1992) observed that when students generate their own mnemonics, instruction may be slowed and learner's performance may also be lower than when mnemonic is created by teacher.

The impact of mnemonic instruction is evaluated most often on criterion- referenced tests and criterion-referenced measures, which tend to rather yield much larger effect sizes than do norm-referenced measures, which are the types of measures teacher tests resemble. Mnemonic instruction has not been shown reliably to affect performances on norm-referenced tests.

According to Moore (2020) Mnemonics have the following drawbacks

- must be recited and practiced in a precised manner in order to work correctly.
- they require time to create, learn and practice.
- can become "crutches" to give the student a false sense of security that they know the information.
- It is easy for a student using mnemonics to rote learn instead of elaborately studying and comparing new and old information meaningfully.
- Over use can result in confusion and an excessive expenditure of time reviewing the material.

2.7.4 Mnemonic Types

According to the University of Florida (2021) many types of mnemonics exist but which one works is only limited by the imagination of the learner:

Mnemonics are taught using the following means:

1. Expression mnemonic

Examples; acronym, name mnemonic

2. Poem

Examples; Ode, Doggerel

3. Music
4. Connection
5. Story
6. Note organisation
7. Keyword
8. Pegword
9. Model
10. Image
11. Loci
12. Kinesthetic

These mnemonics are grouped into

- Auditory mnemonics
- Expression
- Poem
- Music/Song
- Connection
- Story
- Note organisation
- Visual mnemonics
- Keyword
- Pegword
- Model
- Image

- Loci

- Tactile mnemonics

- Kinesthetic

Expression Mnemonics; the first letters of the to-be-remembered items are used to form a familiar word, phrase or sentence.

Examples:

Name Mnemonics; the first letter of each word to be recalled are used to form the name of a person or a thing. ROY G.BIV for the components of white light.

Acronym: the first letters of the words in the list are used to form a word. Examples; In order to remember the cations from the WASSCE list that do not show any reaction when ammonia solution is added, the acronym "aca" is used.

a = ammonia solution

Ca = Calcium. Hence Ca^{2+} is non-reactive in $NH_{3(aq)}$.

Acrostic: the first letters of the list are used to form new words in a sentence:

To remember that the exceptions to the solubility of all Halogens are Silver ion (Argentum) and lead ion we use "Except HoloGene Argentum Leads" and for the exception to sulphates we use "phates can't Lead Bar".

Poem: the information to be retrieved is placed into rhyming text or a non-rhyming text called a doggerel.

Music: the lyrics of a familiar song are replaced by the information to be recalled. The rhyme is maintained or a new song is written with the information. Television advertisements are in the form of Jungles of familiar tunes with the words replaced by the information to be learnt.

Connection: the information to be remembered is linked to something familiar:

To remember that the reactant potential energy for an exothermic reaction energy profile is higher than that of the product use the term "XTD" which is like the familiar word STD. X = Exothermic, T = top, D = down. This means potential energy of reactants is higher than that of product.

Story: The words to be learnt are linked in a story. To enhance its effectiveness any process or phenomenon to be learnt must be reduced to a word:

To remember the ordered list vegetable, Instrument, College, Carrot, Nail, Fence, Basin, Scale, Goat. The words in the list are transformed into the following story:

A vegetable can be a useful instrument for a college student. A carrot can be a nail for your fence or basin. But a merchant would scale that fence and feed the carrot to a goat.

Note organisation: the way learning material is logically organised and presented can enhance learner's comprehension and recall.

Notecards, outlines and Cornell system are methods of note organisation.

Keyword: A new word or concept is associated with a similar sounding familiar word for easy recall. The meaning of the original word is linked to the keyword through an interactive mental image: To remember that the precipitates of lead ion, Aluminium ion, and Zinc ion in sodium hydroxide are soluble in excess NaOH,

'SLAZ' which sound like slicing indicating soluble, is used and for the reagent ammonia solution 'A CuZ' is used. Hence the image is slicing or cutting a 'curse'. The cutting suggests solubility.

Pegword: According to (Richmond & Cummings, 2008), Pegword is a two stage process.

First stage: Learners are asked to learn ten number rhyme pairs (Example: one is bun, two is a shoe and so on).

Second stage: Learners are made to create a mental image or given an image of the to-be-remembered material and the rhyming word (Mastropieri, Sruggs, & Levin, 1985). Example: To remember the first president of Ghana, create a picture of Kwame Nkrumah holding a bun. The types are body peg system, rhythm peg system and shape peg system.

Model: The information to be learnt is put into a form of representation to help recall. Examples of such models are cycles, flowcharts, Venn diagram, model of atomic structure, Bloom's pyramid, Maslow's Hierarchy of Needs pyramid.

Image: The to-be remembered material is constructed into a picture with related meaning. The sillier the image, the better the recall.

Loci: This ancient technique uses a familiar location or space. If the logical journey must be memorised before applying it, then it is not an effective memory palace technique. It helps the brain to reduce cognitive load even further by quickly drawing the space on an index card for reference. The different ordered information are placed at different places in the palace along the journey.

Kinaesthetic: It relies on bodily movement or positioning for recall. Learners recall by doing, touching and moving. It is based on muscle memory. Example: copying notes, playing guitar, gymnastics, walking.

2.7.5 Creating a Mnemonic

According to Mercer and Mercer (1997) mnemonics can be developed with the following steps:

1. Form a word that incorporates important parts of the skill or phenomenon, often understanding the material if possible.
2. Insert extra letters to form a mnemonic word if needed.
3. Re-arrange letter to form a mnemonic word when order is not important.
4. Shape a sentence to form a mnemonic where necessary.

Method of creating mnemonics to improve memory

According to Joyce, Weil and Calhound (2021) mnemonic can generally be created using the following four phases.

Phase one: Attending to the material-use techniques of underlining , listing and reflecting.

Phase two: Developing connections-make material familiar and develop connections using a suitable mnemonic, for instance keyword, substitute-word, link-word system techniques.

Phase three: Expanding sensory images-use techniques of ridiculous association and exaggeration .Revise images.

Phase four: Practice recall: Practicing recalling the material until it is completely learned.

Indeed career guide (2020) outlines the following steps in choosing the right mnemonic for recalling names, spelling difficult words or memorising a given piece of information:

1. Choose the right mnemonic for the right situation. Example , in remembering an ordered list, the pegword system is used.

2. Practice the mnemonic several times to perfect recall and application.

3. Practice whiles saying it loud to others because recall is easier when one hears themselves.

The power of making mnemonic lies in converting dull, inert, and uninspiring information into a form that is vibrant, interesting and sticks out in the mind. The following guides can be employed in choosing an effective mnemonic type:

- Using an image that is obtained from the learning material, whose meaning is indicated by the image.
- Correspondence in part or whole of the sound of the mnemonic and the material to be learnt.
- Anagram can be applied by rearranging the learning material into a more recallable word .
- Inherent in numbers are sequences and structures : for instance even and odd nature of numbers can be used as peg to remember information.
- Onomatopoeia, where a word which phonetically sounds similar to the learning material is used to recall it. Example is oink for the sound of a pig.
- Obscenity and shock, which involve offensive, disgusting and shocking mnemonics are used to effectively recall information. This is useful especially where it is not shared with others (Ten ways to make mnemonics, 2021).

Mnemonic for ions

Anions: SO_3^{2-}, SO_4^{2-}, Cl^-, NO_3^-, CO_3^{2-}, S^{2-}

Cations: a) Non-white ions; Fe^{2+}, Fe^{3+}, Cu^{2+}

b) White ions; Al^{3+}, Zn^{2+}, Ca^{2+}, Pb^{2+}

Table 9: Mnemonic for soluble cations when $NaOH_{(aq)}$ or $NH_{3(aq)}$ is added in excess;

Legend	**Meaning**
S	Sodium hydroxide solution
L	Lead ion, Pb^{2+}
A	Aluminium ion, Al^{3+}
Z	Zinc ion, Zn^{2+}
a	Ammonia solution
Cu	Copper ion, Cu^{2+}

Note.

Soluble precipitate: SLAZ **a**CuZ

Applied Image mnemonic: Learners to imagine someone who slices a Cuss with a cutter while it all dissolves.

Source: Researcher Construct (2021)

Figure 7: shows the slicing of a precipitate.

Table 10: Mnemonic for cations which do not form any precipitate.
i)

Legend	Meaning
S	Sodium hydroxide solution
am	Ammonium ion, NH_4^+
a	Ammonia solution
Ca	Calcium ion, Ca^{2+}
NVR	No visible reaction

Note.

Sam aca NVR

Applied Image mnemonic for sam aca NVR: Learners imagine two students called Sam and Aca who have neutral smells which represents no visible reaction. But as soon as they are hot, only Sam gives ammonia gas.

Source: Researcher Construct (2021)

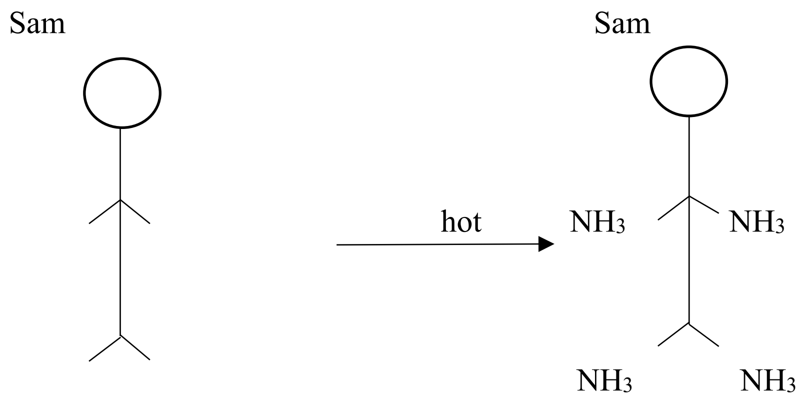


Figure 8: Illustration of what happens when 'sam' is heated.

By default, all the other cations which do not appear in either mnemonics are insoluble. For sodium hydroxide, lead, aluminium and zinc are soluble and ammonium ions do not form precipitate. Therefore, the other four cations form insoluble precipitate in excess sodium hydroxide: Fe^{2+}, Fe^{3+}, Cu^{2+}, Ca^{2+}.

For ammonia solution, copper, zinc are soluble and calcium do not form precipitate. Therefore, the other four cations form insoluble precipitate in excess ammonia solution: Fe^{2+}, Fe^{3+}, Al^{3+}, Pb^{2+}. Because of common ion effect, ammonium ion does not show any visible reaction with ammonia solution.

i) Mnemonics for cations when $H_2S_{(aq)}$ added

Mnemonic for the addition of H_2S:

a) Z**i**nc = Wh**i**te
b) A**l**uminium = Ye**l**low

c)

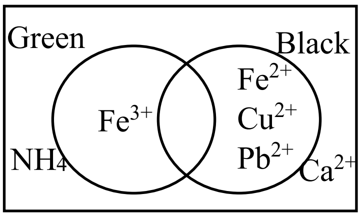


Figure 9: Behaviour of cations when reacted with hydrogen sulphide.

ii) Mnemonic for solubility rules

α) Empty ashalo bin : Scoopy schoops ppt

Applied Story mnemonic for soluble ions: These ions form very empty (soluble) salts when they combine. These ions are in a hollow bin which is empty indicating no precipitate.Image mnemonic for soluble ions:

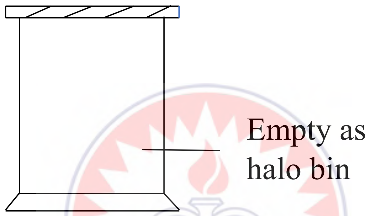


Figure 10: Illustration of the first part of solubility rules of no precipitate.

α) empty=soluble
a=alkali metals and ammonium ion
s=sulphates
halo=halogens
bi=bicarbonates
n=nitrates

s=sulphide
c=carbonate
ho=hydroxide
o=oxide
p=phosphate
s=sulphite
scoopy=student

Applied Story Mnemonic for insoluble ions: These ions are so insoluble that they need to be scooped (insoluble) with a spoon.

Image mnemonic: Learner imagines a spoon with solid on it.

Figure 11 : Illustration of second part of solubility rules, of precipitates.

β) Snash bis scoopsi

β)	
s=soluble	s=sulphite
n=nitrate	c=carbonate
a=alkali metals	o=oxide
s=sulphate	o=hydroxide
h=halogen	p=phosphate
bi=bicarbonate	s=sulphide
s=soluble	i=insoluble

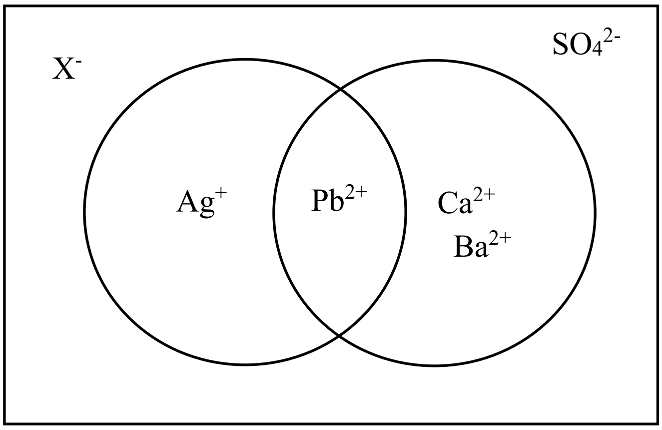
Mnemonic for exception to empty ashalo bin

γ) Except haloGene Argentum

Leads, phate can't leap bar

Except means insoluble for ions which are otherwise soluble. These anions are halogens and sulphate. Cations which form insoluble salts with halogens are Ag^{2+} and Pb^{2+} and of sulphates are Ca^{2+}, Pb^{2+}, Ba^{2+}.

d) Model mnemonic: This is an alternative to the exception mnemonic for halogens and sulphates using the Venn diagram.



U=Exceptions to halogens, X^- and sulphates, SO_4^{2-} . Both anions precipitate Pb^{2+} but only SO_4^{2-} precipitates Ca^{2+} and Ba^{2+} while halogens precipitate only Ag^+ in solution as shown in Figure 12.

Figure 12: Illustration of exceptions to soluble precipitates of halides and sulphates anions.

Differences between rote learning and mnemonic technique

Though rote learning and mnemonics both involve memorisation process and intended retrieval, the former is based on mechanical repetition of learning material whiles the latter involves organising and encoding learning material through creation and use of cognitive cuing structures . Mnemonics use meaningful learning to relate prior knowledge to new knowledge whether remotely or not. However, mnemonics are remembered using schema. (Bellezza, 1981). Mnemonics increase both short and long term retention compared to rote learning. (Kayaalti, 2018). Rote learning is applied to quick learning where memorisation and recall are required, especially in foundational knowledge before learners learn about understanding.

Rote learning is a type of surface learning that may occur when students are unable to relate the new knowledge framework or course, with a misconception (Weeks, Lyne, & Torrance, 2000).

2.8 Relevant Prior Knowledge

Prior knowledge has long been considered the one most important factor influencing learning and student achievement (Tobias, 1994).

The quantity and quality of existing prior knowledge positively influences both knowledge acquisition and the capacity to apply higher-order cognitive problem-solving skills (Dresel, Ziegler, Broome, & Heller, 1998).

Prior knowledge is a multidimensional and hierarchical entity that is dynamic in nature and consists of different types of knowledge and skill. (Hailikari, Katajavuori, & Lindblom-Ylanne, 2008).

According to Biemans, Deel and Simons (2001) prior knowledge is all knowledge learners have when entering a learning environment that is potentially relevant for acquiring new knowledge.

Although teachers using the Lecture method may mediate the activation of prior knowledge in students as one of their instructional tactics, teachers using prior knowledge based strategy specifically teach students about their prior knowledge and how they can intentionally use it to facilitate learning and performance: they teach what prior knowledge is, how it is used to facilitate learning and performance and when and how they can use it (Ellis, 1993).

2.8.1 How to assess prior knowledge

Students come to the classroom with a broad range of pre-existing knowledge, skills, beliefs and attitudes which influence how they attend, organise and interpret incoming information. It will in turn affect how they think, remember, apply and create new knowledge.

There are several different methods to assess pre-existing knowledge and skills in students.

1) Direct measures are tests, concept maps activities, portfolios and auditions.
2) Indirect methods are self-assessment probes (Example; self-reports), inventory of prior courses and experiences.

Concept maps activities involve how learners are able to make connections between concepts and show structure in their organisation of knowledge.

Self-reports consist of asking students to reflect on what they know about a particular topic (Example: answering true or false to questions, brainstorming and making predictions).

Inventory of prior courses taken are indicated by transcript or report sheets about student. Prior learning Portfolios comprises a narration or story of the learner's learning in the past.

2.8.2 Factors affecting effectiveness of prior knowledge

The effects of the declarative prior knowledge compared with that of procedural prior knowledge is different. Hailikari,Katajavuori, & Lindblom-Ylanne (2008) observed that prior knowledge that mainly consisted of declarative did not contribute to students' achievement but those with mainly procedural were likely to succeed.

Therefore, it should not only be what students know at the beginning but how well they know it (Potter & Briggs, 2003). In prior knowledge assessments the type of knowledge being assessed should be known by instructor because it is not all types of prior knowledge that impacts achievement (Birenbaum, 1994).

Declarative prior knowledge, which is at the lowest level, consists of knowledge of facts and meanings that a student is able to remember or reproduce. It is "knowing about" or surface learning (Potter & Briggs, 2003). It is also known as rote learning or "knowledge-telling" which include many facts and details that do not form an integral whole. Students who have just declarative knowledge are able to answer reproductive questions, and when able to answer questions without a component for integration or application (Dochy, 1992). Once prior knowledge and skills are assessed, there is a range of potential responses depending upon the type of course, the uniformity of results and the availability and type of supplemental materials and alternatives. For instance, if the majority of the class possess misconceptions or weak understanding of a concept that instructor views as critical prerequisites, then instructor must decide to include covering it in class, provide a supplementary session on it or provide links to materials for students to engage with it on their own.

On the contrary, if most students demonstrate proficiency in a skill instructor was planning to cover, the topic may be dropped and replaced with another skill that they have not yet developed, or adjust the level of complexity or time one spends on it. Hence individual student lacking many of the prerequisite skills and knowledge could be forewarned that they need proficiency in these areas on their own if they are to succeed in the course. Thus assessing prior knowledge can enable both the instructor and the student to allocate their time and energies in ways that will be most productive.

2.8.3 Activation of prior knowledge

Prior knowledge activation through reflection and recording: Students are simply prompted to bring to mind and record what they know already. Text recall and/or comprehension has been demonstrated to improve by making students answer the question "what do I know already about this topic" either orally or on paper.

Spires and Donkek (1998) found that activating background knowledge through reflection and oral elaboration during text reading was more effective strategy than taking notes on main ideas.

Prior knowledge activation through interactive discussion: Learners are made to discuss a topic and contribute prior knowledge to complete a semantic map in an interactive manner among peers with facilitation from teacher (Dole, Valencia, Greer, & Wardrop, 1991). Schnidt and Patel (1987) however posit that topic area novices may benefit significantly from this approach but experts may not experience significant benefit.

Prior knowledge activation through answering questions: Activation of background knowledge can be performed by having students answer questions before and/or whiles they read new material (Rowe & Rayford, 1987).

Pressley et al. (1992) emphasise that not all questioning interventions are effective: the most effective questioning requires deep processing involving synthesizing and analysing of the to-be-learned material and relating it to prior knowledge.

K-W-L strategy for activating prior knowledge: Ogle (1986) developed this strategy for helping students' access important background information before reading a text.

It combines several elements of other approaches for prior knowledge activation.

K (Know): students reflect on knowledge about a topic, brainstorming a list of ideas about topic and identifying categories of ideas.

W (Want): Teacher helps to highlight gaps and inconsistencies in students' knowledge and students create individual lists of thigs that they want to learn about the topic.

L (Learned): Students learn new material and share what they have learned. Evaluation of K-W-L strategy increases the retention of read material and improves students' ability to make connections among different categories of information as well as their enthusiasm for reading text. (Ogle, 1986)

Computer-assisted activation for prior knowledge: This does not require teacher facilitation in knowledge activation. Biemans, Deel and Simons (2001) observed that students who used this method had developed a higher quality conception than students in a no activation group, even after a two month follow up.

Computer assists students in searching for preconceptions with new information and formulating, applying and evaluating new conceptions.

Prior knowledge activation through interpretation of topic-related pictures: This method consisted of helping students to build and activate prior knowledge using topic related pictures (Croll, Idol-Maestas, Heal, & Pearson, 1986). Though this method improved students' performance, it had a very small sample size without control group, thus the results is only preliminary and tentative at best.

2.9 Lecture Method

This is the oldest method, based on the presentation of content based on the philosophy of idealism. The teacher clarifies the content matter to the student by using gestures, simple devices, changing voice, change in position or facial expression.

Teachers are active and students are passive but teacher ask questions to keep students active and students are passive but teacher ask questions to keep students active. It is a teacher controlled and information centred approach in which teacher works as the sole resource in the classroom instruction. It serves to motivate, clarify, review and expand knowledge (Santosh, 2019). It is useful when considering a new topic, revising or summarising and when covering syllabus quickly.

2.9.1 How to improve the lecture method

Instructor must organise learning material, repeat topic, present material logical, be tailor made to students' standard, encourage students to ask questions (Sharma, 2016).

2.9.2 Advantages of using Lecture method

It is economical, requires no prior arrangement, saves time, it covers the syllabus, useful in large classes in college.

2.9.3 Disadvantages of Lecture method

There is no provision for feedback from students, individual differences are not considered, can be boring, students' needs are not primary, no relevant prior knowledge and students develop hatred for the learning (Sharma, 2016).

CHAPTER THREE

METHODOLOGY

3.1 Overview

This chapter describes the characteristics of the sample and its accessible population . The research design and data collection instrument are then described. Finally equipment for analysing the data is explained

3.2 Research Design

The study type was experimental with both random selection of intact classes and random assignment of participants into the two treatment and one control group. The findings of this applied research is both to improve theory and practice. This causal comparative methodology adopts both quantitative and qualitative approaches. A quasi experimental design would have affected the validity and reliability of the findings, because of its lack of random assignment of treatments to groups.

The research design is represented as follows:

Table 11: Study design of Groups' tests and treatments.

Groups	Pre-test	Treatment	Post-test
E_1	O_1	X_1	O_2
E_2	O_3	X_2	O_4
C	O_5	X_3	O_6

Note:

E_1 represents experimental group 1
E_2 represents experimental group 2
C represents control group
O_1, O_3, O_5 represent pre-test score
O_2, O_4, O_6 represent post-test scores
X_1 represents mnemonic-based instructional method.
X_2 represents Prior Knowledge Instructional method
X_3 represents modified Lecture method

First experimental group **SS3**$_{T1}$ had 12 students and received treatment using mnemonic method, the second experimental group **SS3**$_{T2}$ also had 12 students and treated with the prior knowledge instructional method. The control group, SS3C had the same number of students and received a standard and common instructional method, which is a modified lecture method without reference to relevant prior knowledge nor mnemonic. All three groups received same pre-test and post-test at the same time.

3.3 Population

The population under study is situated in the Ayawaso North municipality of the Metropolitan district of Greater Accra Region at The Roman Ridge, near "Kawokodi Junction". The George Walker Bush N1 road, then Olusegun Obasanjo Highway off the Al-Waleed Bin-Jalal street leads to the school. It was established in 1960 with Ghana Post number 11 Olusegun Obasanjo HWY GA-039-2664.

The target population was all science students offering elective chemistry in SHS running the WASSCE Syllabus to which generalisation will be made. There were about 2500 students in the school with 160 being Science students. The school runs both green and gold tracks of the FSHSP.

The accessible population is Accra Girls' SHS 3 Science students. Form three students were selected because comparatively they had a richer prior knowledge for the treatment group because they had already covered stoichiometry and laws of chemical combination among other topics, compared with forms one and two . SHS 3 Science students had four classes out of the 66 classes. There are 12 classes each for Science, Home economics and Business programmes. General Arts and Visual Arts classes were 24 and 6 respectively.

3.4 Sample and Sampling procedure

Single stage probability cluster sampling method was used: one whole class which had thirty six students on roll was randomly selected from the four science classes. The 36 students were then randomly selected into three groups for different instructional methods to be administered. There was no nonresponse bias and students in the whole class responded to the questionnaire whiles author waited. Majority of the respondents were between the ages of 17 and 19 years. All respondents were females with ages falling within the teenage brackets.

One intact class with 36 students were randomly selected. Since each cluster itself is a mini representation of the larger population sampling from each cluster was not used but probability cluster sampling where all students in the randomly selected cluster are sampled was adopted. A multi-stage cluster sampling would have decreased the sample size and would have been time consuming as well. This was not used because each whole class is already a representation of the population.

3.5 Research Instrument

The instruments applied to collect data were in three parts: questionnaire a follow up semi-structured interview schedule and a chemistry achievement test. (Appendices C and D),

The schedule probes further for clarity regarding respondents where answers to questionnaire are contradictory or required illumination.

The questionnaire was made up of five parts. Part I involved data on both students and teachers' attitudes to chemistry especially ion identification. Students' knowledge of study strategies is solicited under Part II. Part III comprises knowledge of mnemonic devices. Part IV deals with information on the application of mnemonics to learning material. Demographic data was obtained in Part V.

Questions were dichotomous, Likert and differential.

The achievement test was made up of standardised questions from WASSCE past questions, IGCSE past questions and teacher created questions of comparable difficulty, drawn from the syllabus. This served as both pre-test and post-test questions. Students in all three groups were taught by the author beginning with the modified lecture method group, followed by the prior knowledge group and then the mnemonic group. The lesson plan for instruction are in appendices A and B. Each lesson lasted for 40 minutes which was followed by an hour achievement test using the questions in appendix C.

3.6 Validity and Reliability

Face validity was achieved by asking non experts to comment on validity just by the face of it. Further, content validity was achieved with the help of the supervisor. Concurrent validity for student attitude towards ion identification was achieved by measuring participants' likeness for Chemistry. Reliability of the questionnaire was ensured by calculating a Cronbach alpha reliability coefficient during the piloting. The alpha coefficient value obtained was 0.84(Appendix E), indicating an acceptable reliability greater than the recommended lower limit of 0.60. This was obtained for the five factor Likert items on the frequency of use of mnemonic types, during piloting of instrument. Piloting involved 6 students 2 each from the other 3 science classes not sampled in the population for the three groups.

3.7 Data collection procedure

One of the four Science classes was selected by picking one folded paper from an opaque container. 12 students are then selected randomly from the intact class. The 3 groups were instructed using the respective methods and guided by the lesson notes for prior knowledge group (Appendix A) and the mnemonic group (Appendix B). Data collection lasted for a week after pretesting using the same procedure and the test conducted at the end of the lessons. The test lasted for 45 minutes and marked using WAEC mark scheme. All participants in all three groups were served with the questionnaire, which was completed in an average of 15 minutes. A follow up semi-structured interview schedule was administered for outliers or participants whose data prompts for further clarification. Further, the $SS3_{T1}$ group filled a supplementary questionnaire eliciting information about the effect of choice of mnemonic type by students on post test scores. Questionnaire was completed during contact hours to avoid disrupting lessons.

Individual participants who had to clarify some data points were invited and were interviewed for clarification.

Period for instruction was limited to two weeks and all ran concurrently to minimise diffusion of information between groups. To avoid Hawthorne effect, all three groups were given treatments at the same time with the control group receiving a standard instructional method.

3.8 Equipment for Data Analysis

Data collected were analysed using one-way analysis of Covariance for independent groups in SPSS Version 22. Data produced by dependent variables were post test scores and attitudes with independent factor being method of instruction at three levels of treatment of MBIM, RPKBIM and ALM. Pre-test scores represented the covariance.

The following ANCOVA conditions were satisfied for valid results:

By visual inspection

- the covariate and dependent variables were continuous.
- the independent variable was categorical.
- there were independent observations, no student belonged to more than one group of the independent variable.
- the posttest scores were normally distributed for each level of independent variable: The Shapiro-Wilk test of normality produced 0.98, 0.90, 0.92 at 0.05 level of significance for lecture, prior knowledge and mnemonic groups respectively. These values are statistically nonsignificant therefore we fail to reject the null hypothesis of equal normal distribution. (see appendices F1, F2, F3 and F4).
- The Levene's Test of equality of variance at 0.05 level of significance was, statistically nonsignificant with a value of 0.34 (see appendix G). Therefore the variances of all three groups of the independent variable are equal.
- There was no significant outlier above or below the whiskers (see appendix H).
- There was a significant correlation between the covariate and dependent variable as shown in the scatter plot (see appendix I).

The hypotheses were tested at 0.05 level of significance.

Descriptive statistics were obtained in the form of frequency table, histogram and pie chart. Central tendency was in the form of mean. Dispersion was the form of standard deviation and variance.

Correlation between dependent and independent variables was determined using scatter plots and crosstabs between scores and attitudes for all 3 groups.

3.9 Ethical consideration

Participation was voluntary though all students in the intact classes were given treatments. They were made duly aware that participation could be truncated if they so decide even during participation.

The data collected are confidentially analysed, stored and shared with no divulging of students' identity.

Students who were randomly selected into the RPKBIM experimental group and the MLM control group were later taught the MIM after data was collected to prepare for the 2021 WASSCE examinations.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Overview

This covers the presentation and discussion of results of data collected by author from the field. The results and discussion are informed by predetermined hypotheses as indicated in chapter one. The sections in the chapter are results for, general characteristics of the participants, general mnemonic use, comparison between mnemonics and other learning strategies, mnemonic types and hypotheses testing.

4.2 Characteristics of Participants

Sample had a mean age of 17.33 years (SD = 0.89, Appendix J). Gender of all participants was female and all in 3 Science 1 Gold track.

Table 12: Residential status of students for MBIS, RPKBIS and MLM groups.

Status of students	Methods of teaching			
	Lecture method group	Prior knowledge group	Mnemonic	Total
Day	5	5	8	18
Boarder	7	7	4	18
Total	12	12	12	36

The residential status of participants was 50% day and 50% boarder with mnemonic group having the highest and lowest number of day and boarders respectively (see Table 15).

4.3 Research Objective three; To replicate (or refute) and extend knowledge on the connection between providing students with different mnemonic types to choose from, and their learning outcomes.

More than half of respondents (50%) knew about mnemonics (Appendices J and K)

For the effectiveness of mnemonic usage, on a semantic differential scale of 1 to 6 with 1 for "forgets learning material when using mnemonic" and 6 for "effective in helping to remember learning material", there was a mean value of 5.36 (SD=0.87), indicating high effectiveness in mnemonic use because the mean value is 3.

Further, 56% of respondents reported that mnemonics help them to remember learning material and no respondent reported that mnemonics makes them forget (Appendix J). This is consistent with the assertion by Carney and Levin (2000) that, mnemonics are effective in improving both long and short term memories.

A large percentage of respondents (89%) reported that they apply mnemonics to chemistry practicals including qualitative analysis with only 4 respondents (11.1%) reporting of not applying mnemonics to theoretical chemistry. (Appendix L)

According to McCabe et al. (2013) the main reason for using mnemonics is that, the instructor uses them and also because of the nature of the learning material. This is corroborated by this study with a large percentage of participants (75%) reporting that their reason is both because the teacher uses it and also due to the nature of the material.(Appendix M).

Comparison of mnemonics and other strategies

Table 13: Ratings of usage of study strategies

Learning Strategy	Percentage (%)	Mean	Standard deviation
Doing Practice Problems (Solving questions)	18.9	1.14	0.351
Practice mental recall	15.8	1.28	0.454
Use of mnemonic	14.0	1.36	0.487
Rereading class notes	14.0	1.36	0.487
Relating notes to self	11.6	1.47	0.506
Paraphrasing and reorganising notes	11.6	1.47	0.506
Studying materials multiple times	11.6	1.47	0.506
Making and using flashcards	2.5	1.89	0.319

Note Percentages were obtained from the frequencies of strategies for the 36 participants measured on a dichotomous scale.

Doing practice problems was the significantly highest reported learning strategy (M=1.14, SD=0.35). This was followed by practice mental recall then mnemonic use. This was obtained on a dichotomous scale with 'Yes' scoring 1 and 'No' scoring 2 (see Table 15). This result is in agreement with McCabe et al. (2013).

Results for mnemonic types

Table 14: Ratings for usefulness of different mnemonic types.

Study Strategy	Mean	Standard Deviation
Acronym	3.81	1.31
Acrostic	2.97	1.46
Music	2.86	1.36
Note organisation	2.75	1.27
Keyword	2.61	1.25
Model	2.28	1.45

Note Data was obtained on a likert scale with 1=never, 2=occationally,3=sometimes,4=often,5=very often.

The commonly used is acronym (M=3.81, SD=1.3) followed by acrostic (see Table 15: M=2.97, SD=1. ,46) (see Appendix N). This is consistent with observation by McCabe et al. (2013) where just as in this study, acronym and acrostic are only higher than keyword.

4.4 Research objective two: To assess the attitudes of students to ion-qualitative analysis after treatment with different types of learning strategies: Modified lecture, Prior knowledge and Mnemonic.

Table 15: Crosstab ratings of attitude of students to ion identification after treatment.

Attitude	Response	Methods of teaching		
		Lecture	Prior knowledge	Mnemonic
Put effort into studying chemistry and not afraid of it	Yes	33	33	33
	No	33	27	40
	Somehow	33	50	17
Register for ion identification exam	Yes	35	27	39
	No	30	50	20
	Somehow	33	33	33
Opting out of ion identification if had option	Yes	47	42	11
	No	13	20	67
	Somehow	50	50	0
Chemistry as a tertiary course	Yes	28	23	55
	No	50	50	0
	Somehow	50	50	0
Chemistry as favourite subject	Yes	28	17	56
	No	43	43	14
	Somehow	25	75	0
Think teacher is motivated to teach Chemistry	Yes	36	27	36
	No	0	100	0
	Somehow	0	100	0

Answers to the above questions were a measure of the attitude of respondents to ion identification in chemistry using ‘Yes’, ‘No’ or ‘Somehow’ response.

The participants for the mnemonic group scored highest in all indicators for positive attitude to qualitative analysis after treatment. These data are statistically significant, indicating an association between method of teaching and students' attitude to chemistry. Therefore, the null hypothesis that attitude is not affected by teaching method is rejected. This is collaborated by Odeyemi and Akinsola (2014) and Adesoji (2008) who asserts that teaching methods and teacher's general attitude to instruction of subject influence students' attitude to the subject matter.

The prior knowledge group except in the case of "opting out of ion identification if given the opportunity" trailed in attitude to chemistry.

It is of interest to note that, when a follow up interview was conducted on the mnemonic group that had scored 40 for "No" to "put effort into studying chemistry and afraid of it", it is discovered that the respondents rather answered 'No' to 'fear for chemistry' and not to the first part of the question (see Table 16)

4.5 Objective one: To identify the most effective instructional strategy to ion-identification experiments.

Hypothesis testing

H_0: There is no significant difference in the learning outcomes when mnemonic or prior knowledge or modified lecture method are applied.

Table 16: Post-test Ratings for the effectiveness of the three levels of independent variable controlling for covariate which is the post-test scores.

Variable	M	SD
Mnemonic method	27.69	0.61
Prior knowledge method	20.78	0.60
Lecture method	16.37	0.62

Note. Covariates appearing in the model are evaluated at the following values: Pretest

Independent Variable 2=12.61

The mean values for the different levels of method of teaching produced 27.69, 20.78 and 16.37 for mnemonic, prior knowledge and lecture groups respectively. This is consistent with the pairwise comparison (see table 18). This result is consistent with the claim of Odeyemi and Akinsola (2014).

Compution of one-way ANCOVA of the post-test at the three levels of independent variable controlling for the covariate and satisfying the conditions for this statistical tool produced $F(2,32)=67.39$, $P<0.05$ at 0.05 level of significance (Appendix O). This test result is statistically significant therefore the null hypothesis, Ho_1 that method of teaching is not correlated with post-test results is rejected .Therefore effect of treatment is associated with post-test results, thus the alternative hypothesis is correct.

Table 17: Bonferroni Pairwise comparison between the three levels of independent variable.

(I) Method of teaching	(J) Method of teaching	Mean Difference (I - J)	Standard deviation
Lecture	Prior knowledge	-4.41	0.87
	Mnemonic	-11.32	0.91
Prior knowledge	Lecture	4.41	0.87
	Mnemonic	-6.91	0.85
Mnemonic	Lecture	11.32	0.91
	Prior knowledge	6.91	0.85

Using Bonferroni adjustment for multiple contrasts, it was found that all pairwise contrasts were statistically significant, (all $P_s < 0.05$)

The pairwise contrast produced the highest significance for the mnemonic group (see Table 18).

H_{03} : There is no significant difference in learning outcomes when students are given the option to choose from different mnemonics to apply.

All participants in the mnemonic study group answered 'Yes' to whether being offered two mnemonics to choose from improved recall and performance. Therefore, the hypothesis that choice in selecting from a set of mnemonic about the same subject does not improve recall and learning outcomes is rejected.(see appendices P1 and P2). This is corroborated by Coverdale & Nairne (2019).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Overview

This chapter covers an overview of the study, explanations, key findings, whether expected or otherwise. It ends with suggestions to NaCCA, GES, teachers and other researchers for further studies.

5.2 Limitations

1. Although it is expected that the findings will have a limited application in all boys' or mixed schools due to the accessible population being all female , Odeyemi and Akinsola maintain that gender does not have a significant effect on learning outcomes when mnemonic, prior knowledge or modified lecture methods are applied. (Odeyemi & Akinsola, 2014)
2. The validity of the results is affected because whole classes were used however it was improved by randomly selecting the classes and also randomly assigning participants to groups.
3. Instruction strategies were drawn with reference to the WASSCE Chemistry Syllabus (The West African Examinations Council, 2010). Therefore, application of results to other curricula is limited, though this effect was minimised by outlining how to construct own mnemonic by students.

5.3 Summary

This study used experimental designs to comparatively determine the most effective method of teaching to memorize ions during qualitative analysis in Accra Girls' Senior High School. Additionally, the effect of teaching method on the attitude of the participants towards ion-identification is also determined. Finally, the effectiveness of giving the mnemonic group participants the option of selecting the preferred mnemonic for the qualitative analysis is determined. The purpose was achieved through formulation of hypothesis bothering on the effectiveness of teaching method on posttest scores and students' attitude to chemistry and the effectiveness of multiple mnemonic on students' performance.

5.4 Main Findings

As indicated by the field data collected by the author on the most effective teaching method for ion identification and its effects on students' attitude to the analysis, students in the mnemonic group had both attitude and learning outcomes improved more compared with the adjusted lecture method and prior knowledge groups. This may be partly due to the elaborate interaction of participants with the learning material when using mnemonics compared with other method (Fulk & Ryu, 1990).

Students attitude improved more in the mnemonic group because of the mnemonics used and also because 33 students out of 36 reported that their chemistry tutor had a good attitude to chemistry ion identification.

5.5 Recommendation

It is recommended that scheme of work designers in AGISS include mnemonics for the ion analysis and students be encouraged to create and use their own mnemonics especially acronyms for the qualitative analysis and periodically study it using "doing practice problems" since these ranked first among other strategies.

For further research, the population and sample size should be increased and validity improved by randomly selecting sample from multiple and varied senior high school in the municipality. Using factorial analysis, age and gender could be analysed as possible causes for improved learning outcomes.

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APPENDICES

Appendix A

Lesson plan for prior knowledge

Subject: Chemistry

Topic: Qualitative Analysis

Subtopic: Ion identification

Venue: Chemistry laboratory

Class: 3SB (Experimental group B)

Number of students: 12

Date: 30/06/21

Time: 10:00 am

Duration: 1hr

Specific objectives: By the end of the lesson, the students should be able to

1. List all the cations to be identified by students according to WAEC requirement.
2. List all the anions to be identified by students according to WAEC requirements.
3. State all solubility rules for both cations and anions.
4. Give solubility exceptions and three insolubility exceptions
5. Match all sulphides of the following cations to their respective colours: NH_4^+, Ca^{2+}, Pb^{2+}, Al^{3+}, Zn^{2+}, Fe^{2+}, Fe^{3+}, Cu^{2+}.
6. List all cations that dissolve in excess $NaOH_{(aq)}$ and $NH_{3(aq)}$

Advanced Preparation:

1. Teacher made charts of mnemonics (images, models, acronyms, keywords and acrostic).
2. Teacher secured two test tubes, $Pb(NO_3)_2$ and HCl solution.

Relevant prior knowledge:

1. Students have been taught ion formation and solution formation from solute and solvent.
2. Students have been taught the different forms of precipitates that can be formed: crystalline, amorphous, coloured (white, green, blue, brown, black).
3. Students have been taught the equilibrium between precipitation and dissolution.
4. Students have been taught dissolution of complex precipitates.

Reference:

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Table 13: Lesson notes for the prior knowledge group

Step, Content [time]	Equipment	Teaching -Learning Strategy		Core points	Evaluation
		Teacher activity	Student activity		
1.Introduction [3 mins]	Two test tubes, each containing $Pb(NO_3)_2$ solution and HCl solution.	Teacher mixes these solutions	Students observe and take notes.	White chalky precipitate of $PbCl_2$ is formed from $Pb^{2+} + 2Cl^- \rightarrow PbCl_2$.	Write equation for the combination of the other anion and cation H^+ and NO_3^-.
2.Content development [15 mins] Step 1: Required ions [3 mins]	Chart showing the ions	Teacher list all cations and anions required	Students observe and take notes.	Cations: NH_4^+, Ca^{2+}, Pb^{2+}, Zn^{2+}, Al^{3+}, Fe^{2+}, Fe^{3+}, Cu^{2+} Anions: Cl^-, CO_3^{2-}, SO_3^{2-}, SO_4^{2-}, NO_3^-	

Step 2 and 3: [30 mins]	Chart showing all the rules.	Teacher explains rules to students	Students listen and take notes.	1.All nitrates are soluble. 2.All salts of alkali metals and NH_4^+ are soluble. 3.All sulphates are soluble except those of Ca^{2+}, Pb^{2+}, Ba^{2+}. 4.All halogens are soluble except those of Ag^+ and Pb^{2+}. 5.All bicarbonates are soluble 6.All S^{2-}, PO_4^{3-}, SO_3^{2-}, OH^-, O^{2-}, CO_3^{2-} are insoluble except those of alkali metals and NH_4^+.	1.How many ions are to be identified? 2.State the formulae of the soluble ions. 3.State the formulae of the insoluble ions.
Step 4: Precipitate by cations using H_2S in neutral aqueous medium [15 mins]	Chart showing sulphides and colours.	Teacher explains the sulphides and their colours and those that "show" no reaction.	Students listen and take notes.	Sulphides $CaS_{(aq)}$ and $(NH_4)_2S_{(aq)}$ have no precipitate, ZnS, Al_2S_3, Fe_2S_3, PbS, FeS, CuS have White,	

				Yellow Green Black, Black, Black precipitate Respectively.	
Step 5: Soluble cations when $NH_{3(aq)}$ or NaOH is added [15 mins]	Chart showing the cations, their precipitate and solubilities with excess reagent.	Teacher explains the precipitation of cations with hydroxides.	Students listen and take notes.	Al^{3+},Pb^{2+}, Zn^{2+} are soluble in $NaOH_{(aq)}$ and Cu^{2+} and Zn^{2+} are soluble in $NH_{3(aq)}$	1.List 2 cations whose precipitates are soluble in excess NaOH(aq) and NH_3(aq) 2.List 2 cations whos precipitates are insol in excess i. NaOH(aq ii. NH_3(aq)
Application [10 mins]		Teacher asks students to explain three everyday situations that illustrate precipitation.	Students listen and answer expected answer by student 1.Clogging of pipes due to precipitation of Ca^{2+}, Mg^{2+}, CO_3^-, Cl^- ions in water. 2.Curd formation		

		during washing with hard water. 3.Kidney stones.
Closure [10 mins]	Teacher summarises lesson and elicit questions from students for clarification.	Students listen and ask questions.
Evaluation [10 mins]	Teacher verbally asks students questions	Students listen and answer.

Appendix B

LESSON PLAN FOR MNEMONIC

Subject: Chemistry

Topic: Qualitative Analysis

Subtopic: Ion identification

Venue: Chemistry laboratory

Class: 3SA (Experimental group A)

Number of students: 12

Date: 30/09/21

Time: 10:00 am

Duration: 1hr

Specific objectives: By the end of the lesson, the students should be able to

7. List all the cations to be identified by students according to WAEC requirement.
8. List all the anions to be identified by students according to WAEC requirements.
9. State all solubility rules for both cations and anions.
10. Give solubility exceptions and three insolubility exceptions
11. Match all sulphides of the following cations to their respective colours: NH_4^+, Ca^{2+}, Pb^{2+}, Al^{3+}, Zn^{2+}, Fe^{2+}, Fe^{3+}, Cu^{2+}.
12. List all cations that dissolve in excess $NaOH_{(aq)}$ and $NH_{3(aq)}$

Advanced Preparation:

3. Teacher made charts of mnemonics (images, models, acronyms, keywords and acrostic).
4. Teacher secured two test tubes, $Pb(NO_3)_2$ and HCl solution.

Reference:

Ameyibor, K. and Wiredu M. B. (2006). Chemistry for Senior High School (3rd ed). Accra North, Ghana, Mc Millan Limited.

Step, content (Time)	Equipment	Teaching -Learnin Strategy		Core points	Evaluation
		Teacher activity	Student activity		
Content development Step 1: Required ions [5 mins]	Chart showing all the ions.	Teacher lists all cations and anions required	Students observe and take notes	Cations: NH_4^+,Ca^{2+},Pb^{2+},Zn^{2+},Al^{3+},Fe^{2+},Fe^{3+},Cu^{2+} Anions: Cl^-,CO_3^{2-},SO_3^{2-},SO_4^{2-},NO_3^-,S^{2-}	How many ions are required to be identified according to the WASSCE syllabus?
Step 2: Solubility rules for both cations and anions [15 mins]	Chart showing "clear as halo bin", "scoopy schoops", and "Except halogen	Teacher explains the mnemonics and its legend.	Students observe and take notes.	a= alkali metals and NH_4^+ halo= halogen bi= bicarbonate s= sulphate n=nitrate s= sulphide	State the mnemonic of the soluble ions 2. State the mnemonic of the "no precipitate" ions.
Step 3: Exceptions in anions caused by cations (Na^+, K^+, Li^+,		Teacher explains that alkali metal cations when combined	Students listen and take notes.	All anions of Li^+, Na^+, NH_4^+ and K are all soluble. Soluble cation + insoluble anion = soluble salt	Indicate with solid or aqueous for the products formed:

NH_4^+) [15 mins]		with any anion is soluble.		Insoluble cation + insoluble anion = insoluble salt	1.$Ca^{2+} + OH^- \rightarrow Ca(OH)_2$ 2. $Na^+ + Cl^- \rightarrow NaCl$ 3.
Step 4: Precipitate by cations using H_2S in neutral aqueous medium [15 mins]	Chart showing mnemonic for sulphides and colours.	Teacher states different colours for different sulphides using chart.	Students listen and take notes.	The following Sulphides have the following respective Colours: $CaS_{(aq)}$, $(NH_4)_2S_{(aq)}$, $ZnS_{(s)}$, $Al_2S_{3(s)}$, $Fe_2S_{3(s)}$, $PbS_{(s)}$, $FeS_{(s)}$, $CuS_{(s)}$, Clear solution, Clear solution, White, Yellow, Green, Black, Black, Black.	List cations that do not cause precipitation with H_2S
Step 5: Soluble cations when $NH_{3(aq)}$ or NaOH is added [15 mins]	Chart showing "Slaz acuz" and its legend	Teacher explains mnemonic using chart.	Students observe and take notes,	s= sodium hydroxide l= lead a= aluminium z= zinc a= ammonia solution cu= copper z= zinc	List 2 cations whose precipitates are soluble in excess NaOH NH_3 List 2 cations whose precipitates are insoluble in excess NaOH NH_3

Step 6 : No precipitate cations when $NH_{3(aq)}$ or NaOH is added	Chart showing "Sam aca"	Teacher explains mnemonic using chart	Students listen, observe and take notes	S= sodium hydroxide am= ammonium cation a= ammonia solution ca= calcium cation
Application [10 mins]		Teacher asks students to explain three everyday situations that illustrate precipitation	Students listen and answer expected answer by student -Clogging of pipes due to precipitation of Ca^{2+}, Mg^{2+}, CO_3^-, Cl^- ions in water. -Curd formation during washing with hard water. -kidney stones	
Closure [10 mins]		Teacher summarises lesson and elicit	Students listen and ask questions.	

	questions from students for clarificatio n.	
Evaluation [5 mins]	Teacher verbally ask students questions.	Students listen and answer.

Appendix C

Sample survey

The purpose of this study is to investigate the most effective instructional method for qualitative experiment. It is also to provide a template for ion identification and also to improve practice.

Instructions:

- Mark your answer with a tick, ☑ or fill in the dotted lines where provided.
- If you make a mistake, cross the tick out like this ☑ and re-tick the correct answer.
- Please read each question carefully and answer truthfully.
- You are assured of your confidentially.

Survey items

Part I

1. Is chemistry your favourite subject?

Yes ☐

No ☐

2. Chemistry is one of the subjects you intend to study in the university or any tertiary institution?

Yes ☐

No ☐

3. If you have an option for chemistry would you opt out of ion identification practicals?

Yes ☐

No ☐

4. Do you believe chemistry is difficult?

Yes ☐

No ☐

5. Do you believe that you know and understand chemistry?

Yes ☐

No ☐

6. I like to do chemistry exercises, homework, tests and not afraid of examination involving chemical reactions.

Yes ☐

No ☐

7. The chemistry recommended textbook on ion identification is easy to understand.

Yes ☐

No ☐

8. If ion identification was not compulsory for science students, I would not registered for it during WASSCE examination

Yes ☐

No ☐

9. Cation and anion identification is only for some brilliant students to understand.

Yes

No ☐

10. My chemistry teacher shows good motivation during teaching-learning process.

Yes

No ☐

11. I understand qualitative experiment when my chemistry teacher teaches.

Yes ☐

No ☐

12. My chemistry teacher uses teaching method for ion identification I understand.

Yes ☐

No ☐

13. My teacher likes to teach chemistry.

Yes ☐

No ☐

Part II

14. Have you used any of the following study strategies to remember learning material?
    - Doing Practice Problems (Solving questions) ☐
    - Practicing mental recall ☐
    - Studying the same material over multiple times instead of one session only ☐
    - Rereading class notes ☐
    - Relating learning material to myself ☐
    - Paraphrasing and reorganising my notes ☐
    - Using mnemonic devices ☐
    - Making and using flashcards ☐

15.1Have you heard or read about "mnemonics" before?

Yes ☐

No ☐

15.2Do you know what mnemonic device is?

Yes ☐

No ☐

15.3If you choose "yes" in question 15.2, then explain in your own words what "mnemonic devices" are

………………………………………………………………………………………......

....

16. Below are presented different types of mnemonic methods with examples.

- Acronym (Name Mnemonic): The letters of a list to be remembered are used to form a word. Example: ROYG,BIV to remember the list of seven colours in light.
- Acrostic: The first letters of a list one used to form new words in a sentence. Example: my very eyes may just see under nine planets.
- Music mnemonic: The learning material is made into a song or familiar tunes are used, with the list to be remembered forming lyrics. Example 30 days hath September, April, June and November…

- Notes organization: Rearranging notes in a logical or recallable pattern for easy encoding and decoding.
- Keyword: To remember new information a Keyword which sounds like part a mental image which explains the meaning image which explains. Example: Sink I a keyword to create an image of a solid sinking to the bottom of a solution. Hence sink is a keyword for precipitate.
- Model: The information is made into a representation for easy recall. Example: Using Venn diagram, flow chart, Rutherford's model of the atom, hydrological cycle.

- Do you know any of the mnemonic devices above?

Acronym ☐
Acrostic ☐
Music ☐
Note organisation ☐
Keyword ☐
Model ☐

- To what extent do you use the following mnemonics

Type of mnemonic	Never	Occasionally	sometimes	Often	Very often
Acronym	☐	☐	☐	☐	☐
Acrostic	☐	☐	☐	☐	☐
Music	☐	☐	☐	☐	☐
Note organisation	☐	☐	☐	☐	☐
Keyword	☐	☐	☐	☐	☐
Model	☐	☐	☐	☐	☐

Part IV

17.1 On what subject(s) do you use the examples of mnemonics below. (You may leave an empty field or tick more than one).

- Biology ☐
- Chemistry ☐
- Physics ☐

- Mathematics ☐
- None ☐
- Any other

Specify ……………………………………………………………………………………..

17.2 What is the reason for using mnemonic device in chemistry

- The instructor of the subject uses it ☐
- The learning material requires rote transmission (“chewing”) ☐
- These are a lot learning material to study ☐
- My peers/class mates use them ☐
- The learning material is complicated to understand ☐

17.3 In which areas in chemistry do you apply mnemonic devices (You may tick more than one)

Practicals/Experiment ☐

Theory ☐

None ☐

17.4 To what extent are mnemonics effective in helping you to remember learning mate

	1	2	3	4	5		
Forgets learning material	☐	☐	☐	☐	☐	☐	Helps to remember

Part V

18.1 Gender

Female ☐

Male ☐

18.2 Form: …………………………..

Class: …………………………

18.3 Age: …………………….. years

18.4 Status of student

Day ☐

Boarder ☐

18.5 Index Number ……………………………………………..

EXPERIMENTAL GROUP ONE ONLY

17.5.1 Were you provided with two different mnemonics (acronyms) to memorise the precipitation of the cations with NaOH and NH_3 solutions?

Yes ☐

No ☐

17.5.2 Did you memorise both mnemonics given?

Yes ☐

No ☐

17.5.3 Did the acronym you used for the cations help you to remember the precipitation better than the other?

Yes ☐

No ☐

17.5.4 State your reason(s) for memorising both mnemonics or just one mnemonic.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

17.5.5 State the mnemonic you used to memorise the cation precipitation with $NH_{3(aq)}$ and NaOH

…………………………………………………………………………………………

17.5.6 State the other acronym for the cations with NaOH and $NH_{3(aq)}$ that you did not use

…………………………………………………………………………………………

Appendix D
Pre-tests and post-tests
Standardised Achievement Test

Instructions: No form of communication is allowed between students during this test. Do not lend or borrow pen, pencil, calculator, eraser, ruler, paper or any other material during the test.

Attempt all questions in Section A and B on the answer booklet provided..

Time: 45 minutes.

SECTION A

Part I

Tick the appropriate box indicating True or False.

1. You are given the following ions Zn^{2+}, Al^{3+}, Cu^{2+}, Fe^{2+}, Fe^{3+}, Ca^{2+}, Pb^{2+}, NH^{4+}, Na^{+}, SO_4^{2-}, NO_3^{-}, CO_3^{2-}, SO_3^{2-}, Cl^{-}, O^{2-} and HCO_3^{-}. [1 mark]

   i) Cations required by WAEC for qualitative analysis in WASSCE examinations are

Zn^{2+}, Al^{3+}, Ca^{2+}, Pb^{2+}, Cu^{2+}, Fe^{2+}, Fe^{3+} and NH_4^{+} only. [1 mark]

True ☐

False ☐

   ii) Anions to be identified during qualitative analysis according to WAEC requirement are SO_4^{2-}, NO_3^{-}, CO_3^{-}, SO_3^{2-}, Cl^{-}, HCO_3^{-}, S^{2-}.
   [1 mark]

True ☐

False ☐

   iii) The only anions from the WAEC required list which evolve a gas with HCl/HNO_3 are SO_3^{2-} and CO_3^{2-}. [1 mark]

True ☐

False ☐

2. $CaCO_3$ is insoluble but $CaHCO_3$ is soluble in water. [1 mark]

True ☐

False ☐

3. $(NH_4)_2\ CO_3$ and H_2CO_3 are soluble though carbonates are generally insoluble. [1 mark]

True ☐

False ☐

4. Generally, oxides and hydroxides are soluble except those of alkalis [1 mark]

True ☐

False ☐

5. Which of the following reactions will occur or not occur?

- $AgNO_{3(aq)} + Na_2SO_{4(aq)} \longrightarrow NaNO_{3(aq)} + AgSO_{4(s)}$ [1 mark]

True ☐

Fal se ☐

- $CaCl_2(aq) + Na_2SO_4(aq) \longrightarrow CaSO_4(s) + NaCl$ [1 mark]

True ☐

False ☐

- $AgNO_{3(aq)} + NH_4Cl_{(aq)} \longrightarrow AgCl_{(s)} + NH_4NO_{3(aq)}$ [1 mark]

True ☐

False ☐

- $Pb(NO_3)_{2(aq)} + KI_{(aq)} \longrightarrow PbI_{(s)} + KNO_{3(aq)}$ [1 mark]

True ☐

False ☐

6. All SO_3^{2-} are insoluble with no exceptions [1 mark]

True ☐

False ☐

7. All CO_3^{2-} are insoluble except those of Na^+, K^+, NH_4^+ [1 mark]

True ☐

False ☐

8. AgCl is insoluble in water [1 mark]

True ☐

False ☐

9. $PbCl_2$ precipitate forms when $Pb(NO_3)_2$ and HCl are mixed [1 mark]

True ☐

False ☐

10. Which of the following pairs of aqueous compounds would react to give a precipitate [1 mark]

True ☐

False ☐

11. Fe^{2+}, Fe^{3+}, Cu^{2+} are coloured cations which form insoluble gelatinous precipitates even in excess $NH_{3(aq)}$ [1 mark]

True ☐

False ☐

12. White chalky precipitate forms when only Pb^{2+} mixes with aqueous NaOH [1 mark]

True ☐

False ☐

Part II

Circle the best answer

13. Which of the following salts are arranged in increasing order of precipitation in

a. $Na_2SO_4 < AgSO_4 < CaSO_4$
b. $AgSO_4 < Na_2SO_4 < CaSO_4$
c. $Na_2SO_4 > AgSO_4 > CaSO_4$
d. $AgSO_4 > Na_2SO_4 > CaSO_4$ [1 mark]

14. H_2S gas could turn A. $Pb(NO_3)_2$ paper black

B. Acidified $KMnO_4$ solution green
C. Acidified $K_2Cr_2O_7$ paper colourless
D. $Fe(NO_3)_2$ solution green [1 mark]

15. All the following pairs of solutions will form precipitate when mixed except

a. $CaCl_2 + H_2SO_4$
b. $NH_4Cl + NaOH$
c. $Pb(NO_3)_2 + HCl$
d. $ZnSO_4 + BaCl_2$ [1 mark]

SECTION B

16. Match the following sulphide precipitates to the correct colours [1x8 marks]

Sulphide	Colour of precipitate
ZnS	Yellow
Al_2S_3	White
$(NH_4)_2S$	No visible reaction
PbS	Black
CaS	Black
Fe_2S_3	No visible reaction
FeS	Green
CuS	Black

17. The following salts are soluble in water: $Fe(NO_3)_2$, K_2CO_3, $ZnCl_2$, $NaNO_3$, $CuCl_2$. In each of the following cases, select <u>one</u> salt whose aqueous solution

i) Gives a white gelatinous precipitate with $BaCl_2$.

ii) Gives white gelatinous precipitate on adding $NaOH_{(aq)}$.

iii) Gives no visible reaction if added in turns to a solution of each of the other four.

[1x3mark]

18. State the formula of the precipitate formed when aqueous solutions of the following pairs of compound are mixed

[1x3mark]

i) $AgNO_3$ and $MgCl_2$

ii) $Pb(NO_3)_2$ and Na_2CO_3

iii) $ZnSO_4$ and $BaCl_2$

19. A, B, C and D are aqueous solutions of $Zn(NO_3)_2$, $Pb(NO_3)_2$, Na_2CO_3 and HCl but not necessarily in that order.

The solutions are added to one another and the observations made are recorded in the table below. Study the table carefully:

Solution	A	B	C	D
A		White precipitate	Effervescence of colourless gas	White precipitate
B	White precipitate		White precipitate	No visible reaction
C	Effervescence of colourless gas	White precipitate		No visible reaction
D	White precipitate	No visible reaction	No visible reaction	

i) Write all the equations for evolution of gas and white precipitate. [5marks]

ii) Identify the content of A, B, C and D. [6marks]

Appendix E

Cronbach reliability for questionnaire

Case Processing Summary

		N	%
Cases	Valid	6	100.0
	Excluded[a]	0	.0
	Total	6	100.0

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

Reliability Statistics

Cronbach's Alpha	N of Items
.844	6

Appendix F1

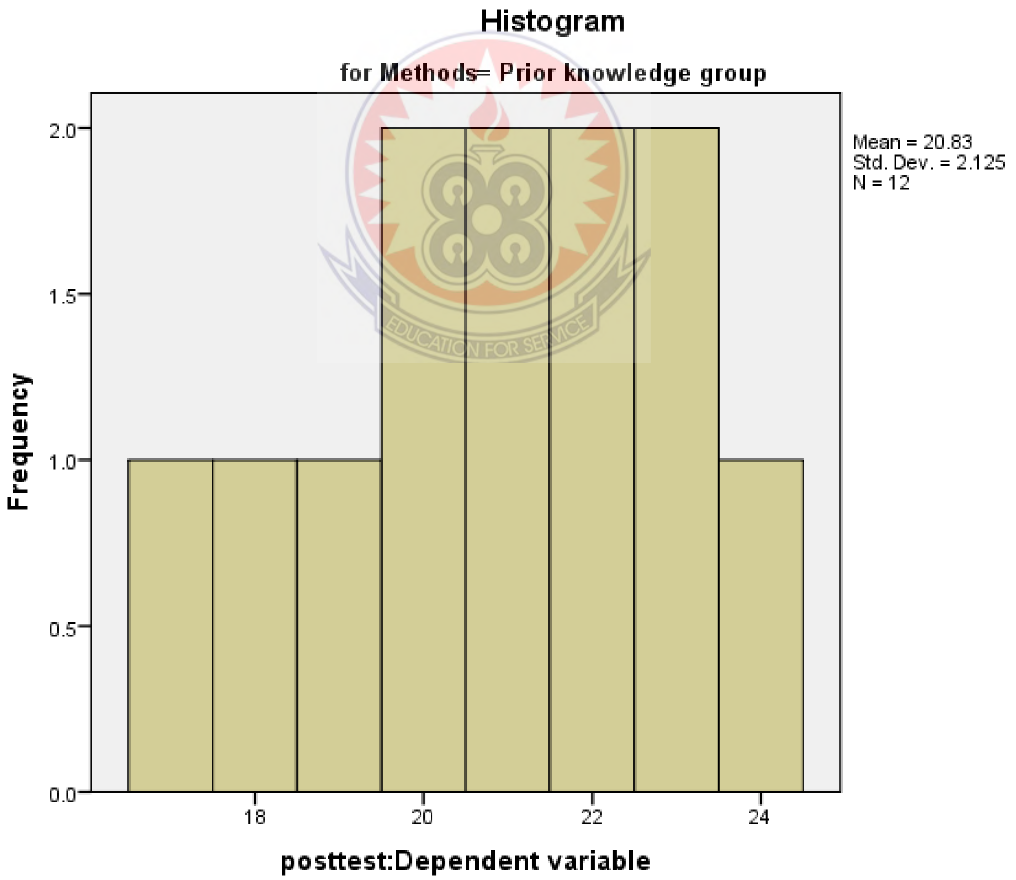
Tests of Normality

	methods of teaching	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	Df	Sig.
posttest:Dependent variable	Lecture method group	.153	12	.200*	.979	12	.980
	Prior knowledge group	.125	12	.200*	.969	12	.895
	Mnemonic group	.145	12	.200*	.970	12	.916

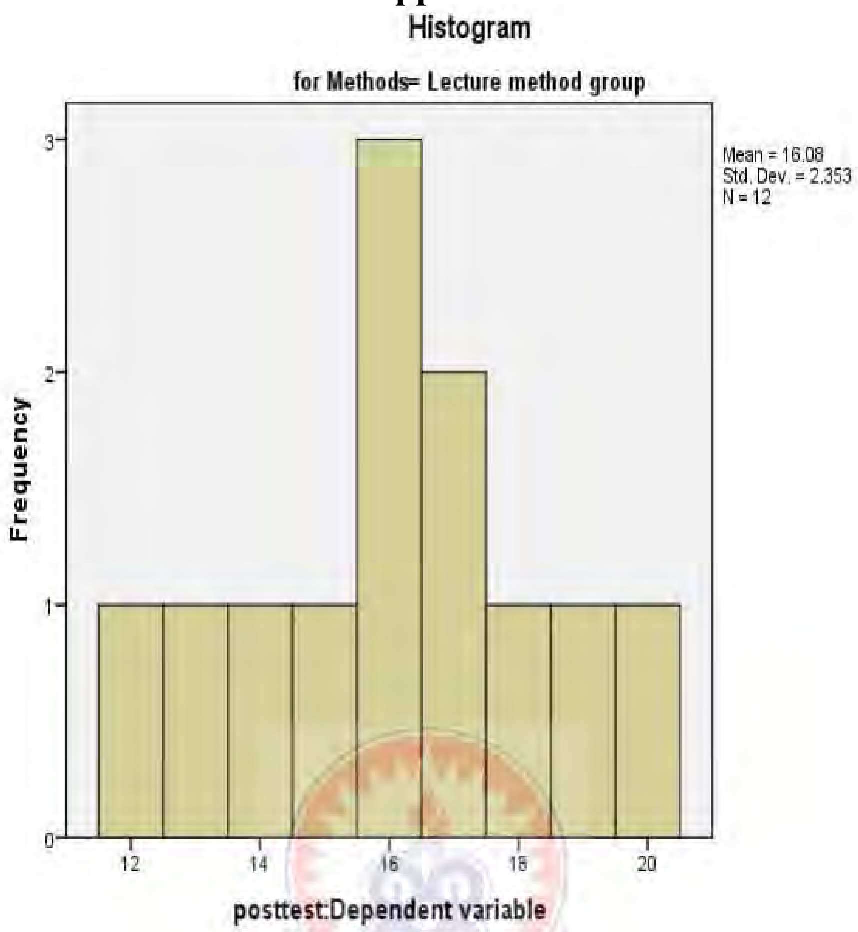
*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

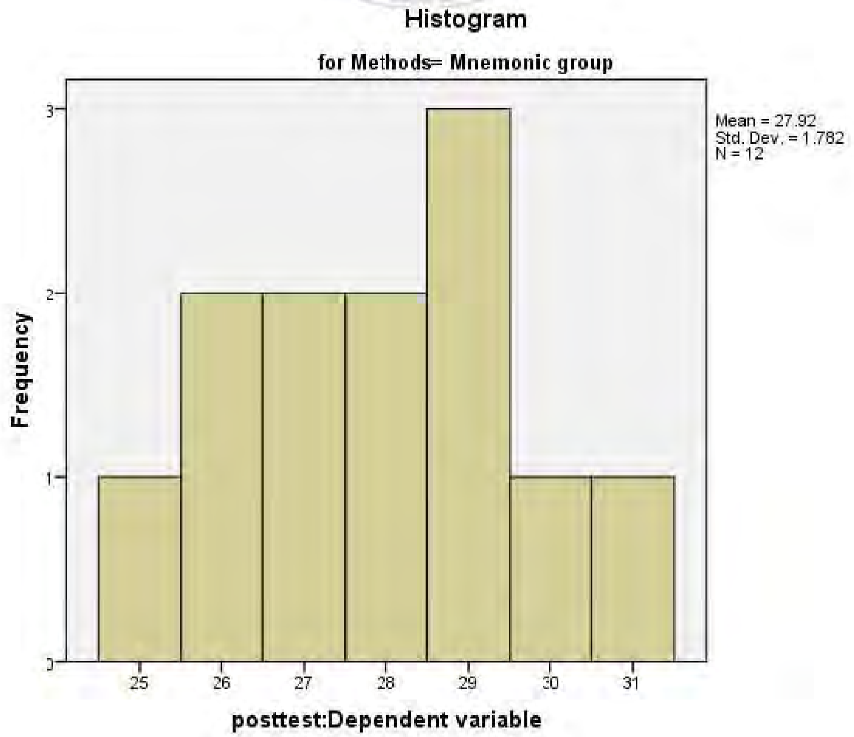
Appendix F2



Appendix F3



Appendix F4



Appendix G

Levene's Test of Equality of Error Variances[a]

Dependent Variable: posttest:Dependent variable

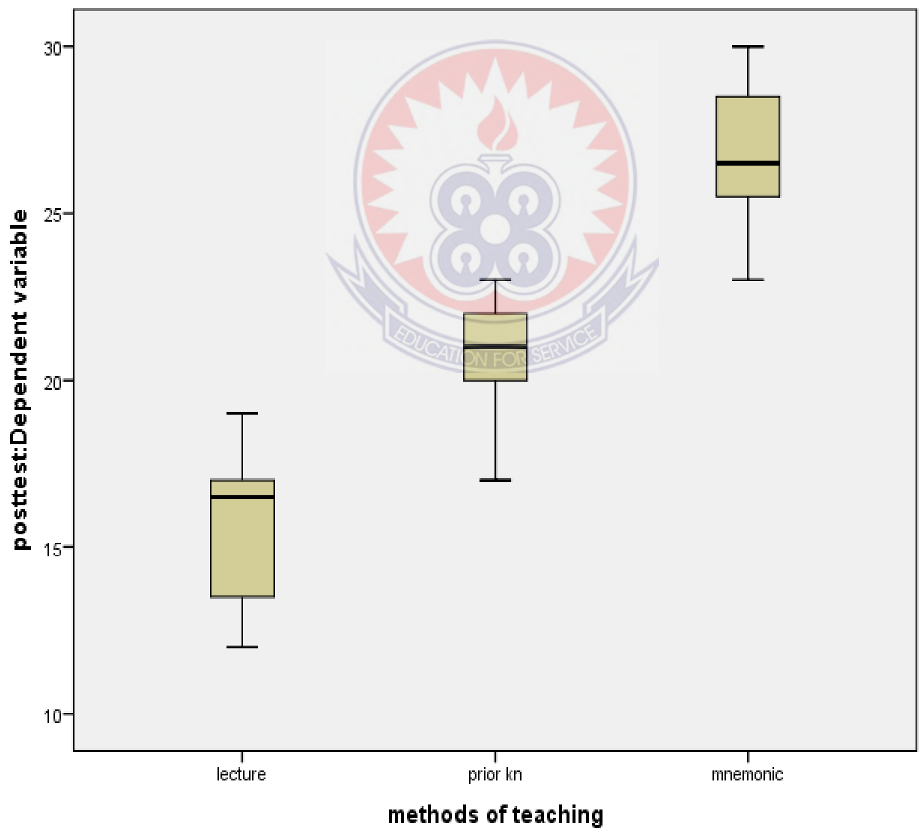
F	df1	df2	Sig.
1.126	2	33	.337

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Methods * Pretest

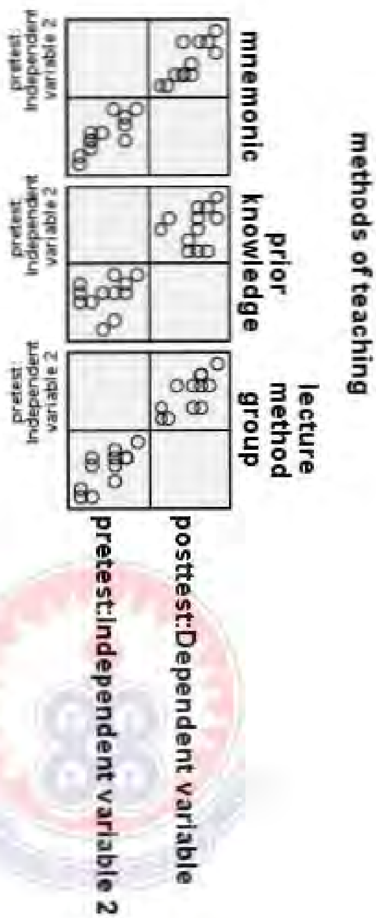
Appendix H

Q-Q Plots showing outliers



Appendix I

Q-Q Plots showing correlation between dependent and independent variables.



Appendix J

Descriptive Statistics

	N	Range	Mean	Std. Deviation	Variance
Age of students	36	4	17.33	.894	.800
Opting out of ion identification if given opportunity	36	2	1.47	.609	.371
Register for ion identification	36	1	1.44	.504	.254
Cation and anion idetification is difficult	36	1	1.89	.319	.102
Learning strategies	36	6	4.64	1.726	2.980
knowledge of mnemonic	36	5	1.58	.937	.879
heard about mnemonics	36	1	1.28	.454	.206
can explain mnemonics	36	1	1.39	.494	.244
usage of acronym	36	4	3.81	1.305	1.704
usage of acrostic	36	4	2.97	1.464	2.142
usage of music	36	4	2.86	1.355	1.837
usage of note organisation	36	4	2.75	1.273	1.621
usage of keyword	36	4	2.61	1.248	1.559
usage of model	36	4	2.28	1.446	2.092
areas in chemistry for usage of mnemonic	36	1	1.89	.319	.102
reason for using mnemonic	36	3	1.78	.929	.863
how is mnemonic effective	36	3.00	5.3611	.86694	.752
comon mnemonic known by students	1	0	3.00	.	.
Valid N (listwise)	1				

Appendix K

knowledge of mnemonic

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	20	55.6	55.6	55.6
	no	16	44.4	44.4	100.0
	Total	36	100.0	100.0	

Appendix L

areas in chemistry for usage of mnemonic

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	does not include practicals	4	11.1	11.1	11.1
	includes practicals	32	88.9	88.9	100.0
	Total	36	100.0	100.0	

Appendix M

reason for using mnemonic

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	because of nature of learning material	20	55.6	55.6	55.6
	teacher and/or student use mnemonics	7	19.4	19.4	75.0
	both teacher and tudents use them and because of the nature of material	9	25.0	25.0	100.0
	Total	36	100.0	100.0	

Appendix N

Central tendencies of types mnemonics

		usage of acronym	usage of acrostic	usage of music	usage of note organisation	usage of keyword	usage of model
N	Valid	36	36	36	36	36	36
	Missing	0	0	0	0	0	0
Mean		3.81	2.97	2.86	2.75	2.61	2.28
Mode		5	3	3	2	3	1
Std. Deviation		1.305	1.464	1.355	1.273	1.248	1.446

Appendix O

Tests of Between-Subjects Effects

Dependent Variable: posttest:Dependent variable

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	849.925[a]	3	283.308	51.857	.000	.829
Intercept	325.035	1	325.035	59.495	.000	.650
Pretest	119.759	1	119.759	21.921	.000	.407
Methods	736.293	2	368.147	67.386	.000	.808
Error	174.825	32	5.463			
Total	17795.000	36				
Corrected Total	1024.750	35				

Appendix P1

effectiveness of option to choose mnemonic

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	effective	12	100.0	100.0	100.0

Appendix P2

choice to select mnemonic from two

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	12	100.0	100.0	100.0