AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

JUNIOR HIGH SCHOOL TEACHERS' CHALLENGES IN TEACHING WRITING AND NAMING BINARY COMPOUNDS AND THE EFFECT OF LOCALLY CONSTRUCTED MODEL KITS ON STUDENTS' PERFORMANCE AND RETENTION

ISSAH IDDRISU

APRIL, 2024

AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

JUNIOR HIGH SCHOOL TEACHERS' CHALLENGES IN TEACHING WRITING AND NAMING BINARY COMPOUNDS AND THE EFFECT OF LOCALLY CONSTRUCTED MODEL KITS ON STUDENTS' PERFORMANCE AND RETENTION

BY

ISSAH IDDRISU
(8211920020)

A thesis submitted to the School of Graduate Studies, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development in partial fulfillment of the requirements for the award of a Master of Philosophy degree in Science Education

APRIL, 2024

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Issah Iddrisu

Signature: …………………………………. Date: ……………………………

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah- Menka University of Skills Training and Entrepreneurial Development.

Prof. Kofi Sarpong (Principal Supervisor)

Signature: …………………………………. Date: ……………………………

Dr. Eric Appiah-Twumasi (Co-supervisor)

Signature: …………………………………. Date: ……………………………

ABSTRACT

In this study a multiple research approach was employed to investigate the challenges encountered by Junior High School (JHS) integrated science teachers in the study of writing and naming of binary compounds in Sekyere Central District. Subsequently, Valency Arm and Y-shaped Model Kits were made from locally available materials, and their effectiveness was evaluated in terms of performance and retention. It was discovered that the experimental group, which received instruction using the model kits, performed better and retained the concepts and principles learned compared to the control group after using the Model Kits in the teaching and learning process of writing and naming binary compounds. These enhanced learning outcomes were noticeable in the three successive tests (Pillai's Trace = 0.440, $F_{(2, 133)} = 52.319$, $p = 0.000$, partial eta squared = 0.440). Following the intervention, 12 randomly selected participants from the experimental group participated in a semi-structured interview. According to the JHS students interviewed in this study, using the model kits to teach writing and naming of binary compounds has several advantages. Four of these advantages were discovered, which include a better understanding of the principles, an enhanced attitude towards writing and naming binary compounds, better retention of principles and concepts, and active participation and interest in lessons. The findings suggest that in the event that the original models or resources are not available, junior high school integrated science teachers in the Sekyere Central District who wish to support successful teaching and learning of writing and naming binary compounds may think about using these Model Kits.

ACKNOWLEDGMENTS

I could have not been able to finish this work without the Lord Jesus Christ and the support, and dedication of my supervisors, family, friends, and colleagues, to whom I am most grateful, and who deserve my appreciation. Most importantly, my sincere appreciation goes to my supervisors, Prof Kofi Sarpong and Dr. Eric Appiah-Twumasi for their outstanding support, useful remarks, suggestions, time, money, motivation and encouragement I got during the period of this work, submission of the manuscript and publications of this work.

Furthermore, my profound gratitude goes to Dr. Opoku Gyamfi, Dr Charles Amoah Adjei and Sheikibu Mohammed for their assistance and comments.

My special thanks to my father, Mamah Iddrisu and mother, Mary Kporkenu who gave me extraordinary support and guidance in adverse times during this study. Also, to my brother and colleague, Mr. Kenneth Darko Ateko for his support.

Finally, I am most grateful to Pastor (Dr) W. F. Kumuyi, Pastor Francis Fosu and Pastor Oppong Thomas for their spiritual help throughout this study and other persons who contributed to the successful completion of the study.

DEDICATION

This work is dedicated to my father, Mamah Iddrisu, my mother, Mary Kporkenu and my siblings: Delphine Kporkenu, Abraham Kporkenu and Saviour Kporkenu

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter talks about the study's background and the problem statement. The main objective, the specific objectives of the study and the research questions are also included in this chapter. This chapter also emphasizes the significance of the study, its delimitations, and its limitations. Abbreviations, operational definitions of terms used in the study, and the study's organizational structure are all captured at the end of this chapter.

1.1 Background to the Study

Any country's growth in science and technology can be facilitated by its commitment to science education. This is due to the fact that science and technology has, and is increasingly transforming the global world in which we thrive, because science and technology has become the backbone of development in recent times. This therefore implies that it is only when countries prioritize science as a means of rescuing and addressing men's needs can the world's persistent problems be lessened (Coffie et al., 2020). As a result, the study of science should not be taken for granted in all levels of education. Hence, according to Vilia et al. (2017) teachers and policymakers are concentrating on making sure that science education continues to assist in educating future people who are scientifically literate and interested in applying science in their daily lives, enabling societies to confront and overcome the new difficulties they are facing.

Our drive to comprehend the earth and the larger cosmos around us has led to the collaborative and creative human endeavor known as science. By studying the Common Core Science Program from basic 7 to basic 9 (junior high school) students can expand on their knowledge from lower basic school level (primary level) and deepen their understanding of science. Every day, science and its products surround us. This is called technology. As a result, scientific data provides the foundation for all government policy decisions that have an impact on our daily lives. Numerous scientific principles are shown by the incredibly complex natural world that we live in. People must be scientifically literate in order to comprehend problems and lead successful lives as they grow up in a world that is becoming more and more technologically and scientifically advanced. Science, technology, and innovation are the cornerstones of a nation's economic, political, social, and physical progress. Therefore, science is an endless creative process that advances knowledge and understanding. It is made up of a corpus of knowledge that aims to analyze and explain experiences and occurrences. Science has transformed our lives and is essential to Ghana's progress in the future (Ministry of Education, 2020).

The study of science in the Junior High School (JHS), according to the Ministry of Education (2020) comprises the foundational knowledge in Biology, Chemistry, Physics and Agriculture which is termed as integrated science. One of the major concepts studied in JHS integrated science is nomenclature of binary compounds. This concept, according to the Ministry of Education (2020) is categorised under the chemistry discipline of the JHS integrated science. The study of the nomenclature of binary chemical compounds according to the Ministry of Education (2020) is studied in Basic 9 at the junior high school.

According to Hartshorn and Yerin (2019), in order to facilitate communication about chemical compounds, their structures, characteristics, and applications, nomenclature was introduced into the field of chemistry. This led to the creation of the International Union of Pure and Applied Chemistry (IUPAC) in 1919, an organization dedicated to providing chemistry with a universal language. The Ministry of Education (2020) states that being familiar with the nomenclature of binary compounds will help one grasp scientific concepts connected to writing and balancing chemical equations. It is critical to have a fundamental grasp of compounds and chemicals because it is vital to our safety. Taskin and Bernholt (2014) suggest that a lot of the chemicals we come into contact with on a daily basis have the potential to be quite reactive, so we need to manage them carefully. Chemistry thus makes it easier to comprehend and distinguish between chemical compounds that are safe and those that have the potential to be harmful.

However, junior high school students struggle to understand the concept and principles of nomenclature of binary compounds (WAEC, 2020; 2019; 2018; 2017), despite the above importance. The difficulties most students experience in responding to test questions on the IUPAC nomenclature of binary chemical compounds in the Basic Education Certificate Examination (BECE) has been highlighted by the WAEC Chief Examiner's Reports in Ghana on numerous occasions (WAEC, 2020; 2019; 2018; 2017). These reports suggest that most Ghanaian BECE "candidates have challenges with the IUPAC naming of inorganic binary compounds" and also "fail to give correct formulae for the compounds".

According to researchers (Nahimana et al., 2023; Essiam et al., 2023; Adu-Gyamfi et al., 2017; Samuel & Ikwuka, 2017), one major reason for the lack of understanding in the writing and naming of binary compounds is because some students consider the topic to be too abstract since little or no usage of teaching and learning materials are employed by teachers. As a result, Quansah et al. (2019) assert that, teachers force students to read textbooks while they are being taught the ideas theoretically, rather than having them engage in activities as recommended by the integrated science curriculum. In effect, students are denied the opportunity to actively construct the meanings of concepts and phenomena in order to take ownership of their learning, hence leading to lack of understanding of the principles and concepts taught.

Adu-Gyamfi et al. (2017) espouse that, it is quite challenging for science students to learn chemistry concepts at the microscopic and symbolic levels. They argue that, when Chemistry concept is represented and taught in shallow, students' understandings are impeded. As a result, the majority of students mistake chemical formulae as a mere combination of letters and numbers. This, they assert, is due to the fact that, understanding Chemistry concepts demand considerably more on using the senses because Chemistry concepts at the microscopic and symbolic levels are invisible and abstract in nature. The microscopic level, according to the authors, is concerned with the nature and arrangement, and motion of molecules used to explain the properties of compounds or natural events; while symbolic level deals with the representations of atoms, molecules, and compounds, such as chemical symbols, formulae, and structures. Since the idea of IUPAC nomenclature of compounds operates at the symbolic level, it may be claimed that most students find it difficult.

Teachers are crucial in implementing policies and deciding on the course of study and instruction in the classroom. According to Tondeur et al. (2017), in a classroom, a teacher observes and defines a teaching environment, forms opinions and decisions, and then implements those decisions and conclusions in the appropriate way. This means that, and as Wenglinsky (2002) suggests, how students are taught has a significant impact on their academic performance. That is, the instructional strategies teachers employ, alongside their beliefs in those instructional strategies have the potential to affect how and what the students learn.

This highlights the need for effective teaching methods integrated with appropriate instructional materials, such as model kits (Erlina et al., 2021), to make the teaching of writing and naming binary compounds more effective and reduce the abstract nature of the content. However, in developing countries like Ghana, model kits are expensive and not easily accessible. Therefore, in such situations, it is recommended to build models or prototype molecular kits from locally available materials within the environment (Nahimana et al., 2023; Quayson et al., 2022;). As a result, the Ministry of Education in Ghana recommends that when the original instructional materials for science teaching are not available, the use of improvised instructional materials can be considered (Ministry of Education, 2020).

Model kits play a crucial role in the teaching and learning of science by providing students with tangible, hands-on experiences that reinforce theoretical concepts (Lombardi et al., 2014). These kits, according to Lombardi et al. (2014), offer a dynamic way to engage students in scientific inquiry, allowing them to explore complex ideas in a concrete and interactive manner. Therefore, by assembling and manipulating models, students can develop a deeper understanding of scientific principles and concepts, such as in Chemistry and Biology. For example, in Chemistry, the representation of atomic structure using model by J. J Thomson (Nahimana et al., 2023). Similarly, in Biology, model kits can illustrate biological structures, such as cells, organs, and organisms, helping students visualize and comprehend the intricate workings of living organisms (Burgin et al., 2018; Feng et al., 2023).

Furthermore, model kits promote critical thinking and problem-solving skills as students encounter challenges and obstacles during the assembly process (Stull et al., 2016). By troubleshooting issues and making adjustments to their models, students learn to apply scientific principles in real-world contexts, fostering a deeper appreciation for the scientific method and inquiry-based learning. Moreover, Stull et al. (2016) furthered that model kits cater to diverse learning styles, allowing students to engage with material through visual, tactile, and kinesthetic modalities. This inclusivity promotes equity in the classroom by accommodating different learning preferences and abilities. Additionally, model kits encourage collaboration and teamwork as students work together to assemble and test their models, fostering a cooperative learning environment that mirrors real-world scientific research and innovation.

According to Ajayi (2017), retention influences academic performance. That is the ability for a student to perform well in Chemistry depends on how they recall the concepts taught in the Chemistry class. Retention in this context can be defined as having the information stored in long-term memory in such a way that it can be readily retrieved for future use (Divoll & Browning, 2010). Therefore, it can be said that a concept learned is not permanently preserved if a student cannot recall it after 24 hours.

Consequently, the material will never be remembered. Students' ability to recall facts and concepts depends on how they learn the material (Ekenobi et al., 2016). In other words, how the information is presented to them through the teaching and learning process has importance in how students remember those concepts. This will make it easier for the brain to recognize new information as being crucial. This, therefore means that, the teaching method or activities students are taken through in the classroom have an impact on how students can retain learned concepts. As a result, it is up to the teacher to select the appropriate instructional methods and activities which will enable learners to better understand what they are taught in the classroom.

Therefore, according to Ekenobi et al. (2016), by employing hands-on activities using model kits that require students interact with materials and resources over time, will enable learners to retain concepts learned. Students taught Chemistry concepts through improvised model kits have been reported to retain concepts better than their colleagues taught through the conventional teaching method (Ogbeba & Ajayi, 2017) and a lot of knowledge is retained through concrete experience when hand-made model kits are used (Keshavarz, 2018). This is also supported by studies including those conducted by Lombardi et al. (2014), Horikoshi (2020), Obodo et al. (2020) who also found the use of model kits to significantly enhance learners' retention.

Another component of this study is the investigation of students' perceptions on the use the locally constructed model kits in the teaching and naming of binary compounds. This exploratory aspect of the study seeks to add insights that have been largely absent from the literature. According to Vitoria et al. (2018), the way students view a teaching approach greatly affects their interest and engagement in learning and class participation. Many studies have been conducted to investigate students' perceptions on the inclusion of model kits in their learning. Generally, students respond positively towards the use of model kits in the teaching and learning of science (Sarkodie &Adu-Gyamfi, 2015; Teng &Jingjing, 2023; Turner, 2019). As a result, in this study students' perceptions on the effectiveness the locally constructed model kits in nomenclature of binary compounds will be assessed. Against this background, the researcher sought to investigate the challenges JHS teachers encounter in teaching writing and naming of binary compounds, and to assess the effectiveness of locally constructed model kits in understanding and retaining writing and naming of binary compounds among junior high school students in the Sekyere Central District.

1.2 Statement of the Problem

According to Ministry of Education (2020), students' understanding in the writing and balancing of chemical equations and advanced study of the nomenclature of inorganic compounds in the SHS will be hindered if they fall short of understanding of writing and naming of binary chemical compounds. According to Hartshorn and Yerin (2019), another reason chemical nomenclature was introduced in the study of Chemistry was to facilitate communication about chemical compounds, including their structures, properties, and applications. For this reason, the International Union of Pure and Applied Chemistry (IUPAC) was founded in 1919 with the goal of creating a universal language for chemistry.

Even though the writing and naming of binary compound is fundamental and important to the study of chemical nomenclature (Zumdahl & Zumdahl, 2013). JHS students find it difficult to comprehend the principles in the writing and naming of binary chemical compounds. The WAEC Chief Examiner's Reports in Ghana have highlighted the challenges faced by most students when answering test questions on the IUPAC nomenclature of binary chemical compounds in the Basic Education Certificate Examination (BECE) on multiple occasions (WAEC, 2020; 2019; 2018; 2017). The reports suggest that the majority of Ghanaian BECE candidates "fail to give correct formulae for the compounds" and "have challenges with the IUPAC naming of binary chemical compounds."

This is because of the abstractness of the concepts and principles in writing and naming binary compounds (Adu-Gyamfi et al., 2017; Samuel & Ikwuka, 2017) due to little or no usage of teaching and learning materials (Hanson, 2017). This means that teachers should consider integrating the use of appropriate instructional materials in their instructional strategies which they select to convey meanings of concepts to students (Ministry of Education, 2020), which includes the use of model kits (Quayson et al., 2022). The use of model kits has been investigated by researchers to enhance students' understanding of concepts in other fields of study (Erlina et al., 2021; Gyasi et al., 2018; Quayson et al., 2022). To date, however, there has not been a thorough analysis of how junior high school students' learning outcomes and retention in the writing and naming of binary compounds can be affected by the use of locally made or improvised model kits. With a focus on binary compounds in the teaching and learning of Chemistry concepts in junior high school classrooms, the current study is significant in that it fills the evidence gap currently present on the impact of locally made Model Kits on chemistry learning.

1.3 Purpose of the Study

The purpose of this study was to assess challenges JHS teachers encounter in teaching writing and naming of binary compounds and the impact of locally constructed model kits on academic performance, retention, and perception in the teaching and learning of writing and naming of binary compounds.

1.4 Specific Objectives of the Study

The specific objectives of this study were to evaluate:

1. the challenges JHS integrated science teachers face in teaching writing and naming of binary compounds.
2. the effect of locally constructed Model Kit on JHS students' performances in writing and naming of binary compounds.
3. the effect of locally constructed Model Kit on JHS students' abilities to retain the concepts in the writing and naming of binary compounds.
4. how JHS students perceive the effectiveness of locally constructed Model Kit in the writing and naming of binary compounds.

1.5 Research Questions

The following are the research questions for the study:

1. What challenges do JHS integrated science teachers face in teaching writing and naming of binary compounds?
2. What is the effect of locally constructed model kits on JHS students' performances in writing and naming of binary compounds?
3. What is the effect of locally constructed Model Kit on JHS students' abilities to retain the concepts in the writing and naming of binary compounds?

4. What perception do JHS students have on the effectiveness of locally constructed model kit in the writing and naming of binary compounds?

1.6 Null Hypotheses

Research Questions 2 and 3 were formulated into null hypotheses and tested in the study:

H_{01}: There is no significant effect of locally constructed molecular model kit on JHS students' performances in writing and naming of binary compounds.

H_{02}: There is no significant effect of locally constructed model kit on JHS students' abilities to retain the concepts in the writing and naming of binary compounds.

1.7 Significance of the Study

This study will first of all, inform Integrated Science instructors in the Sekyere Central District about the need to maximize the use of student-centered teaching methods which can help improve learners' understanding of nomenclature of binary compounds. Moreover, the locally constructed Model Kits presented in this study could contribute to Integrated Science teaching in developing countries where model kits are expensive and difficult to access. They could also revive the interest of science teachers in such situations to adapt or adopt the developed Valency Arm and Y-Shaped Model Kits for their lessons.

1.8 Justification of the Study

The teaching and learning of writing and naming of binary compounds pose a lot of challenges to JHS students and integrated science teachers in Ghana, which presents a gap in literature. Literature provides studies where researchers have developed model kits to help students understand concepts better. However, much attention has not been drawn to the teaching and learning of writing and naming of binary compounds. This study therefore, intends to fill this gap in using locally constructed Model Kits to aid junior high school students' understanding and retention of writing and naming of binary compounds.

1.9 Delimitations of the Study

Firstly, the use of quasi-experimental design means that not all students within the Sekyere Central District participated in the study. Moreover, basic 9 junior high students were selected to participate in the study since writing and naming of binary compounds studied are among basic 9 students according to Ministry of Education (2020). Finally, more than one model kits were used as suggested (Kaumal & Wijayawardana,2017)

1.10 Limitations of the Study

The study's participants were not randomly assigned to experimental and control groups because intact classes were engaged, which made it necessary to use caution when extrapolating the study's conclusions. Also, the designed Valency Arm Model Kit has the drawback of being limited to the illustration of binary chemical formulas including elements with one, two, and four valencies. Comparably, it is also simple to demonstrate binary chemical formulae between elements with two and three valencies using the Y-shaped Model Kit. Consequently, as is the case with the Y-Shaped Model Kit limitation, the Y-Shaped Model Kit will be helpful in a circumstance where the Valency Arm Model Kit is limited.

1.11 Operational Definition of Terms

Academic Performance – the extent to which a student has attained his/her short-term educational goals, and is measured by a test, an assignment, a project or an examination.

Model Kits – unassembled collections of parts and components that, when put together, create a detailed replica of a particular object.

Retention – the ability of an individual to remember or recall information or experiences after a period of time.

1.12 Organization of the Study

The study is divided into five chapters, each of which focuses on a different area of the subject. The study's background, problem statement, purpose, objectives, research questions, significance, delimitations, limitations, and definition of words are all covered in chapter one. In chapter two, the literature pertinent to this subject is reviewed. This included reviews of conceptual, theoretical, and empirical studies. Research design, population, sampling technique, data collecting tools, data collection methods, data processing and analysis are all covered in the third chapter. The presentation of the results and a discussion of them are included in chapter 4. The overview of the study, the findings, the recommendations, and the ideas for additional research are all included in chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter presents a review of the literature that relates to this study. The review of the literature in this chapter were categorised as theoretical review, conceptual review, which talked about the various concepts that were related to this study, thus, the concept of hands-on activities and model kits, as well as advantages and challenges in using hands-on activities. Also captured in this chapter were the concepts of academic performance and retention, binary compounds and their nomenclature, as well as students' difficulties in nomenclature of binary compounds. All these concepts were conceptualized in the conceptual framework of the study. Additionally, the empirical review of this study was also highlighted in this chapter. The chapter ends with summary of the reviewed literature.

2.1 Theoretical Review of the Study

This study is underpinned by constructivism and Kolb's experiential learning theory.

2.1.1 Constructivism

According to Golder (2018), constructivist conceptions of learning have their historical roots in the works of Dewey, Bruner, Vygotsky, and Piaget. An important tenet of the constructivist theory focused on the importance of experience in ensuring that people learn more effectively through tasks. In other words, people derive knowledge and meaning from their experiences (Golder, 2018). Therefore, in this constructivist theory of learning, the implication is that the learner is seen as an active participant in the process of acquiring new knowledge. Also, Saif and Laszlo (2020) assert that constructivists hold that solving problems in the real world may be effectively done in a collaborative work environment as a tool to connect prior learning and experience with the present while also supporting the social creation of knowledge. Thus, while constructivism's core principles support the learning preferences and traits of adult learners, it lacks a clearly defined implementation plan.

According to Piaget (1976), While cognitive development is a mental process that is attained through experimentation and observation, Vygotsky (1978) saw cognitive development as a social process that is attained through interactions with other educated members of the community. As a result, Piaget's work is referred to as "cognitive constructivism" and that his theory comprises two major elements, "ages" and "stages" (Golder, 2018). These components aid in forecasting what students can and cannot comprehend at various ages and phases. According to Piaget's theory of cognitive development, humans must "construct" their own knowledge "individually" through past experiences in order to be able to form mental images. This means that people are not simply passive recipients of information and cannot automatically comprehend and apply it. To Piaget (1976), each student in a classroom has unique experiences and cognitive structures, called schemas, that are based on those earlier experiences. These schemas are created as a result of assimilation and accommodation during the course of four developmental phases in an effort to find "equilibration" or balance (Powell & Kalina, 2009).

Piaget (1976) asserts that as learners move from one developmental stage to the next, they experience "disequilibrium," which is characterized by cognitive conflict, mental instability, or an inability to make sense of the information they are being given. "Disequilibrium" is the uncomfortable state that results from having to modify one's preexisting schema in order to settle a dispute and feel more at ease. Assimilation is when children bring in new knowledge to their own schemas and accommodation is when children have to change their schemas to incorporate the new information or knowledge (Powell & Kalina, 2009). When learning, this adjusting process takes place as one processes new knowledge to make it fit into existing memories. This process needs to be facilitated in the classroom by the teachers.

According to Piaget, a child passes through four phases of development: the preoperational stage (two to seven years old), the concrete operational stage (seven to eleven years old), the formal operational stage (eleven years old to adulthood), and the sensorimotor stage (zero to two years old). As children get older in Piaget's sensorimotor stage, they start to learn about their surroundings through their own senses, physical activity, and eventually language. The next preoperational stage of development sees children gaining linguistic skills but still unable to understand what other people are thinking. According to Piaget, children go through two sub-stages in this stage: "symbolic function," where they start to recognize pictures or symbols for various objects in their immediate environment, and "intuitive thought," where they start asking a variety of questions about everything in their environment (Powell & Kalina, 2009). Children start to replace intuitive cognition with their own logical reasoning within Piaget's concrete operational stage, which is a crucial developmental stage in the brain related to logical development. From childhood until maturity, children in Piaget's formal operational stage will begin to address issues with higher order thinking or abstract concepts.

According to Piaget's (1976) theory, equilibration, assimilation, and accommodation are all related to children's capacity to independently and cognitively generate new knowledge within developmental stages and resolve conflicts. Understanding that every student experiences this process at a unique pace aids the teacher in promoting constructivist learning. As a result, all educators have an obligation to comprehend these stages and work within the logical and intellectual capabilities of their students. Therefore, in a constructivist setting, the teacher's main responsibility is to establish the conditions, present the problems, and provide the encouragement needed to inspire students to generate their own knowledge by firsthand experience.

The "social constructivism" of Vygotsky's work, which emphasizes the social context of learning, is very similar to Piaget's theories of how knowledge is formed and how people learn. According to Vygotsky, social interactions-such as those between students and teachers—are crucial components of learning (Albadi, 2019). Also, the social constructivists do not distinguish between culture and the mind (Powell & Kalina, 2009). Thus, for them, education is an interaction among the learner, the culture, and the people in the society. To Vygotsky (1978), children are born with the rudiments of cognitive development. After being honed through social interaction, these foundational abilities eventually lead to the development of more intricate brain functions. For example, a child is born with the basic ability to remember things. The way a youngster remembers changes as they interact with others and their environment. A child studying in a flashcard-heavy setting, for instance, will use similar repetition techniques to help them remember things.

In such a setting, it is expected that students will take an active role in discussion, reflection, adaptation, and evaluation as well as in engaging with their peers and the classroom teacher through social contact. These social elements include things like language, culture, customs, tangible items, peer and interpersonal contact, tools, and symbols. Their independent dialogue with one another and with their community produces a dynamic learning environment for effective and lifelong learning (Saif & Laszlo, 2020).

Vygotsky believed that with the help of a more experienced teacher, children might study at a much higher level (Vygotsky, 1978). Learner competence and aptitude for learning are fostered by the guidance and support provided by most professional peers as well as specialists. Here comes a prominent concept used by Vygotsky (1978) known as the "Zone of Proximal Development (ZPD)", which distinguishes between actual (development) and potential (learning) levels of development. Actual level is achieved independently by the learner, and it refers to the prior knowledge or abilities of the learner, whereas the potential levels, refers to what the learner can do or become, which is obtained by the guidance of an adult (Taber, 2011). One major method the teacher can employ in this ZPD is scaffolding.

The idea behind scaffolding is to give a student a task that is within the ZPD but currently outside of their area of expertise. Then, through modeling, advice, suggestions, and other forms of help, the learner can do the assignment with assistance (Taber, 2011). According to Vygotsky's theory, what is accomplished initially on an interpersonal level might integrate into the Zone of Actual Development (ZAD) and become internalized, enabling subsequent achievement of goals without assistance. As the student masters the work, the teacher's duty should be to provide help and then progressively reduce it until the ZAD and the ZPD surrounding it have changed (Taber, 2011). Here, Vygotsky promotes small group formation among students, using hands-on activities to construct their own knowledge. By forming groups, students with varying ability levels can learn from those who have mastered a particular skill set (Akpan et al., 2020; Applefield et al., 2001).

Vygotsky's theory places more emphasis on a teacher as facilitator of learning through social interaction in teaching, while Piaget's theory places more emphasis on the role of a teacher as a facilitator by providing a support to the learner to explore and the discovery of knowledge. Active participation, problem-based learning, inquiry-based learning, and teamwork are characteristics of constructivist learning activities. In addition to imparting knowledge, a teacher's job is to also act as a co-learner by encouraging students to question, challenge, and formulate their own ideas, opinions, and conclusions. This involves leading, facilitating, coaching, provocation, and co-exploring in ways that enable students to participate in critical and creative thinking, analysis, and synthesis of ideas during the learning process (Albadi, 2019).

2.1.2 Kolb's Experiential Learning Theory

The Experiential Learning Theory, as Healey and Jenkins (2000) acknowledged, is heavily advocated by David Kolb. The works of Dewey, Lewin, and Piaget on experience learning are the foundation of Experiential Learning Theory (ELT). This means that in contrast to behavioral learning theories, which do not acknowledge the relevance of awareness or subjective experience in the learning process, and cognitive learning theories, which prioritize cognition over emotion, experience is a key component of ELT (McCarthy, 2016). Therefore, as highlighted by Kolb et al. (1999) the term "Experiential Learning" is used in the theory to stress the crucial part that experience plays in the learning process. In view of this, Kolb et al. (1999) define learning as the process through which knowledge is formed by transforming experience. That is, understanding and modifying experience work together to produce knowledge.

The theory, as Healey and Jenkins (2000) expounded, suggests a method for organizing and sequencing the curriculum and, in particular, shows how a course may be presented to enhance student’ learning. Inferring Kolb's four stages of learning—experience, reflect, generalize, and test—it suggests that learning is cyclical and comprises these four phases (Figure 1):

1. Concrete Experience (CE): feeling
2. Reflective Observation (RO): watching
3. Abstract Conceptualization (AC): thinking
4. Active Experimentation (AE): doing

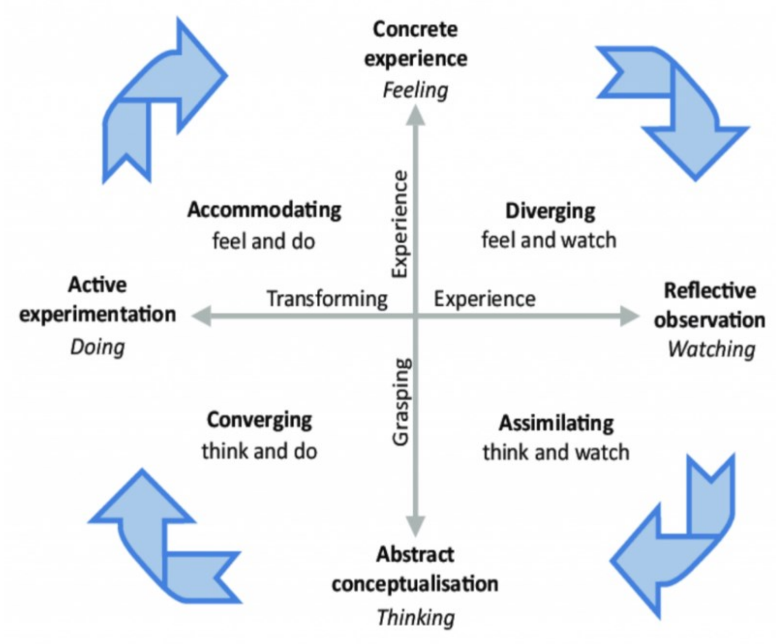


Figure 1: The Experiential Learning Cycle and Basic Learning Styles (Kolb et al., 1999)

As already stated, knowledge results from the combination of grasping and transforming experience (Kolb et al., 1999). Some students learn through "experiencing the concrete", palpable, felt aspects of the world, depending on their senses and immersing themselves in actual reality. Others prefer to think about, analyze, or plan in detail rather than relying solely on feeling to receive, understand, or retain new information. This process is known as "abstract conceptualization" or symbolic representation. Some of us also like to go right in and get things done, while others would rather watch others closely who are engaged in the activity and think back on what transpires. The doers choose "active experimentation", whereas the observers favor "reflective observation" (Kolb et al., 1999). The stages are briefly explained as follows:

***Concrete Experience* (CE):** The foundation for the learning process is provided by this stage. Individuals acquire lessons through adaptation and open-mindedness rather than by approaching a scenario or problem in a methodical way. This is the stage where the learner is actively experiencing an activity. According to the theory, every experience must begin with something new to us or a repetition of something that has already happened to us (Akella, 2010). Kolb believed that the secret to learning is engagement. It is not enough for pupils to read about it or observe it in action. For learners to acquire new information, they must actively engage in the task (McCarthy, 2016).

***Reflective Observation* (RO):** This step entails thinking back on the experience and making a note of anything new that was encountered. During this phase, students reflect on their experiences and explain how and why they occurred. They consider what they have experienced, focus on it, and critically evaluate it. In other words, the learner is actively thinking back on their experience at this point (Akella, 2010). McCarthy (2016) adds that at this stage of the learning cycle, the learner has the chance to ask questions and share the experience with others. Communication is essential now because it helps the student see discrepancies between what they have learned and what they have really experienced. A comprehensive analysis of the events that occurred is also made possible by a rich vocabulary.

***Abstract Conceptualization* (AC):** In this phase, the theory or subjective concept is connected to the observations and reflections made in the RO stage. Students understand events and challenges using logic and concepts rather than emotions. In this case, the student is either given a theory or model of what needs to be seen, or they are asked to conceptualize one. At this stage, novel concepts are created. For instance, when something unexpected occurs, they attempt to determine why (Akella, 2010).

Active experimentation **(AE):** In the last phase, students apply fresh concepts to various circumstances. Once again, students participate in an activity, but this time, they attempt to apply what they have learned to novel circumstances. They possess the ability to predict results, assess assignments, and make plans for future applications of newly acquired knowledge. Allowing students to apply what they have learned and show how it pertains to their daily lives will help ensure that the information is retained in the future (Akella, 2010).

Generally speaking, a learner goes through these four stages of learning, conceptualised in a cycle, as shown in figure 1, that starts with a real experience and ends with he/she actively experimenting with the new information. The cycle is typically repeated numerous times by learners during the course of their particular learning cycles, and learning occurs when all four stages have been successfully completed. Through this, a learner converts experience into knowledge, action, reflection, and modification (Akella, 2010). The input received from the learning cycle is then used to inform future actions and the assessment of their effects.

After having perceived the experience, the students must alter it in order to understand it. Here, as stated by Healey and Jenkins (2000), people's preferences for doing (active exploration) and watching (reflective observation) vary. Therefore, Kolb suggests that students may use various learning styles depending on the circumstances. As a result, four learning styles that each corresponds to a different approach to problem-solving are identified by Kolb (Kolb et al., 1999). These styles include "divergers, "assimilators", "convergers" and "accommodators".

"Divergers" favor knowledge gained via hands-on experience and critical observation. They have various points of view about events. To come up with fresh, original ideas, they hold brainstorming sessions. "Assimilators" value contemplative observation and abstract conceptualization. Assimilators like abstract tasks like coming up with action problems to address issues but are not interested in really putting them into practice. "Convergers" learn through active exploration and abstract conception. Their expertise is in the use of ideas in real-world situations. They heavily rely on speculative deductive reasoning. "Accommodators" excel at hands-on learning and active experimenting. They are capable of carrying out experiments and plans, as well as quickly changing conditions (Akella, 2010; Healey & Jenkins, 2000). The learning style chosen by an individual is a reflection of their abilities, environment, and learning background. If the subject matter is delivered to learners in a way that matches their preferred learning style, they will learn the material more effectively.

By implication, Kolb's philosophy is centered on experiences since Kolb viewed them as a necessary step in the process of changing or transforming anything. Merely memorizing or recalling concepts cannot be used to gauge learning because there is no gain for the learner. According to Kolb's approach, learning can only be characterized as something that is produced as a result of the experience. According to the theory, learners can participate in hands-on activities or other group activities and play their assigned role; thanks to concrete experiences. The ensuing discussion that follows this performance gives the students the opportunity to analyze their experience, come to conclusions, and choose how they will behave going forward. Following the debriefing, the learner can abstract the information from his/her observations and try out new behaviors that he/she can apply to subsequent tangible experiences.

2.2 Conceptual Framework of the Study

This study, which is situated within the context of hands-on activities and improvisation, is influenced by the constructivism and Kolb's experiential learning theory. The philosophical underpinnings of these theories suggest that learners become active participants, trying to find meanings of concepts on their own during the learning process. Through that, their understanding of the concept matter will be enhanced. Since concepts are learned practically, there is a less chance of students forgetting information stored. Consequently, students will retain concepts when there is a need to use information in the future. Based on these theories, variables in this study were conceptualized as depicted in Figure 2.

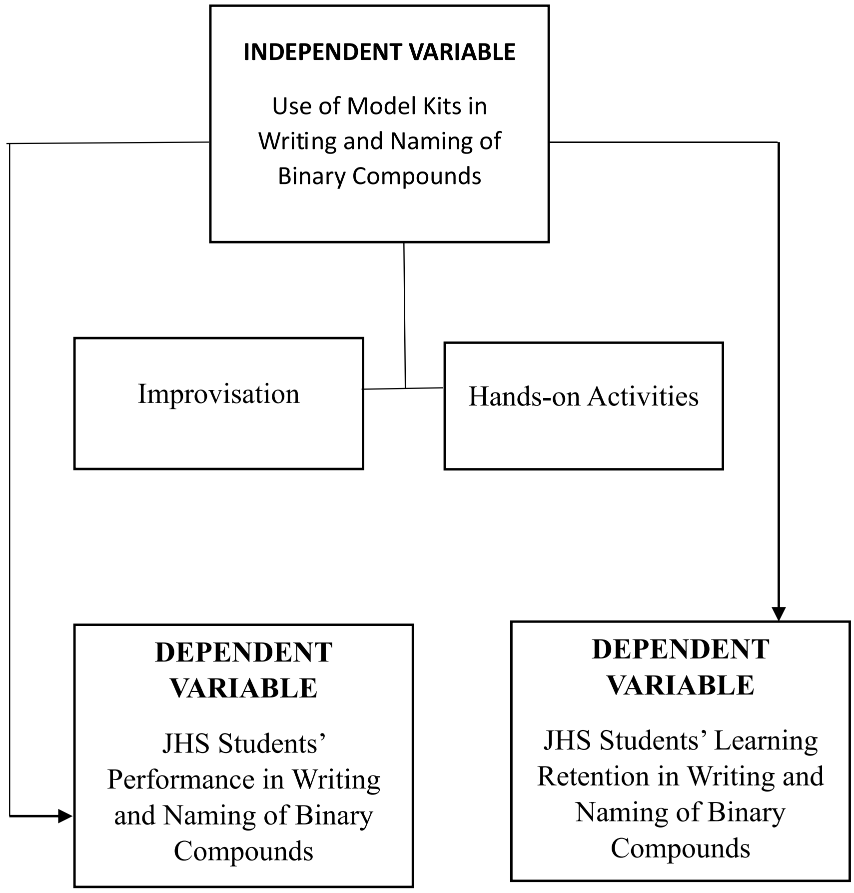


Figure 2: Conceptual Framework of the Study

The independent variable was the use of Model Kits in Writing and Naming of Binary Compounds, situated in the context of improvisation and hands-on activities. This variable was theorized as factors affecting the dependent variables, which are JHS students' academic performances and retention in writing and naming of binary compounds. In Figure 2, the teacher plays a role as a facilitator who prepares the instructional content, lesson plan and selects appropriate teaching and learning activities to be undertaken by the students. The learners' role in Figure 2 is to actively perform activities selected by the teacher during the instructional process. Instead of simply listening and watching what happens in the classroom, students should actively engage with what the teacher is saying by doing their own independent research. Hands-on activities then enhanced into students' academic achievement and retention.

2.3 Conceptual Review

2.3.1 The Concept of Hands-on Activities

The concept of hands-on science is founded on the conviction that a science curriculum for elementary school students should be based on the approach learners use naturally to make sense of the world around them (Haury & Rillero, 1994, p. 17). Thus, to comprehend science, one "must" experience it. Through these activities, students should be able to actively engage in manipulating materials and ordinary things from the outside world. The most efficient method of teaching should take advantage of children's innate propensities for observation and exploration.

Therefore, "hands-on activities," according to Ajayi and Ogbeba (2017), refers to any activity that allows the learner to handle or manipulate a scientific process. According to Musharrat (2020), hands-on learning refers to any teaching method that includes pupils actively manipulating objects to gain knowledge or comprehension, as well as action and first-hand contact with natural events. From the above definitions, one can say that, in hands-on learning, practical exercises are introduced into the class that serve as tangible aids in explaining and imparting concepts to students.

According to the Ministry of Education (2020), science is an endeavor undertaken by humans in collaboration and creativity that stems from our aspiration to comprehend the surrounding environment and cosmos. Instructors must therefore support learning in an enabling scientific classroom in order to deliver high-quality science instruction.

At higher educational levels, this will give the groundwork for science and scientific-related courses as well as the means of learning about and comprehending the world around us. Hence, educators ought to motivate students to comprehend how science explains what is happening, predicts behavior, and examines the causes and origins of objects in our surroundings. This means that students must have access to real-world situations where they can use their information, as well as support in integrating or trading that knowledge, in order to fully master science concepts (Ateş & Eryilmaz, 2011).

Hands-on activity, involves physically doing experiments, recording data, discussing results, and inferring outcomes, are integral parts of this type of learning, which are the basic scientific processes. In fact, Flick (1993) states that hands-on activities are not activities used as “adjuncts” but rather they are integral part of science instruction. In other words, the learner must devise a procedure to test a hypothesis, carry it out using a variety of practical tools, see it through to completion, and then be able to explain the outcomes.

According to Ateş and Eryilmaz (2011) and Ajayi and Ogbeba (2017), employing hands-on activities does not necessarily include laboratory works. This is because, unlike laboratory works, hands-on activities do not necessarily need some special equipment and special medium. Thus, hands-on activities are based on the use of everyday gadgets, simple set-ups or low-cost items that can be found and assembled very easily. This means that, an instructor who wants to use hands-on activities can improvise where materials and equipment are unavailable. However, Flick (1993) suggests that there are at least three conditions that are necessary for a teacher to say that students are engaged in hands-on science activities. To Flick (1993), the absence of any one of these conditions invalidates the claim of engagement in hands-on science. These conditions are explained as follows;

Firstly, students should manipulate elements of the natural world, either individually or in groups. Effective classroom instruction includes a variety of additional crucial teaching strategies that work in tandem with practical learning experiences. These other methods alone should not be mistaken for practical science, either (Flick, 1993). Watching videos or using computer simulations, for instance, may be investigative tools but do not by themselves qualify as manipulation of the environment. Although seeing demonstrations or static displays can be useful for learning new material and for stimulating scientific thought, they do not, by themselves, constitute hands-on science training. A special note should be made on active field trips to museums, zoos, and other attractions. The majority of the time, these kinds of activities involve only minimal manipulation of the natural environment, and occasionally, as with the majority of zoos, none at all. This does not lessen the significant contribution these locations contribute to education. Yet, it's crucial to realize that an hour-long "walk and talk" through a factory or past cages does not require manipulating the environment in order to comprehend experiential learning, especially at the elementary level. Due to the limitations of a typical museum visit, even the engaging exhibits at modern scientific centers require additional action to satisfy the other two requirements.

Secondly, in order to comprehend a portion of their natural world, pupils should be using several sides of their intelligence, as theorized by Gardner (1983). It is difficult and requires knowledge, awareness, and a special type of love on the side of teachers to follow this intellectual application. According to Willingham (2021), there's a chance that learners are looking to grasp ideas that are not being covered in a lesson. Gardner's (1983) theory of multiple intelligences lends credence to this. In light of this, it is possible for unexpected results to arise when various characteristics of intelligence are applied to hands-on education. The teacher's sensitivity to the thoughts and lifestyles of the children will, however, determine how much the teacher believes the outcome supports a deeper understanding of the natural environment. This means that, it is the responsibility of the teacher to adjust the instruction and assessment to students' needs.

The third condition is that student observations, judgments, and conclusions should be held accountable (Flick, 1993). This is due to the professional level of science having a discipline that demands remarkable documentation, verification, and communication efforts. So, if students are made accountable for the actions and observations they claim to make, they are learning science. Accountability entails paying attention to the feedback from other students and considering the significance of one's own thoughts. Students demonstrate their accountability by addressing differences and parallels between their opinions and those of others. Without a doubt, accountability will change depending on the task, the age, and other factors. Accountability requires, at the very least, keeping records. Images, notes, graphs, tables, semantic maps, writing, and audio and video recordings can all be used to represent them. Computers may be used to support any of these techniques.

2.3.1.1 Components of Hands-on Activities

Flick (1993) suggests that every instruction that employs hands-on activities should have these three components, which are explained as follows.

An Instructional Intervention: A quality science lesson includes instructional interventions that capture and hold students' interest. Successful instructional interventions involve feedback techniques that satiate students' informational needs while simultaneously encouraging more inquiry. but, Flick (1993) believes that it is possible to respond to students’ inquiries in a way that discourages follow-up inquiries. The manner in which a question is addressed may make students feel insulted or diminished. Even if they don't fully comprehend, pupils may believe that there shouldn't be any more questions after receiving answers that go well beyond what was asked for.

Instructional Materials: A good hands-on activity makes use of elements that encourage students’ engagement with their surroundings. Through interacting with the environment, one can alter or modify important elements and receive sensory feedback on outcomes. For instance, while the interactions involved in creating a model of the solar system out of various-sized bails and balloons and hanging it in the classroom are useful, they might not be the most crucial ones for assisting kids in understanding space. Comparing images to the moon's actual nighttime phases or observing representations of the earth and moon at similarly sealed solar distances on a playground may provide for easier access to and control over important parts of the learning environment. Adkins (2020) asserts that in learning, one often progresses from the concrete to the abstract. The easiest things for people to learn about are those that they can see with their five senses: sight, sound, touch, smell and taste. They can manipulate characters, relate particular to larger concepts, and use logical reasoning skills as their comprehension of abstract concepts increases. But these skills take time to develop, and most individuals need real-world instances of novel concepts throughout their whole lives. Additionally, concrete learning experiences work best when they take place in a concept's closely related environment.

Procedures: Procedures that highlight significant structural and functional aspects of materials as well as the environment being studied are part of successful science experiments. Therefore, in order to emphasize the value of assisting students in understanding the objects they are working with, procedures are separated from the instructional intervention. For example, before moving on to instruction concerning matter and its properties, it is crucial that students have plenty of chances to experience the peculiar traits of the substance. To put it another way, before exposing kids to more "specific" knowledge, they must first build a "romance" with the notion of learning about this subject.

2.3.1.2 Some Benefits of Using Hands-on Activities

Several advantages of hands-on learning that appear obvious have been supported by research. First, hands-on activities can improve students' ability to remember the material, have a sense of accomplishment when completing a task, and apply the knowledge they have gained to various learning settings with more ease. (Ekwueme et al., 2015). By so doing, when many learning methods are used, as in hands-on learning, the information has a better chance of being stored in the memory for later useful retrieval. According to Haury and Rillero (1994), students who struggle in the classroom due to behavioral disruption or hearing difficulties are more likely to be on task when they are actively participating in the learning process.

Also, students learn scientific ideas while also honing their creativity and critical thinking skills via hands-on experience with science. Instead of memorizing the right answers, it requires students to analyze the witnessed occurrences, which forces them to think. Therefore, students who participate in hands-on activities are more likely to trust facts rather than authority (encyclopedia, minister, doctor, text, teacher, parent). The majority of pupils reside in an authoritarian society where they have little to no opportunity to practice making decisions because almost everyone directs them and tells them what to do and when to do it (Haury & Rillero, 1994). Again, hands-on activities give students a common set of experiences so that regardless of gender or socioeconomic class, everyone may take part in conversations on an equal footing. This prevents people who have more experiences under their belts due to their background or riches from receiving preferential perks.

According to Bloom et al., (1973), there are three main domains of learning, and it is therefore important for teachers to ensure that these three domains of learning are achieved. These domains are the cognitive (which concerns the knowledge), affective (which concerns the emotions and feelings) and the psychomotor (which concerns the skills). It is imperative to understand that learners of these days enter the classroom with varying needs and as such effective methods must be adopted in planning and delivering of every lesson in order to ensure that such needs are addressed. As a result, Flick (1993) asserts that the use of hands-on activities can accommodate all three domains of human learning. To Flick, the knowledge (cognitive) component of learning in hands-on activities includes knowledge of the nature of science and technology, scientific material, and overarching themes or concepts. Students can gain knowledge about the nature of science and technology as the concurrent human pursuits of developing explanations for natural phenomena (science) and resolving issues associated with human adaptability in the environment (technology) through engaging in hands-on activities (technology). Also, students can study part of the expanding body of information and procedures referred to as science content.

Finally, practical exercises offer chances to connect experiences to broad conceptual topics. The psychomotor (skills) component of hands-on learning includes training the senses as well as developing gross motor, fine motor, and eye-hand coordination skills. Together with broad organizational skills like data gathering, problem solving, and decision making, students can study scientific processes like inference, data analysis, and hypothesising. Students have the chance to acquire social (interpersonal) skills, as well as intrapersonal and metacognitive awareness skills through cooperative group settings and the requirement to connect with a variety of new materials (Flick, 1993). The attitudes dimension of hands-on learning includes “attitudes of science” and “attitudes toward science” (Flick, 1993). Thus, scientists acquire certain mental habits known as "attitudes of science" in order to preserve the objectivity of their research and the veracity of their findings. They include dispositions like skepticism, reliance on evidence, and tolerance for ambiguity. Students’ “attitudes towards science”, according to Flick (1993) include those towards their own selves, their education, and their future. By identifying with scientific researchers through hands-on activities, learners are able to see a connection between their present and future experiences.

With hands-on instruction, students utilize their senses to learn; they see, touch, and manipulate actual items to finish tasks. This results in the lifelike rendering of letters, numbers, shapes, colors, and other objects. Learners gain excitement and engagement since they are having fun in this way, which helps them increase their attention span. They also start to comprehend the purpose behind what they are doing. By learning to manage, communicate, concentrate, and dedicate themselves to finishing activities and developing problem-solving skills, they are then able to grow their knowledge, improve their long-term memory, and strengthen the development of their fine motor skills (Sulyman et al., 2022). Instead of passively reading a book or attending classes, students learn best when they actively engage with a subject and participate in activities. (Djami & Kuswandono, 2020; Munyaradzi, 2013).

In other words, children learn best when they can touch, feel, measure, manipulate, draw, make charts, record data, and find solutions for themselves rather than having them provided to them in a textbook or lecture. This means that they would rather be active participants than passive viewers and that they usually solve problems by trial and error rather than relying on information that is given to them. Hands-on activities, thus allow learners to learn through experience and can give them an opportunity to immerse themselves in a learning environment, while putting their acquired skills to use and building new skills (Sulyman et al., 2022).

2.3.1.3 Some Examples of Hands-on Activities

Many hands-on activities are available for teaching basic science and technology. Few of them are described below.

Conducting experiments: This refers to the practical evaluation of theories and hypotheses. Students can apply theoretical ideas to practical problems through activities like science experiments and building projects. Concepts are solidified and practical abilities are developed, which are helpful in both educational and professional situations in the future (Uzor et al., 2022).

Building models or prototypes: A model is a condensed representation or framework that aids in the comprehension, forecasting, or simulation of complicated systems or events. An idea, concept, or design is represented physically or visually via models and prototypes. Simple drawings, sketches, and 3D computer models are just a few examples. They can also be physical mock-ups, miniature copies, or working prototypes. Common models used in science include the DNA Double Helix Model (which represents the structure of DNA), the atomic model (which represents the structure of an atom), the planetary model (which represents the solar system), etc. (Uzor et al., 2022).

Creating artwork: This refers to the process of creating or making forms that are regarded as works of art, whether they are tactile, auditory, or visual. Artwork can take many different forms, including photography, computer art, installations, performance art, and more. When someone creates art, he/she utilize his/her imagination, talents, and techniques to convey concepts, feelings, or ideas through the medium of their choice. A specific message or aesthetic vision is communicated by the selection, manipulation, and arrangement of materials in this process (Uzor et al., 2022).

Participating in simulations or role-playing: Computer-based simulations are models or representations of actual systems or processes. They are employed to copy or emulate the actions of the actual system. With the use of simulations, students can apply their academic knowledge in real-world contexts. They provide hands-on chances without the accompanying risks or costs, bridging the gap between classroom learning and real-world experiences. Simulations are intended to offer insights into potential system behavior under various circumstances or scenarios. Simulations give learners the chance to experiment with the impact of various conditions or inputs on the system's output. When it is difficult, expensive, or even impossible to conduct tests or make observations in the real world, this can be especially helpful (Uzor et al., 2022).

Practicing a skill or technique: Putting into practice a skill or technique like empathy maps, character paintings, or brainstorming techniques helps students visualize and organize their thoughts, which makes it simpler for them to comprehend and solve complex challenges (Uzor et al., 2022).

2.3.1.4 Challenges in Using Hands-on Activities in Science Classrooms

It is challenging to engage students personally in large classrooms and to establish settings where they can connect and get feedback. Technology might assist close this gap, but generally speaking, we haven't created truly strong tools to support and enhance the science curriculum. Early students' involvement in genuine research can be very effective, but in large classrooms it can be difficult to locate topics that can be heavily parallel but also individual to the student. Hands-on activities are frequently carried out in group settings, which can provide difficulties in managing behavior and group dynamics. It can be difficult to maintain order, promote teamwork, and control the different personalities and skill sets present in a group (Musharrat, 2020; Uzor et al., 2022).

Inspiring the interest of authorities is a significant obstacle to building a more active learning environment in a school. Older instructors who learned science through conventional lectures might not think that anything has to change. As a result, teachers may not receive the needed support to implement novel teaching methods in their classrooms. Giving junior faculty members the freedom to design courses from start will inspire them to adopt or develop new strategies. Furthermore, hands-on activities frequently need for supplies, tools, or equipment. Implementing such initiatives may be hampered by a lack of resources, particularly in circumstances where there are financial restrictions or insufficient access to critical supplies (Musharrat, 2020).

Another possible disadvantage of utilizing hands-on activities is the amount of time required for execution. In hands-on activities, it is recommended that educators spend more time engaging with their students. It takes careful planning, assembling supplies, setting up the exercises, and organizing content presentations to teach science through hands-on activities. To maintain the student's attention, the instructor needs to plan more outside of the classroom and devise new activities. Providing pupils with a space for reflection is another duty of the educator. Hands-on learning can experience difficulties with time management, but these issues can be resolved with careful planning and execution (Fisher et al., 1998).

Assessment and evaluation are part of the challenges in using hand-on activities in science classroom It can be difficult to evaluate the results of hands-on activities or the learning outcomes. Alternative evaluation mechanisms must be developed by educators because it may be difficult to evaluate experiential learning using traditional assessment methods. Fisher et al. (1998) emphasized that traditional assessment techniques, which include paper and pencil tests, do not coordinate with experiential teaching methods. The goal is to assess the processes of science, along with content material.

2.3.2 Improvisation in Science Teaching and Learning

According to Mboto et al. (2011) and Yeboah et al. (2019), if scientific classes are taught and learned without the use of tangible instructional aids, it will be very difficult for teachers to explain concepts to basic school students. But the issue of inadequate instructional materials for students in African schools has remained over time (Akuma & Callaghan, 2016; Mayeem et al., 2018). As a result, it is crucial to give the improvisation of educational materials more consideration. Ndihokubwayo et al. (2018) state that enabling children to actively explore their environment and learn by doing is the ultimate goal.

The process of developing educational materials when standard materials are hard to come by or unavailable within a particular community is known as improvisation (Okori & Jerry, 2017). The phrases "self-created models" and "low-cost equipment" were used by Akuma and Callaghan (2016) to describe homemade instructional materials. Botes (2021) and Akuma and Callaghan, (2016) both state that these materials are typically made from easily accessible local resources or materials like tin cans, plastic, straws, wood, cardboard, etc.In order to ascertain the advantages of these resources for science education, Udu (2018) states that instruction can be conducted with improvised resources in situations where specific teaching instruments are either insufficient or unavailable. According to Mboto et al. (2011) as well as Rivera and Sanchez (2020), resources could enhance students' engagement and performance in the classroom. It can also sustain students' interests and help them become more creative (Mayeem et al., 2018; Osei-himah et al., 2018).

2.3.3 The Benefits of Model Kits in Science Lessons

According to Adu-Gyamfi et al. (2017), learning concepts related to chemistry at the microscopic and symbolic levels is extremely difficult. This is due to the fact that comprehension of chemical concepts transcends sensory awareness, since Chemistry spans microscopic and symbolic levels that are both invisible and abstract. Teachers can use model kits to address the abstract aspect of chemical ideas, such as binary compounds (Ibe et al., 2021). In this study, the best and most appropriate hands-on activity for teaching children how to name binary compounds is using model kits. They aid in improving comprehension and retention of concepts (Keshavarz, 2018; Owo, 2022).

In Model Kits, atoms and connections are put together to form three-dimensional representations of molecules or atoms. Typically, these kits come with a variety of coloured and shaped plastic or wooden components that can be constructed to simulate molecular structures, bonding isomerism, and atoms (Dori & Barak, 2001). Students can have a better understanding of molecules' characteristics and interactions by visualizing their structures (Ramesh et al., 2020). For numerous decades, it has been established and acknowledged that teaching chemical ideas through physical models is a successful method. For instance, in 1904 and 1911, respectively, J. J. Thompson and Rutherford created the concrete representation of atomic structure (Gyasi et al., 2018).

Model kits help students understand chemical bonding by enabling them to observe the formation of compounds firsthand. It's critical to comprehend the idea of particles within matter, decipher symbols, and visualize atoms in compounds in order to comprehend chemical structures, bonding, and other concepts (Turner, 2019). Furthermore, Model Kits offer a practical chemistry experience that fosters comprehension and enjoyment through direct engagement with the material. This method makes sure that instruction starts with real-world examples before going on to abstract ideas, which improves retention (Quayson et al., 2022). Model Kits function as an educational tool that promotes improved learning and memorization. They are made to accommodate a variety of learners, from novices to experts. Adu-Gyamfi (2017) further highlights that teaching and studying Chemistry through model kits enables the depiction of topics at the microscopic level at the macroscopic one. Crucially, it facilitates students' ability to visualize abstract ideas in a tangible way (Comba, 2009).

Thus, it has been proposed in the literature (Kaumal & Wijayawardana, 2017; Quayson et al., 2022) that teaching binary compound writing and naming is better suited for the use of Model Kits. Using model kits in the classroom facilitates experiential learning by using students' senses to actively observe, touch, and manipulate tangible things to accomplish a variety of activities. This makes the display of letters, numbers, shapes, symbols, colors, and objects realistic and accurate. Fun activities can boost engagement and excitement, lengthen students' attention spans, and aid in their understanding of the tasks' ultimate goals. Students gain knowledge, enhance their capacity to visualize concepts in their minds, and comprehend and interpret chemical formulae and symbols by learning how to manage, communicate, focus, and commit to finishing tasks and honing their problem-solving abilities (Turner, 2019; Sulyman et al., 2022).

In contrast to depending exclusively on textbooks, students learn more efficiently in the classroom when they are allowed to modify, acquire data, evaluate information, and come to their own conclusions about an issue. Through participation and hands-on experience, Model Kits enable learners to learn new skills and gain information (Sulyman et al., 2022). They help pupils become more independent, encourage teachers and students to solve problems creatively and innovatively, and improve a variety of skills like reading, math computation, and communication. Furthermore, Model Kits foster learning, comprehension of concepts, and general development, providing a basis for advanced study of nomenclature (Ekwueme et al., 2015; Sulyman et al., 2022). These kits include tasks that require mental and physical skills (Ateş & Eryilmaz, 2011). The material being taught and studied has greater value for pupils when they are actively involved with the Model Kits (Alkan, 2016; Pirttimaa et al., 2017). Significantly, this method emphasizes "hands-on" science courses and problem-solving strategies, which are in line with the expectations of 21st-century classroom instruction (Gakuba et al., 2021).

Pupils who are taught using Model Kits are more likely to remember what they have learnt, feel proud of themselves, and be able to use what they have learned in other learning contexts (Ekwueme et al., 2015). Model kits, according to Abban-Acquah and Edusei (2023), are especially helpful for kids who have difficulty in the classroom, such as disruptive behavior or hearing issues, as they keep these students focused throughout instruction. Furthermore, by giving students practical experiences with science, Model

Kits not only help them understand scientific topics but also develop their creativity and critical thinking skills. Students are encouraged to analyze observed phenomena, which challenges them to think critically, as opposed to just memorizing the proper answers.

As a result, it is critical to acknowledge that students arrive in the classroom with a variety of needs, and that successful strategies for lesson design and delivery are required to address these needs. According to Penny et al. (2017), all three learning domains can be addressed through the usage of Model Kits. As a result, by using Model Kits in science classes, students are able to learn about the distinctive features of both science and technology. This helps them to address problems pertaining to human adaptation in the environment and to formulate scientific explanations for natural events. Utilizing Model Kits also helps children build their gross, fine, and eye-hand coordination skills, which is a component of psychomotor learning.

Students utilize model kits to complete assignments by using their senses to see, touch, and manipulate real objects. As a result, characters, numbers, shapes, colors, and other objects are rendered realistically. Additionally, by actively participating in this hands-on method, students become enthusiastic and extend their attention span. Likewise, Sulyman et al. (2022) contend that using Model Kits encourages students to take charge of their education, communicate clearly, focus, and stick with tasks until they are finished. Additionally, they argue that using Model Kits in science classes helps students develop their fine motor skills, improves their ability to solve problems, acquire new information more quickly, and strengthens their long-term memory.

2.4 The Concept of Retention

Retention is essential for the transfer of knowledge because if the students do not recall prior knowledge, the instructor will spend the majority of their time reviewing and reteaching it (Toheed et al., 2017). Retention therefore, according to Amin and Malik (2014) is the ability to understand, hold onto, and recall knowledge for a longer amount of time. It is, in essence, the process of obtaining data that has been encoded and stored. Retention is the second stage of memory, after encoding and before retrieval. Because any stored knowledge is kept in human memory stores, Toheed et al. (2017) explains that retention of content would not be feasible without human memory processes. Information can be remembered in a variety of ways. The creation of associations in memory stores is essential for learning and remembering new information. As a result, both memory and the formation of associations are necessary for the encoding and retention of new information.

The retention and retrieval of information in memory requires that the information to be firmly embedded within a neural network, which can be done through the use of as many human senses as possible (Amin & Malik, 2014; Pillado et al., 2020). These, according to Davis (2007) include: sight, touch, smell and hearing. All of these senses should be engaged when learning new information. To Davis, when engaging as many senses as possible at once, retention of information improves the most. This is because, when learning new information, the brain seeks to associate this material with previously stored knowledge through assimilation. When we learn something new, our brain creates new neural pathways. By implication, hands-on practice when engaging in learning is important for retaining this information in long-term memory stores.

Human memory functions can be categorized as the brain's capacity to comprehend, remember, and recall information. Recall is the process through which encoded events and information are retrieved from memory in response to external stimuli. Retention stores encoded events and information. Recall is the sole means to gauge memory performance even if memory development occurs over several stages. Just how much data is encoded? How much knowledge is kept? How much data was retrieved? How well is your memory performing? By asking someone and documenting their recall responses, you can find the answers to all of these questions throughout the memory recall phase. The right answers will reveal how well your memory performs, how much information you've kept, or how much information has been encoded (Amin & Malik, 2014).

Both short-term and long-term memories exist in the human brain. Recalling recent lessons learnt or memories requires the use of the short term. On the other hand, lifelong experiences are not like that. If a particular technique is used, it can only be held for a long time. Short-term memory is destined to be forgotten because it has a limited lifespan (Bullock, 2021). However, Bullock emphasises that long-term memory is advantageous for one's overall well-being, academic performance, skill development, and all positive and negative life experiences. The development of skills, management of a career, and examination and assessment, all benefit from long term memory. This memory retains knowledge in two forms:

The first, “procedural memory”, refers to remembering how to do something, like riding a bicycle, driving a car, swinging a golf club, and tying a shoelace, how to prepare a gas, or how to do any other thing. As practice of the skills continues, these memories become more efficient and can be performed with little conscious thought or recall. Procedural memories are processed primarily by the cerebellum. The second form of long-term memory is declarative memory, and it describes the remembering of names and objects, as in where one lives and the kind of car one owns. The description of laws in Chemistry, which is more specific, factual, and is to be retained for gaining something, is also declarative memory. Declarative memory can be further divided into episodic and semantic. Episodic memory refers to the memory of events in one's own life history, while semantic memory is knowledge of facts and data that are independent of that history. A memory's endurance can be increased, for instance, using a variety of methods, including hands-on activities (Amin & Malik, 2014).

The kind of teaching technique utilized affects the learner's capacity to retain information. More learning is retained using some methods than others. The National Training Laboratories of Bethel, Maine, developed the learning pyramid, (as shown in Figure 3) based on research on learning retention after students were exposed to various teaching techniques. The pyramid displays the percentage of brand-new knowledge that students, who were predominantly taught using the given teaching style, were able to retain after 24 hours. The proportions do not add up. The teaching approach that results in an average retention of only 5% of learning after 24 hours is the lecture, which is at the top of the pyramid. This outcome is not unexpected given that in lectures, there is typically little active students' participation or mental rehearsal. The teacher is telling in this manner, while the students are listening just long enough to record the teacher's auditory and visual feedback. There is little to no elaborate rehearsal, and rote rehearsal is the norm. Students' engagement in the learning process grows as they move down the pyramid, and retention rises. The approach at the base of the pyramid entails having pupils start using what they've learned right away or teaching others. After 24 hours, this resulted in retention of over 90% (Sousa, 2016).

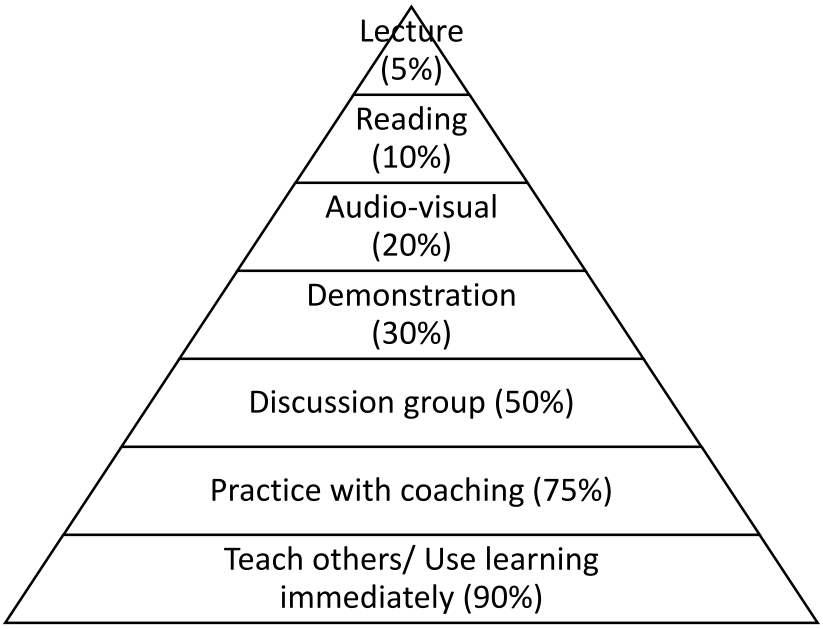


Figure 3: Learning Pyramid Showing Average Retention Rates (adapted from National Training Laboratories Institute for Applied Behavioral Science)

Therefore, Bullock (2021) accentuates that the use of intervention strategies in the classroom is crucial because it enables teachers to recognize the unique needs of each student and group them according to their levels of need. Students can establish a regular plan by using instructional intervention tactics.

2.5 The Concept of Binary Compounds

Binary compounds belong to one of the four categories of inorganic compounds, as stated by Wirtz et al. (2006). Compounds classified as binary contain precisely two different types of elements. The term "bi," which basically means two, is the root of the word "binary" (Petrucci et al., 2011). These compounds tend to show strong chemical bonds like ionic, metallic, and covalent. The discovery of the ionic compounds brought the relevance of the binary compounds to a new level. The majority of ionic compounds seen in the periodic table are essentially composed of two elements: a metal and a non-metal. Although binary ionic compounds often begin as two compounds, they can create polyatomic ionic compounds and have extremely complicated characteristics. Although a binary compound only contains two elements, Petrucci et al. (2011) suggest that it can contain more than two atoms. Examples of binary compounds include water (H_2O), carbon monoxide (CO), hydrochloric acid (HCl), sodium chloride (NaCl), and silicon dioxide (SiO_2), Magnesium oxide (MgO). There are three types of binary compounds binary acids, binary ionic compounds, and binary covalent compounds (Anne, 2021).

A binary acid consists of a hydrogen cation bonded to another atom as an anion. Binary acids are also called hydracids (Petrucci et al., 2011). Naming depends on whether the compound is a liquid or whether it exists in gaseous or anhydrous form. Examples are hydrochloric acid (HCl), hydrofluoric acid (HF) hydrogen bromide (HBr), hydrogen sulfide or dihydrogen sulfide (H_2S). A binary ionic compound is a compound with a metal cation and a non-metal anion. Examples include sodium chloride (NaCl), sodium fluoride (NaF), zinc iodide (ZnI_2), is sodium phosphide (Na_3P), magnesium oxide (MgO), aluminum oxide (Al_2O_3), calcium chloride ($CaCl_2$), iron (II) oxide or ferrous oxide (FeO), iron (III) oxide or ferric oxide (Fe_2O_3), copper (II) chloride ($CuCl_2$). Binary covalent compounds form when two non-metals form a covalent bond. This type of compound is also called a binary molecular compound. Often, two nonmetals combine in a variety of ratios. For example, nitrogen and oxygen form NO, NO_2, and N_2O.

2.5.1 Importance of Naming Binary Compounds

Naming a compound in Chemistry is an important requirement in Chemistry (Taskin & Bernholt, 2014). Compound names were not assigned in the early days of chemistry. Early scientists came up with names like laughing gas, blue vitrol, quicklime, Epsom salts, milk of magnesia, gypsum, and sugar of lead. Such names, according to Taskin and Bernholt (2014) are called "common names". It was evident as chemistry developed that naming substances by their common names would result in unacceptably chaotic situations. There are currently over five million chemical compounds recognized. (Djoumbou et al., 2016). It would be impossible to learn the common names of these compounds by heart. Also, because it is crucial for our safety, it is essential to have a basic understanding of compounds and chemicals.

Many of the chemicals we encounter every day have the potential to be highly reactive and should be handled with caution (Taskin & Bernholt, 2014). Therefore, understanding and identifying which chemical compounds are safe and which ones have the potential to cause harm are made easier by Chemistry (Egorova & Ananikov, 2017). Naturally, the answer is to use a system for naming compounds where the name provides some information about the compound's makeup. A chemist who has mastered the system should be able to write the compound's formula or, if given a name, identify the compound.

2.5.2 Students' Difficulties in Nomenclature of Binary Compounds

It has been established in the literature that students encounter difficulties in the nomenclature of binary compounds. For example, Baah and Anthony-Krueger (2012) reported that SHS 3 chemistry students found it challenging to write the correct names of some elements in compounds. With H_2S, for example, students thought that S was Sulphur rather than Sulphide. Also, they reported that SHS students demonstrated lack of knowledge about valency. Similarly, Adesoji and Babatunde (2016) explained students' inability to write formulas of compounds correctly, as well as wrong use of coefficients and subscripts. These weaknesses and challenges are reflected when JHS students sit for their BECE external examinations. Specifically, the Chief Examiner reported in 2018 that "writing of the formula for compounds was a big challenge for many candidates" (WAEC, 2018, p 1). Also, in 2019, candidates failed to give the systematic names of $MgCl_2$ and FeS (WAEC, 2019).

2.5.3 Challenges Teachers Encounter in Teaching Writing and Naming of Binary compounds

Teaching writing and naming of binary compounds presents numerous challenges for educators. One of the primary obstacles according to Dorsah et al. (2024), is the lack of engaging and interactive teaching materials can hinder effective instruction. Traditional teaching methods, such as lectures and textbook exercises, may not be sufficient to engage students and help them internalise the concepts. Innovative teaching tools, such as molecular model kits, interactive simulations, and educational software, can significantly enhance student understanding. However, Dorsah et al. (2024) emphasised that not all schools have access to these resources, and teachers may not have the training or time to effectively integrate them into their lessons.

Again, Dorsah et al. (2024) found that large class sizes also present a significant challenge when teaching the writing and naming of binary compounds. In a crowded classroom, individual attention is hard to come by, and students who struggle with the material may not receive the support they need. The complex nature of chemical nomenclature requires personalised guidance (Gyasi et al., 2018), which may be difficult to provide in a large class setting. Teachers therefore, may find it challenging to monitor each student's progress and identify those who need extra help, resulting in some students falling behind.

Limited instructional time further aggravates the difficulties of teaching this topic (Handur et al., 2017; Musharrat, 2020). According to the authors, the packed curriculum often forces teachers to cover a wide range of content in a short period, leaving little room for thorough exploration of any single topic. However, the intricate rules and conventions of naming binary compounds demand careful, detailed instruction and ample practice, which may be hard to achieve within a constrained timeframe. Teachers must balance the need to move quickly through the curriculum with the necessity of ensuring deep understanding, often leading to a compromise that can impact student learning outcomes.

2.6 Empirical Review of Improvised Models on Students' Learning Outcomes in Science

In order to ascertain the advantages of these materials for science education, Udu (2018) states that in situations where specific teaching tools are either unavailable or insufficient, instruction can be executed with the use of improvised resources. These resources have the potential to enhance students' performance and involvement in the classroom (Mboto et al., 2011; Rivera & Sanchez, 2020), foster their creativity Horikoshi (2020), and maintain learners' interests (Osei-himah et al., 2018). As a result, researchers have carried out experimental studies to ascertain the efficacy of improvised instructional materials in science education.

For example, Lombardi et al. (2014) studied the effect of using plastic models, organ dissections, and virtual dissections on student' learning and perceptions. Lombardi et al. (2014) employed an experimental design using 26 students enrolled in the Human Anatomy and Physiology I course from the University of Maryland. The sampled students were divided into three treatment groups, namely; organ dissections, virtual dissections, or plastic models. Students who used plastic models achieved significantly higher overall scores on both the initial and follow-up exams than students who used organ or virtual dissections. Specifically, students in the plastic model treatment had an overall median score of 95.4, with inter-quartile range of 9.1 which was significantly higher than (p=0.009) the median score of students in the organ dissection treatment (77.3, p= 0.006) or the virtual dissection treatment (70.4, p = 0.007), with inter-quartile ranges of 18.2 and 22.7 respectively. Lombardi et al.(2014), also sought to assess students' retention of concepts after a period of two months and reported that the overall score of the students in the plastic model treatment (67.9, p=0.002) was higher than both the median scores of students in the organ dissection treatment (45.8, p=0.003) and virtual dissection treatment (37.5%, p=0.017). Therefore, from Lombardi et al.'s study, it can be concluded that, though all groups used hands-on activities, students' who used plastic models performed best among their counterparts.

Mayeem et al. (2018) created improvised models to teach chemical formulas and chemical nomenclature to senior high school (SHS) students. According to Mayeem et al. (2018), SHS students' comprehension of chemical equations and chemical nomenclature was improved by the usage of improvised models after an independent sample t-test revealed a significant difference between students taught using improvised models (M=20.21, SD=6.05) and those taught without improvised models (M=10.63, SD=4.27; t=12.93, p=0.00). When teaching seventh-grade students about gas laws using homemade teaching materials, Rivera and Sanchez (2020) discovered that students' comprehension of the subject improved in comparison to the traditional teaching approach. Specifically, an independent sample t-test revealed significant diffference between students exposed to localized materials (M=30.24, SD=4.94) and those exposed to traditional teaching method (M=28.37, SD=4.05; t=4.338, p=0.00).

Additionally, Obodo et al. (2020) found that in comparison to the traditional teaching approach, the usage of improvised teaching materials increased science achievement of second-year junior secondary school students. In their study, a one-way ANCOVA results revealed that there was a significant effect of teaching method on the posttest scores of students ($F_{(1, 139)} = 5.766$, $p = 0.018 < 0.05$), where students taught using improvised teaching materials performed better (M=24.80, SD=21.80) than those taught without improvised teaching materials (M=18.51, SD= 7.50). Quayson et al. (2022) also investigated the effect of using molecular models on trainee teachers' understanding in learning spiro and binary compounds. In their study, Quayson et al. (2022) used a paired-sample t-test and found out that students performed significantly better after using molecular models (M=18.20, SD=1.61) than before using molecular model (M=7.80, SD=3.15; t=17.29, p= 0.000).

2.7 Summary of Literature Review

The literature review showed that the use of Model Kits, situated in the context of improvisation and hands-on activities, support the Constructivism Theory by Vygotsky as well as Experientail Learning Theory propounded by Kolb. Teachers who employ these models through hands-on activities adhere to the philosophy that students learn best when they are given opportunities to practice what they learn in the classroom. As a result, hands-on activities are instructional approaches which allow students to take active part during classroom lessons. Also, the literature review revealed that JHS students exhibit difficulties in chemical nomenclature of binary compounds, as well as teachers facing difficulties in teaching writing and naming of binary compounds, amongst which include the lack of teaching and learning resources. Nevertheless, research has shown that the use of Model Kits, which is rooted in student-centeredness, can improve students' academic performances, as well as help them to retain concepts learned better than the conventional teaching method which is predominantly characterised by the use of lecture. This is because, in using the model kits, learners, through hands-on activities learn to apply the principles involved in the material, and by applying the concepts learned improves students' understanding and retention of concepts.

However, the literature also pointed out that, with the positive effects of hands-on activities on students' academic performances and retention of concepts, there are some implementational challenges associated with its employment. It could be deduced that the employment of model kits has been researched into in diverse geographical locations, including Ghana. However, it appears little attempt have been made to investigate the effect of model kits on JHS students in the writing and naming of binary compounds. Thus, the literature revealed a gap where little research has been conducted in Ghana to investigate the effect of Model Kits on JHS students' understanding and retention of chemical nomenclature of binary compounds.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter outlines the research's study area. It also explains the design that was used to collect the data. The chapter goes on to describe the population, sample, and sampling methods that were utilized to determine the study's sample size. The research instruments that were used to gather the data for the study are also thoroughly described in this chapter. This chapter also covers the research instruments' validity and reliability. The process of gathering the data and the procedure for analysis round out the chapter.

3.1 Study Area

The study was conducted in the Sekyere Central District, which is one of the thirty (30) administrative districts in the Ashanti Region of Ghana. It is located on the northern part of the region, and shares boundaries with Mampong Municipal, Atebubu District, Sekyere East, Sekyere South, and Ejura-Sekyeredumasi. The capital of the district is Nsuta. Some major towns in the district include Kwamang, Nsuta, Beposo, Atonsu, Jeduako, Birem, Kyebi, and Bonkrong. The land size of the district is 1,631.1 sq. km and it is located within longitudes 0.05 degrees and 1.30 degrees west and latitudes 6.55 degrees and 7.30 degrees north. It has about 150 settlements with about 70 percent being rural. The rural areas are mostly found in the Afram Plains portion of the district where communities with less than fifty (50) people are largely located (Sekyere Central District Assembly, 2014).

3.2 Research Perspective

Rahi (2017) explains the term "paradigm" as a fundamental set of assumptions held by scientists, which are a set of agreements regarding how problems are to be understood, how we interpret the world, and how we conduct a study as a result. Accordingly, a paradigm guides an inquiry for particular research. In view of this, Creswell (2014) stated that the most advised strategy for determining what constitutes valid study is to adhere to the research paradigm. This is crucial because, by choosing a certain paradigm, the researcher does not get caught up in his own philosophical expertise and instead chooses a position that is more advantageous than the alternatives. Creswell added that a specific method for a study will only be appropriate if the researcher knows and chooses well the philosophical assumption or viewpoint supporting that study. Considering this, various research perspectives or paradigms have been found to provide the basis for which research is conducted. These are positivism, post-positivism, interpretivism, pragmatism, constructivism, and transformative paradigms. However, this study is grounded in Pragmatism paradigm, as the philosophical perspective of the study.

The Pragmatist approach to research presupposes that neither is it possible to ascertain social reality as it is created under the Interpretivist paradigm, nor is it possible to acquire what is considered the truth about the real world only by virtue of a single scientific method, as proposed by the Positivist paradigm (Kivunja & Kuyini, 2017). As a result, Kivunja and Kuyini highlighted that proponents of this paradigm search for research methodologies that might be more useful and pluralistic that might permit the combination of techniques that, when used together, might shed light on participants' actual behaviour, the beliefs that underlie that behaviour, and the consequences that are likely to result from various behaviours. Therefore, the perspective of the pragmatism promotes the application of mixed approaches (a blend of quantitative and qualitative approaches) as a practical means of comprehending human behaviour, which is the purpose of this study. Therefore, with the pragmatism worldview, the qualitative approach was employed to answer research questions 1 and 4, while research questions 2 and 3 were answered by adopting quantitative measures.

3.3 Research Design

A research design is a plan that offers the general structure for gathering data for a study. According to Creswell (2014), the overarching strategy for linking the conceptual research concerns to the relevant and doable empirical research is known as research design. In other words, research design concerns the planning of scientific inquiry, the development of a strategy for finding out something. This, according to Kaur (2016), involves: theory, conceptualisation, formalisation, operationalisation of variables, preparations for observation (choice of methods, selection of units of observation and analysis), observation, data analysis, and report. Thus, Bostley (2019) added that application of the research design ensures that the study's objectives and research questions are achieved and answered by using the appropriate research methodologies. Generally, various types of research designs exist depending on the nature of inquiry the researcher aims to embark. These according to Creswell (2014) include quantitative design (comprising experimental, correlational, and survey designs), qualitative design (comprising grounded theory, ethnographic, and narrative research designs). By seeking to address the research questions quantitatively and qualitatively, as theorised by pragmatists using pretest/posttest quasi-experimental control group design in order to measure the potential effects of the treatment before and after the intervention, through a multiple research approach. Multiple research approach according to Creswell (2014), is a comprehensive research approach that integrates both quantitative and qualitative methods across multiple phases of a study. This approach typically involves a sequence of data collection and analysis phases, where the findings from one phase inform the subsequent phases (Cohen et al., 2007). Thus, in this study, a semi-structured interview was initially conducted to ascertain the challenges JHS teachers encounter in teaching writing and naming of binary compounds. By so doing, research question 1 was answered. This initial phase informed the design of locally constructed model kits which were experimented in the form of an intervention to test their effectiveness on students' performance and retention, using statistical analyses. This helped to answer research questions 2 and 3. Following the intervention, another semi-structured interview session was held with students which allowed for the possibility to solicit students' perceptions on the use of the model kits in teaching writing and naming of binary compounds. It was done to gain a more holistic understanding of the research problem (Bostley, 2019), as reflected in the discussion of the results of the study.

3.4 Population

A population is a collection of people or objects who share a particular trait. In other words, a population is all individuals or objects of interest to the researcher (Cohen et al., 2007). VanderStoep and Johnston (2009) put it that a population is "the universe of people to which the study could be generalized" (p. 26). Within the population are target population and accessible population (Cohen et al., 2007). A target population, also called the sampling frame, according to Creswell (2014), is a collection of people whom the researcher can recognize and examine because they have certain distinctive qualities. The accessible population are those eligible members of the target population who are available for the researcher to study. In this study the target population comprised all JHS students and JHS integrated science teachers in the Sekyere Central District, while the accessible population comprised all public JHS students and JHS integrated science teachers in the name within the Sekyere Central District in the Ashanti Region of Ghana.

3.5 Sample Size and Sampling Technique

According to VanderStoep and Johnston (2009) in almost all cases, it is not practicable to research an entire population. Therefore, researchers typically study a subset of the population, and that subset, according to Marczyk et al. (2005) is called a sample. The kind of sampling method you choose in a study depends on a number of variables, including the sample size, population diversity, and research design (Cohen et al., 2018). Cohen et al. (2018) add that the larger the sample the better, as this not only gives greater reliability but also enables more sophisticated statistics to be used.

In this study, to ensure that all the teachers have the equal chance of been selected and to obtain a good representative of all the integrated science teachers simple random sampling was employed to select 12 teachers according to the recommendation of Onwuegbuzie and Collins, (2007). These 12 teachers were sampled for an interview to elicit their views concerning the challenges they encounter in the teaching and learning of writing and naming of binary compounds. Also, to determine the effect of locally constructed Model Kits on JHS students' performance and retention in the writing and naming of binary compounds, simple random sampling is employed to select four JHSs. From the four JHSs, two schools were randomly assigned experimental group while two schools were randomly assigned control groups to minimize the impact of confounding variable, which can affect the outcome of the study (Cohen et al., 2018). After the intervention, students from the experimental group were randomly selected to solicit their perceptions on the use of the model kits in teaching writing and naming of binary compounds.

3.6 Research Instruments

Various types of instruments were used to collect data from participants in this study. These include semi-structured interview guide and an achievement test.

3.6.1 Interview Guide

One advantage, according to Cohen et al. (2018), for using interview in research is that it allows for greater depth than is the case with other methods of data collection. In this study, two semi-structured interview guides (Teacher Challenges Interview Guide and Students' Perceptions Interview Guide), each with five open-ended items were designed by the researcher. Teacher Challenges Interview Guide (Appendix G) was used to solicit teachers' views on the challenges they encounter in the teaching and learning of writing and naming of binary compounds. Students' Perceptions Interview Guide (Appendix H) was also used to solicit students' perceptions of using locally constructed Model Kits in teaching and learning of writing and naming of binary compounds.

3.6.2 Achievement Test

Tests, according to Creswell (2014), are commonly used in quantitative research to measure the performance of research participants. The gains or attainment level of a student after going through a sample of learning task is called academic achievement. Achievement test measures the knowledge gained from formal learning situations. In this study, two sets of achievement test were designed by the researcher. The tests were in the form of pre-test, post-test, delayed post-test 1 and delayed post-test 2, which were used to measure junior high school students' performance and retention of writing and naming binary compounds. The pre-test and post-test consisted of essay-type items on writing and naming of binary compounds. However, the delayed post-test 1 and delayed post-test 2 consist of parallel and reshuffled items from the pre-test and post-test, respectively. The pretest was used to determine students' entry characteristics prior to the intervention, while the posttest, delayed posttest 1 and delayed posttest 2 were used to assess the efficacy of locally constructed Model Kits on JHS students' performance and retention of writing and naming of binary compounds.

3.7 Validity of the Instruments

In order to assess the validity of the instruments, the interview guides and the achievement tests were given to a panel of two experienced science education researchers and two chemistry lectures for their comments and suggestions (Elangovan, & Sundaravel, 2021). The pretest, posttest, delayed posttest 1, and delayed posttest 2 were given to panelists to evaluate the items' ability to measure students' performance and retention of writing and naming binary compounds. After the various comments and suggestions by the panelists, modifications were made on the items where necessary.

3.8 Pilot-Testing of the Instruments

After the review of the instruments by the panelists, the instruments were pilot-tested using JHS students from the same population but did not take part in the main study. Forty-two (two intact classes) students were selected to participate in the piloting of the instruments. The choice for the sample size for the pilot-testing conformed to the recommendation by Hertzog (2008) who suggests that participants for pilot-test should preferably be a minimum of 30-40.

3.9 Reliability of the Instruments

Two raters received the pilot test results for scoring because the instruments included essay-type items. After that, reliability studies were performed on the raters' scores using Cohen's kappa, an inter-rater reliability measure. The pre-test, post-test, delayed post-test 1, and delayed post-test 2 yielded kappa values of 0.732, 0.719, 0.779, and 0.765, in that order. According to Mchugh (2012), these values indicate moderate agreement between the raters for each set of instrument. As a result, the pilot test results were considered reliable enough to be utilized for the main study's instrument.

3.10 Data Collection Procedure

During data collection, both quantitative and qualitative data were collected and this lasted for a period of 12 weeks. The data collection procedure was done in three stages.

3.10.1 Pre-Intervention Stage

In the first phase of the procedure, official permission was sought from the various head teachers of the selected schools for the study. The various JHS integrated science teachers were also informed, and their consent sought. The purpose and benefits of the study were explained to school heads, various integrated science teachers and students from sampled schools, and assuring them of confidentiality of the results and information provided by teachers and students. This was done in the first week of April, 2023. After permission was granted by the various school heads to begin the study, 12 JHS integrated science teachers in the Sekyere Central District were sampled to be interviewed in order to ascertain the various challenges JHS teachers encounter in using hand-on activities during the teaching and learning of integrated science. Teachers' consent was therefore sought for their opinions to be recorded for subsequent transcription and analysis. This activity took place in the third week of April, 2023.

Subsequently, four (4) JHSs in the Sekyere Central District were randomly sampled to participate in the quantitative phase of the study, where random sampling was also employed to categorise the schools into experimental and control groups. To ensure that there would be no interaction which would affect the validity of the results of the study, each sampled JHS was randomly selected from different circuits. The sampled schools were then visited, in the fourth week of April, 2023 to begin the pretest. In order to ensure that students were prepared for the pretest, students were informed one week prior to the conduction of the pretest. In the first week of May, 2023, the pretest was conducted in the sampled schools. The pretest was to ensure that students who participated in the study performed at approximately equal levels before the intervention. The pretest was conducted by the researcher in the sampled schools. Because the same instrument was used for the posttest, the marked scripts were not given to the students.

3.10.2 Intervention Stage

After successfully conducting the pretest, the next phase of the data collection, which was the intervention stage, began. At this stage, the researcher taught the content in all four (4) sampled schools in order to control for teacher differences. The intervention stage lasted a period of four (4) weeks (from second week of May to second week of June), where the principles of writing and naming of binary compounds were taught to both experimental and control schools. However, during the intervention, the experimental group was taught writing and naming of binary compounds using the locally constructed Model kits, while the control group was taught the same principles without the Model Kits.

3.10.3 Description and Construction of Model Kits

3.10.3.1 Description of the Y-shaped Model Kit

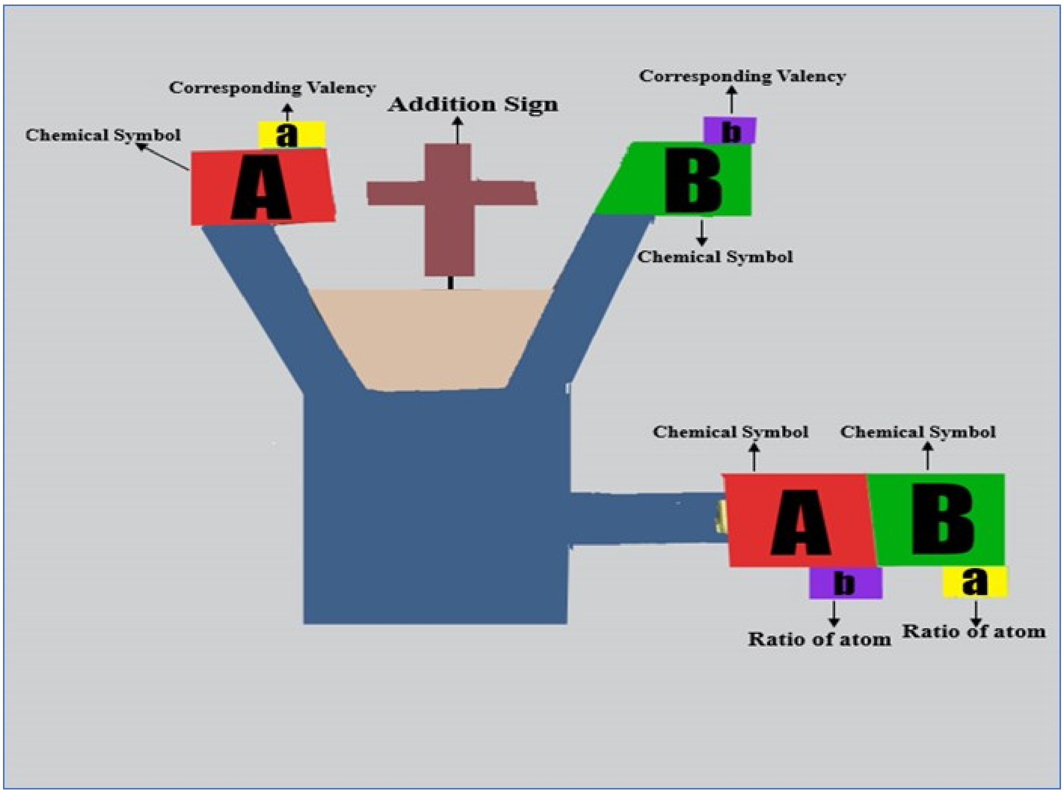


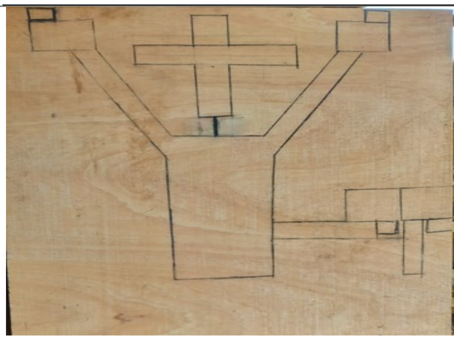
Figure 4: A Pictorial Representation of the Y-Shaped Model Kit

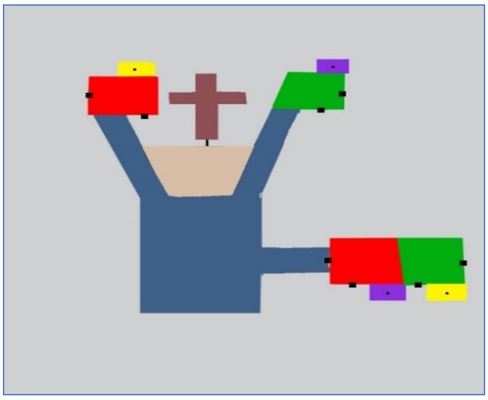
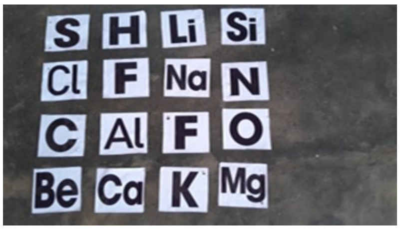
Figure 3.1 is a representation of the Y-Shaped Model Kit. It consists of the positions of chemical symbols and their corresponding valencies. **A** and **B** are positions for chemical symbol, while **a** and **b** are positions for valencies of atoms in the two upper arms. **A** and **B** are positions for chemical symbols, while **a** and **b** are positions for the ratios of atom in the lower arm.

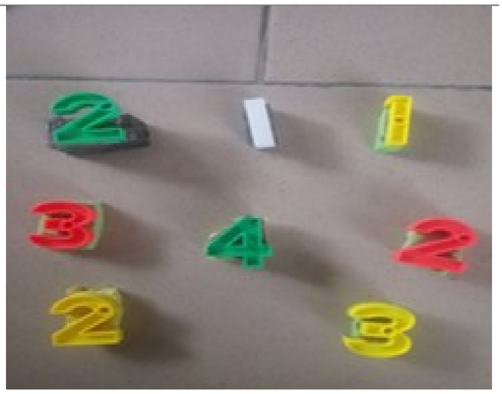
3.10.3.2 Construction of Y-Shaped Model Kit

The Y-Shaped Model Kit was constructed using a piece of plywood, printed numerals, printed chemical symbols, shower sandals, pencil, saw, super glue and brush. Table 1 presents the procedure used to construct the Y-Shaped Model Kit.

Table 1: Steps in Constructing the Y-Shaped Model Kit

Step	Description	Diagram
1	Draw the outline of the Y-Shaped Model on a plywood.	
2	Cut- out the Y-Shaped Model drawn on the plywood.	

3	Support the cut-out of the Y-Shaped Model behind to enable it stand firmly.	
4	Paint the position of the first chemical symbol on the left upper arm in orange colour. The position for its corresponding valency at the top of the chemical symbol yellow. The addition sign in the middle brown. The position for the second chemical symbol on the right upper arm green. The position for its corresponding valency at the top of the chemical symbol violet. The position for first chemical symbol on the lower arm orange and the ratio of atom below it violet. The position for the second chemical symbol on the lower arm green and the ratio of atom below it yellow.	
5	Print the chemical symbols and cut them out individually.	

6	Cut-out 5cm by 5cm square of 20 pieces of plywood.	
7	Fix the printed cut-out the chemical symbols on the pieces of plywood.	
8	Fix the printed numerals representing the valencies on pieces of shower sandals using super glue.	

It is important to note that, for easy identification of the parts and use paint the parts with various colours. Also, put one nail on each of the parts for the valency and ratio of atom to help fix the valency and ratio of atom. Again, put clippers on the parts of the chemical symbols to help fix the chemical symbols.

3.10.4.1 Description of the Valency Arm Model kit

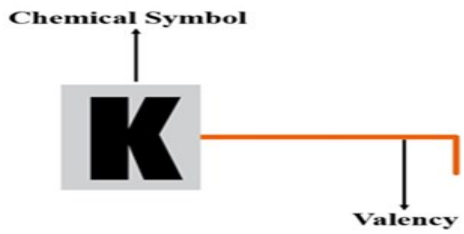


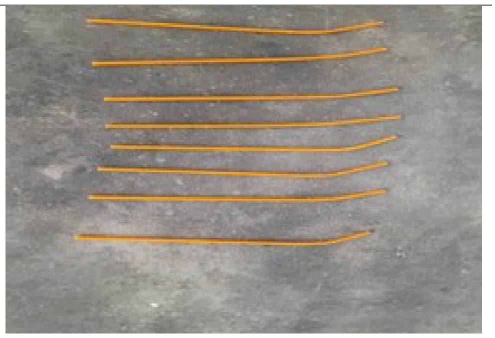
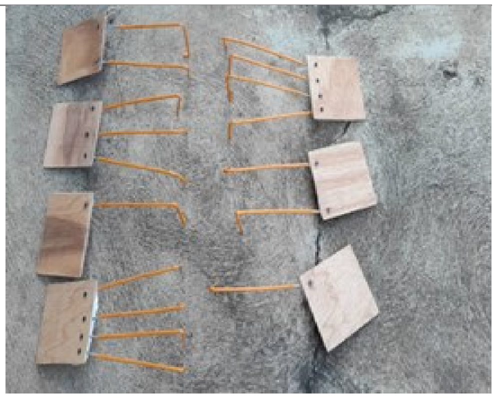
Figure 5: A Pictorial Representation of the Valency Arm Model Kit

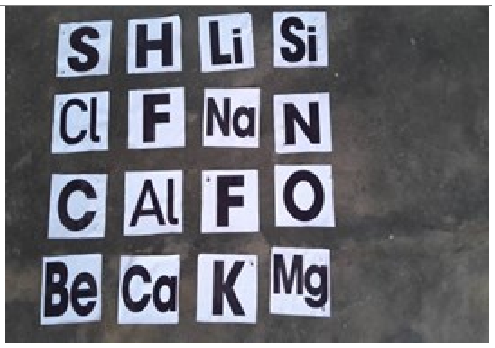
Figure 2: is a representation of the Valency Arm Model Kit. It is consisted of chemical symbol of the element and its corresponding valency of the element.

3.10.4.2 Construction of Valency Arm Model Kit

The Valency Arm model kit was constructed using a piece of plywood, nails, printed chemical symbols, pencil, screw, aluminium metal rods, hammer and hacksaw blade. Table 2 presents the procedure used to construct the Valency Arm Model Kit.

Table 2: Steps in Constructing Valency Arm Model Kit

Step	Description	Diagram
1	Cut-out 20 small square pieces of plywood of about 5cm by 5cm.	
2	Cut pieces of aluminum metal rods of about 30 cm long, broaden one end and create a hole there using a hammer and a nail.	
3	Wrap a straw around each aluminum metal rod to prevent any possible damage to the student.	
4	Fix the aluminum metal rods based on the valency of the atoms at one end of the square plywood using a screw.	

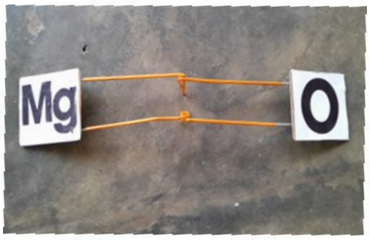
5	Print the chemical symbols and cut them out individually	
6	Fix the printed chemical symbols on each plywood based with their respective valencies	

3.10.4.3 Application of the Locally Constructed Model Kits for the Teaching of Binary Compounds

This section offers four instances of how to use the locally constructed Model Kits to instruct students in writing and naming of binary compounds. The section specifically shows examples of forming silicon dioxide and magnesium oxide using our Valency Arm Model and aluminum oxide and calcium fluoride using the Y-Shape Model Kit.

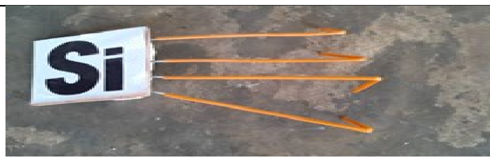
Exemplar 1: Forming the chemical formula of Magnesium oxide (MgO) using the Valency Arm Model Kit. The step-by-step procedure for forming magnesium oxide (MgO) with the Valency Arm Model Kit is displayed in Table 3.

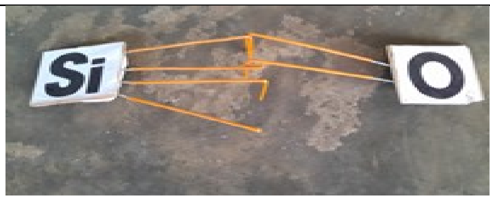
Table 3: Step-by-Step Procedure of Writing the Chemical Formula of Magnesium oxide Using Valency Arm Model Kit

Step	Description	Diagram
1.	Let students select the Valency Arm Model of Magnesium (**Mg**) with two valencies.	
2.	Guide students to connect the Valency Arm Model of Oxygen (O) with two valencies to the magnesium Valency Arm Model.	
3.	Students brainstorm to name the binary chemical formula they arrived at following Step 2.	**MgO**

Exemplar 2: Writing the chemical formula of Silicon dioxide (SiO_2) using the Valency Arm Model Kit. The step-by-step procedure for forming silicon dioxide (SiO_2) with the Valency Arm Molecular Model Kit is displayed in Table 4.

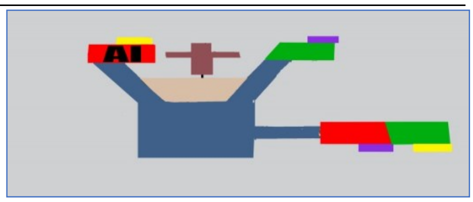
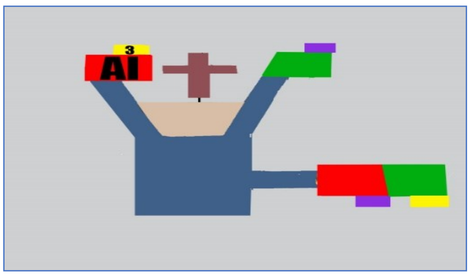
Table 4: Step-by-Step Procedure of Forming the Chemical Formula (SiO_2) Using Valency Arm Model kit.

Step	Description	Diagram
1.	Let students select the silicon (**Si**) Valency Arm Model with four valencies.	

2.	Guide students in connecting the Valency Arm Model of oxygen (**O**) with two valencies to the silicon Valency Arm Model.	
3.	Guide students connect the other two silicon valencies with another oxygen Valency Arm Model.	
4.	Students brainstorm to come up with the name of the binary chemical formula that was discovered following Step 3.	**SiO_2**

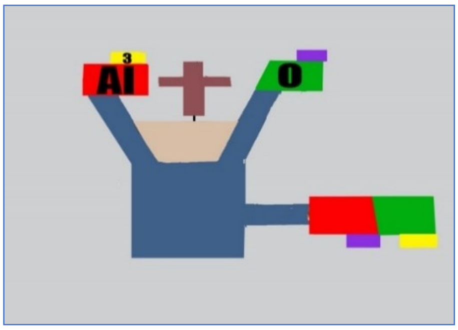
Exemplar 3: Writing the chemical formula of Aluminum oxide (Al_2O_3) using the Y-Shaped Model Kit. The detailed procedure for utilizing the Y-Shaped Model Kit to write Aluminum oxide (Al_2O_3) are provided in Table 5.

Table 5: Using a Y-shaped Model Kit to Form Al_2O_3

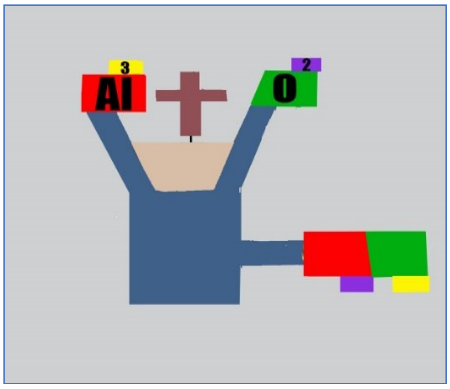
Steps	Description	Diagram
1.	Help students to attach the atomic symbol **Al** to the model's left arm's orange color.	
2.	Assist students in placing the corresponding valency 3 on the yellow	

section above **Al** on the model's left arm.

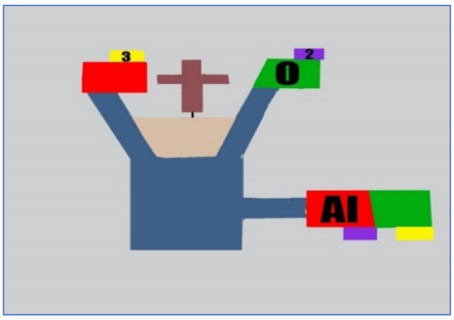
3. Assist students in attaching the chemical symbol **O** to the green-painted portion on the model's right arm.



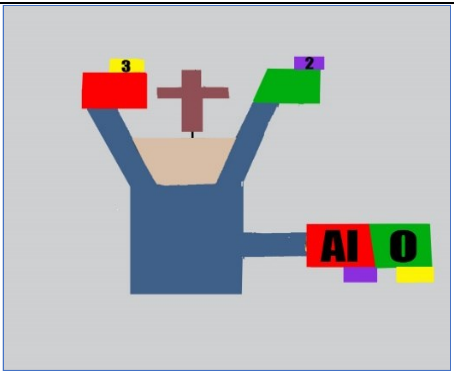
4. Assist students in fixing the corresponding valency 2 on the violet color above **O** on the model's right arm.



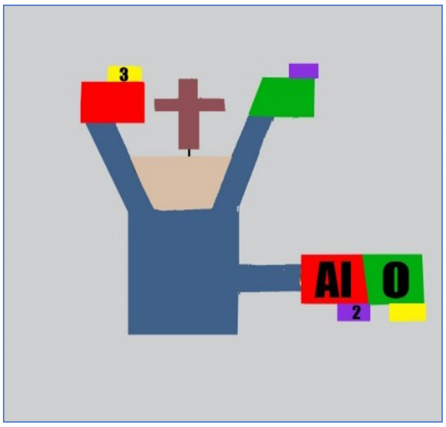
5. Assist students in taking out the chemical symbol **Al** from the left arm and replacing it on the orange-painted portion of the model's lower arm.



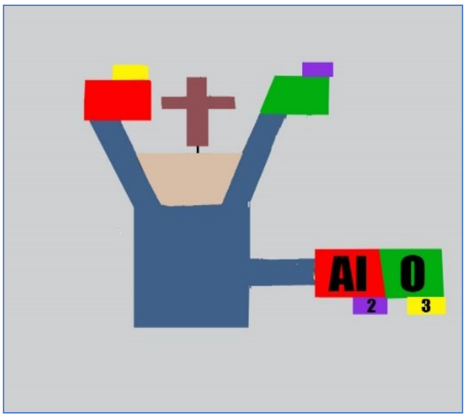
6. Assist pupils with removing the chemical symbol **O** from the right arm and placing it on the green area that has been painted on the model's lower arm.



7. Help students take off the valency 2 on the left arm and replace it on the area of the model's lower arm that is painted violet beneath **Al**.



8. Help the students take off the valency 3 on the right arm and attach it to the yellow area on the model's lower arm below **O**.

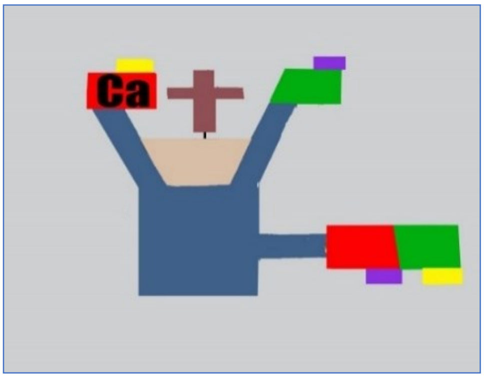
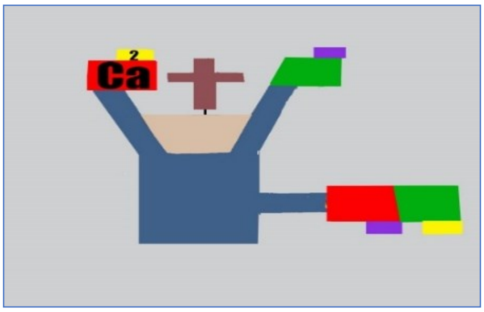
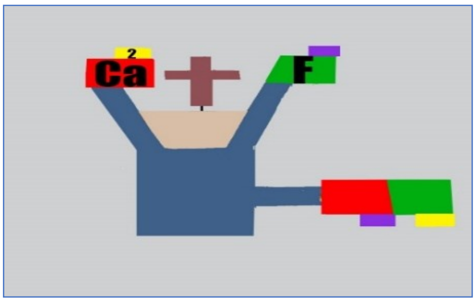
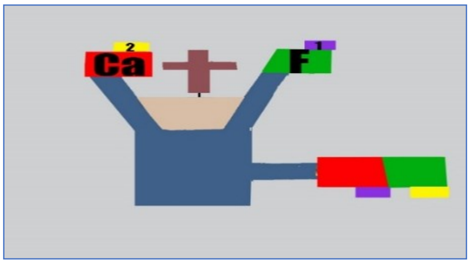


9. Students should brainstorm to name the binary chemical formula they arrived at following Step 8.

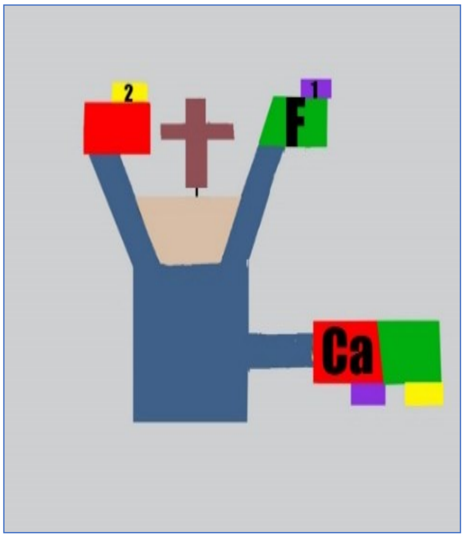
Al_2O_3

Exemplar 4: Writing the chemical formula for Calcium fluoride (CaF_2) using Y-shaped Model Kit. As shown in Table 6, Calcium fluoride (CaF_2) can be written using the Y-Shaped Model Kit through the following step-by-step procedure.

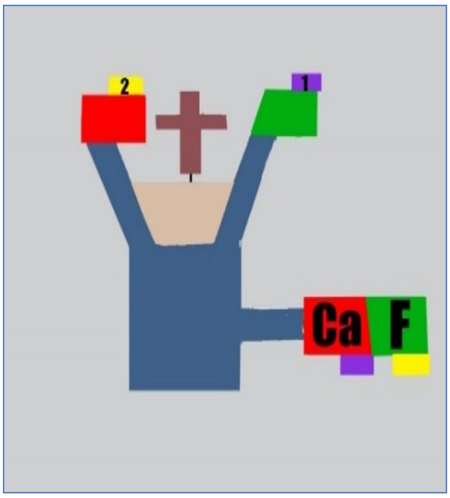
Table 6: Step-by-Step Description of How to Use the Y-Shaped Model Kit to form Calcium Fluoride (CaF_2)

Step	Description	Diagram
1	Assist students attach the chemical symbol **Ca** to the orange-painted portion of the model's left arm.	
2	Assist students in attaching the corresponding valency **2** to the yellow-painted portion on the model's left arm.	
3	Help students affix the chemical symbol **F** to the green-painted portion on the model's left arm.	
4	Assist students in placing the matching valency **1** on the section of the model's right arm that has been painted violet.	

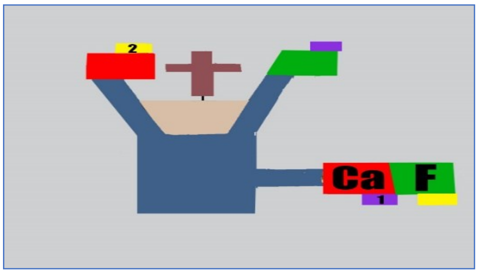
5 Assist students in removing the chemical symbol **Ca** from the left arm and replacing it on the orange-painted portion of the model's lower arm.



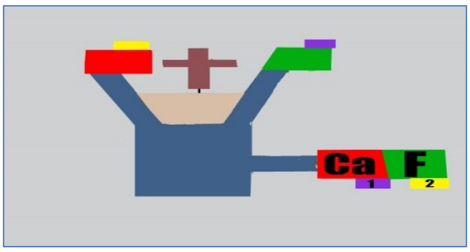
6 Help students take off the chemical symbol **O** from the right arm of the model and attach it to the area of the model's lower arm that has been painted green.



7 Assist students in taking off the valency 1 on the left arm and replacing it on the area of the model's lower arm that is painted violet beneath **Ca**.



8. Assist students in taking off the valency 2 on the right arm and replacing it on the yellow-painted



	area below the symbol **F** on the model's lower arm.	
9.	Students should brainstorm to name the binary chemical formula they arrived at following Step 8.	**Ca_1F_2** **CaF_2**

3.10.5 Post-Intervention Stage

After the intervention stage, students were given one week to revise their notes, after which the posttest was conducted. This took place in the first week of July, 2023. The conduction of the posttest was also done by the researcher from the various schools. The same instrument which was used during the pretest was used for the posttest. Also, students' ability to retain the learned principles and concepts of writing and naming of binary compounds was measured at three-week intervals, specifically during the post-test, delayed post-test 1, and delayed post-test 2. According to Coleman (2022) and Clearwater (2022), learners tend to forget between 50% and 70% of the concepts they acquire in a day or two, and 90% of them in a week. Regarding the precise time frame for assessing learners' retention of concepts, there is, nevertheless, disagreement in the literature. For example, Kovács et al. (2019) assessed learner retention after two months, whereas Valderama and Oligo (2021) assessed it weekly for seven weeks in a row. In order to assess students' retention, Faught et al. (2016) also employed a three-month interval across a 12-month period.

After conducting the delayed posttest 2, twelve (12) JHS students from the experimental group were sampled for an interview to ascertain qualitatively, their perceptions towards the use of locally constructed model kits in the writing and naming of binary compounds. As with the teachers, students' permissions were also sought for their perceptions to be recorded for further transcribing and analysis. The quantitative and qualitative data were then ready for analysis.

3.11 Data Analysis Procedure

This study employed a multi-phase mixed method design where the collected data were qualitatively and quantitatively collected in multiple phases and analysed to answer the research questions. The nature of research question 1 in this study was qualitative and was thus answered using thematic analysis from the responses of teachers in the interview. Also, research question 2 was quantitative in nature and was answered using means, standard deviations, mean difference, normalized gain and effect size on the pretest and posttest scores of experimental and control groups. However, inferentially, any difference in mean scores of the posttest scores between the experimental and control groups was tested using an independent sample t-test since there was no significant difference in the pretest scores of both groups (Pallant, 2011). By so doing, hypothesis 1 was tested.

Similar to research question 2, research question 3 was quantitative in nature and was answered quantitatively using the means, standard deviations and mean differences on the posttest, delayed posttest 1 and delayed posttest 2 scores of experimental and control groups. Any difference(s) in mean scores were inferentially tested using Mixed Between Within-Subjects Analysis of Variance, also known as Split-Plot Analysis of Variance (SPANOVA) since the same subjects (participating students) were measured at different times (Pallant, 2011). This was done in order to test hypothesis 2. Research question 4 was also qualitative in nature and was therefore answered qualitatively using thematic analysis from the perceptions of the students which were solicited during the face-face interview with 12 randomly selected participants from the experimental group.

3.12 Ethical Consideration

Permission to conduct the study was sought beforehand from head teachers, JHS science teachers, as well as the students. During the first interactions, the goal of the study was explained and assurances were given about its secrecy. Therefore, the students' and participating schools' names were rendered anonymous to maintain anonymity.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter highlights the presentation of the results and findings of this study, as well as the discussion of the findings. Descriptive, inferential, and thematic analyses were conducted on the data collected. The results are presented according to the research questions.

4.1 Results for Research Question 1

What challenges do JHS teachers of integrated science face in teaching writing and naming of binary compounds?

The challenges were sought from teachers qualitatively through semi-structured interview. Teachers' responses were thematically analysed, where the themes include unavailability or outmoded teaching and learning materials, lack of improvisational skills, inadequate support from authorities, insufficient time to complete the syllabus, and large class size. Some representative statements from sampled teachers were transcribed and presented. Names used in representative statements are pseudonyms.

Theme 1: Unavailability or outmoded teaching and learning materials (TLMs)

One of the major challenges JHS teachers reported that they encounter in the teaching of writing and naming of binary compounds in Integrated Science is unavailability or outmoded teaching and learning materials (TLMs). Teachers complained that since majority of the teaching and learning materials they require to successfully teach the concepts of integrated science are lacking, it becomes very difficult to effectively engage students in the teaching and learning process. For instance, Yaw stated that:

> "*There are no teaching and learning materials at our disposal which will help us employ hands-on activities in our lessons. Sometimes it is very difficult to plan any hands-on lesson when the materials which will help us do that effectively are not available. In my school here, I can confidently say that, we do not have one chemistry material, model or apparatus which we can use to plan hands-on lessons. What I do is that I teach them by drawing diagrams and writing structures and equations on the board and explain the processes to them*".

Kwame also stated, with regards to unavailability and outmoded teaching and learning materials that:

> "*One major challenge which I think is preventing us from using hands-on activity is that, we do not have appropriate teaching and learning materials. Even if some materials are available, they may be outdated, in poor condition, or insufficient in quantity. This limits the effectiveness of hands-on activities and creates frustration for both teachers and students. For example, we used to have few laboratory apparatuses like test-tube rack, models which depict atoms of the various elements, burettes and pipettes, which we used during the teaching of some chemistry concepts. However, all of them are not in good condition to use anymore*".

Moreover, Nti said that:

> "*It is true that we encounter difficulties in using hands-on activities, and one of them is the lack of teaching and learning materials. Sir, I have taught science at the JHS for ten years and one of the topics I find my students expressing difficulty in understanding is naming of compounds and balancing chemical equations. I once went to the internet to see if I could get a demonstration to help them understand better how the principles work. I found a video, but how there was no means to show this video because we do not have projectors and even no electrical socket. Later, I thought to find representative objects to demonstrate to them, but I found none. This is really posing some great challenges, and you know we all want our students to understand every concept we teach them, not only for examinations, but also for life-long learning*".

Theme 2: Lack of improvisational skills

JHS science teachers further stated that, another major challenge in writing and naming of binary compounds is the lack of improvisational skills. Teachers expressed that, sometimes they desire to improvise some of the appropriate and necessary teaching and learning materials, but they only have limited knowledge and skills to improvise these materials. For instance, in the interview, Mansa highlighted that:

> "*… of course, we lack the necessary teaching and learning materials to effectively teach the Chemistry concepts in science. However, the knowledge and skills to improvise some of these materials in the absence of the standard ones are limited. Sometimes, personally I will have to pay others to design some materials for me but I saw it drains me financially so I stopped*".

Tevo in relation to lack of improvisational skills also stated that:

> "*… as for me, I have never attempted to improvise because I know that I do not have the necessary skills to do so. Even how to gather the appropriate materials and construct them into a unit is a challenge for me. Sometimes, I look for videos and if I cannot use the videos due to circumstantial challenges beyond me, I teach the way students can understand*".

In another voice, Foriwaa also stated that:

> "*Oh, for me I think one of the major challenges to use hands-on activities is that I do not have the needed skills to create artificial objects using locally-made materials. Maybe I will need to learn further on that, because if the school and authorities cannot afford or replace malfunctioning teaching and learning materials, the best way the teacher can help as a problem solver, is to design alternative ones. But currently, the skills and knowledge to do so are lacking*".

Theme 3: Inadequate financial support from authorities

In their quest to use hands-on activities in the teaching of writing and naming of binary compounds, JHS science teachers lamented that they lack the adequate support from school and educational authorities in various schools. For example, Bossman articulated that:

> "*This issue of teaching Chemistry concepts theoretically has been the latest deliberation among some teachers in our school here. Our major concern is not students passing their examinations, but the skills they would acquire after the three years of training in science, which will equip them to adapt to high school and advanced learning. But in my school here, I think this challenge does not*

hang on the shoulders of only the teacher, but also the authorities. I think we do not have the necessary support from the authorities. For instance, there are some materials like molecular models, which will expose the student to the reality of the Science or Chemistry they are learning. Purchasing these is beyond the responsibility of the teacher. I cannot use the little salary I receive to fund my classroom lessons and activities. I think the authorities have to intervene".

Hawa also articulated that:

"*Oh, I think the authorities are not helping in this situation. I do not know who is responsible to provide the needed assistance to help teachers use hands-on activities in teaching Chemistry concepts in science. There are times science teachers in this school want to use hands-on activities in some lessons, and when we put it before our head, he will only tell us that there is no money to supply the materials for that lesson. I remember, there was a time I wanted to teach formation and naming of compounds, and I thought it would be best to use some models or maybe something to represent these atoms and their charges I discussed with my head teacher if it would be possible to get some materials for students to practice these concepts experientially, but it was to no avail. So, like I said, I do not know who is responsible, but the reality is that, we lack the needed financial support*".

Moreover, Nelson also stated that:

"*It is very important to use hands-on activities to teach these concepts. But I know that hands-on activities frequently need supplies and equipment like lab* *tools, art materials, scientific kits, or even standard school supplies like paper, scissors, and glue. Therefore, without enough financing, teachers might not be able to buy these supplies, which would make doing hands-on learning challenging or impossible*".

Theme 4: Insufficient time to complete the syllabus

Another major challenge JHS science teachers reported that they encounter in the teaching and learning of writing and naming of binary compounds is insufficient time to complete the syllabus. Teachers reported that, the time they have been allotted to teach Chemistry concepts to prepare their students for final year examinations cannot help them to successfully use hands-on activities in their lessons, which they admit that its employment demands time. For instance, Peter articulated that:

"*The JHS science curriculum is voluminous, which teachers must make sure they complete before students sit for their Basic Education Certificate Examination (BECE); and completing this whole syllabus within a space of three years becomes a difficult task for me as a teacher. Sometimes, I wish I could use hands-on activities, but I realize the periods allotted for science on the time table are insufficient to use hands-on activities. Because, I know that to use hands-on activities requires thorough preparation, as well as making sure that all students fully participate in every activity, and that demands time. So, to do that always is very difficult, to be honest. And at the end of the day, I am going to be judged by how well students pass my subject. Imagine what will happen if I do not complete the syllabus with the reason of using hands-on activities for students to get better understanding of the concepts*".

Another teacher, Danso also expressed on issue related to time constraint that:

> "*Time is a major challenge to me as a science teacher, if I want to use hands-on activities in my science lessons to teach Chemistry concepts. This is because, I will have to plan these activities to include all students in the classroom, not neglecting anyone. And doing that is a difficult job to me as a teacher, seeing the numerous responsibilities we shoulder such as marking of exercises and assignments, as well as other co-curricular activities. Sometimes, if I want to do that, I will have to schedule extra classes for students after school, which I think some parents are not happy about. So, what I do is to explain concepts to them with diagrams and if possible, charts*".

Still concerning time as a challenge, teacher Adoma said in the interview that:

> "*… it is true that we want students to grasp concepts and own what they learn. But I think that can be possible if we get time. And at the moment that is not possible because students have to be tested on about eight or nine subjects before they can advance to the next level in their academic lives. Therefore, as a science teacher, who aims to complete the science syllabus within a short space of three years, I only have to try alternative ways to help students learn concepts which will not demand a lot of time*".

Theme 5: Large class size

Teachers bemoaned the large class sizes in the JHSs was not helping them to effectively include all students to participate in every lesson they plan to use hands-on activities. In specificity, Kyei voiced out that:

"*Hmmm, this question is worth asking. My colleague teachers and I always complain about the large class sizes in our school. You know that most of the Chemistry concepts we teach are abstract and students need to experience them through concrete activities before they can understand them better. However, since the class sizes are very large, which in my school, there are averagely 50 JHS students per class, it becomes difficult to plan activities which can include all learners in the lesson. So, what I resort to is only to draw diagrams on the board and sometimes complement with some textbook stuff and that is it*".

Dede also added to Kyei's voice that:

"*… sir, in my school for instance, on the average there are 53 JHS students in each classroom. Looking at this, obviously it will be very challenging to involve all students to actively participate in hands-on lessons; and Science or Chemistry is not a subject we can only lecture to students, who at this stage in their academic journey, need to feel what they learn in real life in order to develop positive attitudes towards the subject, as well as helping them to better understand the concepts better*".

On the challenge of large class size, James also expressed that:

"*Sir, the JHS classes we have been assigned to teach are too large. This is very challenging in terms of planning hands-on activities during the teaching of some of the Chemistry Concepts. For instance, the teaching of atoms and compounds, acids, bases and salts, mixtures etc., in my opinion need to be taught hands-on, because these concepts are abstract. When you tell a student to give the name of a compound and you teach him only the principles by stating* *them on the board,* the *only consequence is that; the student will soon forget everything because they will be forced to memorise the principles without any active engagement of these principles. And this too must be planned so that all students will actively participate, but when you have a class of 50 students and above, it becomes difficult to include all students in our Ghanaian context*".

4.2 Results for Research Question 2

What is the effect of locally constructed Model Kit on JHS students' performances in the writing and naming of binary compounds?

The research question was analysed quantitatively. Specifically, mean, standard deviation, mean difference, normalized gain and effect size were used on the pretest and posttest scores of JHS students in the experimental group (taught using locally constructed model kit) and control (taught using conventional teaching method) of which the results are presented in Table 7.

Table 7: Descriptive Statistics of Pretest and Posttest Scores of Experimental and Control Groups

Group	N	Pretest Mean (M1)	SD	Posttest Mean (M2)	SD	Effect Size (*d*)	Normalized Gain (*g*)
Experimental	69	8.87	2.711	20.06	4.011	1.38	0.53
Control	67	8.76	2.075	15.66	2.056		0.32
Mean Diff.		**0.11**		**4.40**			

As revealed in Table 7, there was an improvement in the performance of the experimental group from the pretest (M=8.87, SD=2.711) to the posttest (M=20.06, SD=4.011), as well as an improvement in the performance of the control group from the pretest (M=8.76, SD=2.075) to the posttest (M=15.66, SD=2.056). However, after the intervention, the posttest scores revealed that the experimental group obtained a higher mean posttest score than the control group leading to a mean difference of 4.40.

To further evaluate the impact of each of the two teaching methods on JHS students' performance in naming binary compounds, the class average normalized gain was also calculated, as shown in Table 7. The normalized gain accounts for differences in the pretest scores by determining what fraction of the total possible gain from pretest to posttest is achieved (Coletta & Steinert, 2020; Lorenzo et al., 2006). Normalized gain, g, proposed by Hake (2002) is defined as the change in score divided by the maximum possible increase, as shown in Appendix E.

Hake (2002) developed a scale of interpretation to interpret normalized gain values. According to Hake's gain classification, $g \leq 0.3$ = low gain; $g \leq 0.7$ = medium gain; $g \geq 0.7$ = high gain. Therefore, from Table 4.1, the normalized gain (g) for the experimental group was 0.53, which falls in the medium gain category. However, the control group obtained a normalized gain, g of 0.32, which falls into the low gain category. Therefore, comparing the experimental and control groups, the experimental group benefited more from the treatment than the control group.

Furthermore, the magnitude of the difference between the experimental and control groups was determined by an effect size analysis using Cohen's *d* formula (Appendix F). This involves determining the difference in the mean scores between the posttest mean scores of the experimental and control groups, and dividing by the pooled standard deviation.

Pallant (2011) states that $d \leq 0.2$=small effect, $d \leq 0.5$=medium effect, and $d \geq 0.8$ = large effect. Therefore, as revealed in Table 7, the effect size (*d*) value of 1.38 indicate a large effect.

4.3 Testing Hypothesis 1

The results of research question 2 revealed that the use of locally constructed Model Kit was more effective than the conventional teaching method. Therefore, to determine whether the effect of using locally constructed Model Kit on JHS students' performances in writing and naming binary compounds was statistically significant, research question 2 was formulated into a null hypothesis and tested using an independent sample t-test (assuming equal variances). This is because before the intervention, students in both groups were compared based on their prior performances using their pretest scores to determine whether students in both groups performed significantly equal. An independent sample t-test was thus conducted on the pretest scores of experimental and control groups.

However, an independent sample t-test assumes that the pretest scores collected should approximate normal distribution. As a result, normality test was conducted on the pretest scores for both groups. The normality test on the pretest scores was conducted using Shapiro-Wilk's test, which Kwak and Park (2019) argue that is a more powerful test to determine the normality of collected data in a study. According to Kwak and Park (2019), the null hypothesis for normality test is that the data are normally distributed, which means that the null hypothesis is rejected if the p-value is less than 0.05. The results of Shapiro-Wilk tests of normality are presented in Table 8.

Table 8: Results for Shapiro-Wilk Test of Normality for Pretest Scores of Experimental and Control Groups

		Shapiro-Wilk		
	Group	**Statistic**	**df**	**p**
Pretest	Experimental	.968	69	.079
	Control	.966	66	.067

From Table 8, it can be seen that the Shapiro-Wilk test of normality of the pretest scores for experimental and control groups were 0.968(p=0.079) and 0.966(p=0.067) respectively. The results as presented in Table 8 indicate that null hypothesis, which states that the data were normally distributed was accepted for the pretest scores for the experimental and control groups.

Also, an independent sample t-test maintains that the variances in pretest scores within the experimental and control groups should be equal (Pallant, 2011). According to Pallant (2011), the assumption of equal variances operates on the null hypothesis that the variances in scores for both groups are equal. As such, the null hypothesis is rejected if the p-value is less than 0.05. This assumption was tested and the results are presented in Table 9.

Table 9: Results for Test of Assumption of Equal Variances in Pretest Scores for Experimental and Control Groups

		Levene's Test Statistic	
		F	**p**
Pretest	Equal Variances Not Assumed	4.908	.028

As seen in Table 9, the Levene's test statistic, F, which tests for the assumption of equal variances in pretest scores within each group was significant (F=4.908, p=0.028). Therefore, the null hypothesis was rejected, suggesting that the variances in pretest scores within each group were not equal. Hence this assumption was violated. Therefore, using the second row of the output generated by SPSS, the results of the independent sample t-test are presented in Table 10.

Table 10: Results of Independent Sample t-test on Pretest Scores of Experimental and Control Groups

Group	N	Mean	SD	t	df	p
Experimental	69	8.87	2.711	.262	134	.794
Control	67	8.76	2.075			

As revealed in Table 10, there was no significant difference in pretest score between the experimental (M=8.87, SD=2.711) and control groups (M=8.76, SD=2.075; $t_{(134)}$=0.262, p=0.794). This indicates that JHS students assigned to both experimental and control groups were at significant equal levels of performance.

Since there was no significant difference in pretest scores between the experimental and control groups prior to the intervention, as shown in Table 9, hypothesis 1 was therefore tested using an independent sample t-test on the posttest scores of experimental and control groups. Hypothesis 1 thus states that "*there is no significant effect of locally constructed model kits on JHS students' performances in writing and naming of binary compounds*".

However, an assumption of normality of posttest scores was tested prior to the conduction of the independent sample t-test on the posttest scores of students. Using the Shapiro-Wilk's test, the normality assessment, which Kwak and Park (2019) states is based on the null hypothesis that the data are normally distributed, was conducted on the posttest scores, and the results of the Shapiro-Wilk tests of normality are presented in Table 11.

Table 11: Results for Shapiro-Wilk Test of Normality for Posttest Scores of Experimental and Control Groups

		Shapiro-Wilk		
	Group	**Statistic**	**df**	**p**
Posttest	Experimental	.968	69	.076
	Control	.964	66	.055

From Table 11, it can be seen that the Sapiro-Wilk test of normality for the posttest scores for experimental and control groups were 0.968(p=0.076) and 0.964(p=0.055) respectively. The results as presented in Table 11 indicate that null hypothesis. Hence the posttest scores were deemed approximately normal. The independent sample t-test on the posttest scores of experimental and control groups was therefore conducted and the results are presented in Table 12.

Table 12: Results of Independent Sample t-test on Posttest Scores of Experimental and Control Groups

	Group	N	Mean	SD	t	df	p
Equal variances Not assumed	Experimental	69	20.06	4.011	8.087	102.097	.000
	Control	67	15.66	2.056			

Levene's test for equal variance: F = 27.763, p = 0.000

Table 12 reveals that there was a significant difference in posttest scores of experimental and control groups ($t_{(134)}$ = 8.087, p=0.000<0.05), indicating that the null hypothesis was rejected.

4.4 Results of Research Question 3

What is the effect of locally constructed Model Kit on JHS students' abilities to retain the concepts in the writing and naming of binary compounds?

The question was answered quantitatively using mean, standard deviation, and mean difference of posttest, delayed posttest 1 and delayed posttest 2 scores of experimental and control groups. The results are presented in Table 13.

Table 13: Descriptive Statistics of Posttest, Delayed Posttest 1 and Delayed Posttest 2 Scores of Experimental and Control Groups

Group	Posttest		Delayed Posttest 1		Delayed Posttest 2	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Experimental	20.06	4.011	18.36	2.491	16.99	2.592
Control	15.66	2.056	12.07	2.382	6.73	3.112
Mean Difference	**4.40**		**6.29**		**9.93**	

The results presented in Table 13 shows that, after the intervention, the trend in retention in the writing and naming of binary compounds for the experimental group observed in posttest, delayed posttest 1 and delayed posttest 2 were 20.06 (SD=4.011), 18.36 (SD=2.527), and 16.99 (SD=2.592) respectively. Also, the control group obtained a trend in retention scores of 15.66 (SD=2.056), 12.07(SD=2.382), and 6.73 (3.112) for posttest, delayed posttest 1 and delayed posttest 2 respectively. This resulted in an increase in mean differences of 4.40, 6.29 and 9.93 for posttest, delayed posttest 1 and delayed posttest 2 respectively.

The trend in retention in the writing and naming of binary compounds between the experimental and control groups can be inspected graphically using the estimated marginal means of pretest, posttest, delayed posttest 1 and delayed posttest 2 scores for both groups as shown in Figure 6

Figure 6: Trend in Retention in Writing and Naming of Binary Compounds of Experimental and Control Groups

As shown in Figure 6, in the three testing times (posttest, delayed posttest 1 and delayed posttest 2), there was a higher estimated marginal mean score for the experimental group than the control group. Nonetheless, as time progressed, the estimated marginal means for the control group reduced sharply from the posttest to delayed posttest 1, and subsequently to delayed posttest 2. Comparatively, there was a small decrease in estimated marginal mean scores from posttest to delayed posttest 1 and then to delayed posttest 2 for the experimental group.

The decrease in estimated marginal mean scores is a result of the fact that there was a decay in writing and naming of binary compounds within both groups as time progressed (Ansquer et al., 2019). However, Figure 6 shows that the decay of writing and naming of binary compounds within the control group was far more than within the experimental group.

4.5 Testing of Hypothesis 2

Hypothesis 2 states that there is no significant effect of locally constructed Model Kit on JHS students' abilities to retain the concepts in the writing and naming of binary compounds. This hypothesis was tested using a Mixed Between-Within Subjects Analysis of Variance, also known as Split Plot Analysis of Variance (SPANOVA) on JHS students' scores across three time periods after the intervention (posttest and delayed posttest 1 and delayed posttest 2). However, it was ensured that assumptions of normality, homogeneity of variance-covariance matrices also known as homogeneity of intercorrelations, and homogeneity of variances, were not violated.

The assumption of normality maintains that the three data set (posttest scores, delayed posttest 1 scores and delayed posttest 2 scores) are normally distributed across experimental and control groups. This is tested on the null hypothesis that "the data sets are normally distributed" (Kwak & Park, 2019). However, using Shapiro-Wilk's test of normality, the results of the normality assessment for the posttest scores of experimental and control groups are presented in Table 11. Therefore, Table 14 shows the results of Shapiro-Wilk's test of normality for delayed posttest 1 and delayed posttest 2 scores.

Table 14: Results for Shapiro -Wilk Test of Normality for Delayed Posttest 1 Scores and Delayed Posttest 2 Scores of Experimental and Control Groups

		Shapiro-Wilk		
	Group	**Statistic**	**df**	**Sig.**
Delayed Posttest 1	Experimental	.973	69	.142
	Control	.974	66	.187
Delayed Posttest 2	Experimental	.983	69	.487
	Control	.974	66	.170

As can be seen from Table 14, the Shapiro-Wilk test of normality for delayed posttest 1 scores for experimental and control groups were 0.973(p=0.142) and 0.974(p=0.187) respectively, and that of delayed posttest 2 scores for experimental and control groups were 0.983(p=0.487) and 0.974(p=0.170), indicating an acceptance of the null hypothesis. Hence the delayed posttest 1 scores and delayed posttest 2 scores were deemed approximately normal.

The assumption of homogeneity of intercorrelations according to Pallant (2011), upholds that for each of the levels of the between-subjects variable (between the groups), the pattern of intercorrelations among the levels of the within-subjects variable (repeated measures) should be the same. This assumption was thus tested using Box's M statistic, which operates on the null hypothesis that, the observed covariance matrices of the dependent variables are equal across groups. The results are presented in Table 15.

Table 15: Results for Box's Test of Equality of Covariance Matrices

Box's M	F	p
44.380	7.217	.000

Table 15 shows that the observed covariance matrices of the dependent variables were not equal across groups since the value of Box's M (44.380) was significant (F=7.217, p=0.000). Therefore, the assumption of homogeneity of variance-covariance matrices was violated.

Also, the assumption of homogeneity of variances was tested using Levene's test statistic, based on the null hypothesis that the variations in posttest, delayed posttest 1 and delayed posttest 2 scores are equal for experimental and control groups. The results are presented in Table 16.

Table 16: Levene's Test of Equality of Error Variances

	Levene Statistic, F	df1	df2	p
Posttest	27.763	1	134	.000
Delayed Posttest 1	.050	1	134	.823
Delayed Posttest 2	2.333	1	134	.129

From Table 16, Levene's statistic for posttest (F=27.763, p=0.000) was significant, while Levene's statistics for delayed posttest 1 (F=0.050, p=0.823) and delayed posttest 2 (F=2.333, p=0.129) were not significant. This means that the assumption of homogeneity of variances was violated for the posttest scores while there was non-violation of the assumption of homogeneity of variances for the delayed posttest 1 and delayed posttest 2 scores across the experimental and control groups.

Since there were violations of assumptions of intercorrelations as well as homogeneity of variances for posttest scores, and also with only two groups being compared in this study, Pillai's Trace was used as the test statistic for analysis instead of the commonly reported Wilk's Lambda (Pallant, 2011) in the conduction of the mixed between-within subjects analysis of variance. The results are presented in Table 17.

Table 17: Results of Mixed Between-Within Subjects ANOVA on posttest, Delayed posttest 1 and Delayed Posttest 2 Scores of Experimental and Control Groups

	Effect	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Time	Pillai's Trace	.734	183.721	2.000	133.000	.000	.734
Time * Teaching Method	Pillai's Trace	.440	52.319	2.000	133.000	.000	.440

There was, therefore, a significant interaction between the teaching method and the test period, as seen in Table 17 (Pillai's Trace =0.440, $F_{(2, 133)}$ = 52.319, p =0.000, partial eta squared =0.440). Additionally, as Table 4.6 and Figure 4.0 demonstrate, there was a significant main effect for test time (Pillai's Trace=0.734, $F_{(2, 133)}$= 183.721, p=0.000, partial eta squared=0.962). Both groups showed a decline in test scores over the course of the three testing periods, indicating a significant difference in the trend of retention in writing and naming of binary compounds between the experimental and control groups. Consequently, the null hypothesis is disproved.

Simple effect analysis was done to identify any significant differences in test scores for the experimental and control groups at each testing period because there was a significant interaction effect between the teaching technique and test time. The results are shown in Table 18. Since three comparisons were done simultaneously when performing the simple effect analysis, a Bonferroni correction was made to lower the possibility of making a Type I error, which is the rejection of the null hypothesis when it is true (Pallant, 2011). To apply the Bonferroni adjustment, the initial α-value of 0.05 was divided by the total number of comparisons—three in this case—to do the correction. This resulted in a new α-value of 0.0167. In light of this, the mean differences in Table 18 are considered significant if their p-values are smaller than 0.0167.

Table 18: Simple Effect Analysis of Posttest, Delayed Posttest 1 and Delayed Posttest 2 Scores Across Groups

Time	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Posttest	Experimental	Control	4.401*	.549	.000	3.315	5.487
Delayed Posttest 1	Experimental	Control	6.288*	.418	.000	5.461	7.115
Delayed Posttest 2	Experimental	Control	10.254*	.491	.000	9.284	11.224

Based on estimated marginal means

*. The mean difference is significant at the .0167 level.

b. Adjustment for multiple comparisons: Bonferroni.

In all the three testing times—the posttest (mean difference=4.401, p=0.000), delayed posttest 1 (mean difference=6.288, p=0.000), and delayed posttest 2 (mean difference=10.254, p=0.000)—there were significant differences between the experimental and control groups, as Table 18 demonstrates. Table 13 and Figure 1 demonstrate that these differences favored the experimental group.

4.6 Results for Research Question 4

What perception do JHS students have on the effectiveness of locally constructed Model Kit in the writing and naming of binary compounds?

This research question was also aimed at soliciting JHS students' perceptions on the effectiveness of locally constructed Model Kit in the writing and naming of binary compounds. Therefore, to answer this research question, 12 JHS students from the experimental group were sampled for a semi-structured interview where their responses and opinions were solicited, transcribed and analysed in themes. The perceptions of JHS students were grouped into four themes which are better understanding of the principles of writing and naming of binary compounds, improved attitude towards writing and naming of binary compounds, better retention of principles and concepts, and active participation in class lessons. Some representative statements from students under each theme are stated below.

Theme 1: Better Understanding of Principles

JHS students revealed in the semi-structured interview that the application of the principles in the naming and writing of binary compounds was not easily understood, as a result they could only memorise the formulae and names of some common compounds without applying the principles. However, the use of locally constructed

Model Kits in teaching and learning of naming and writing of binary compounds made them understand the principles better. For example, a transcribed voice from Zon stated that:

> "*… oh sir, so where were all these things that could be used to teach this topic? What I did when we studied this writing and naming of binary compounds at first was that, I did chew and pour for the names and formulas for some of the compounds, and those that were difficult to remember, I did not bother myself. But this time, how you even used that material to teach us is what I am happy about. At first, I thought it was a combination of any of the symbols of the elements. I now see and understand all the laws and principles which apply to writing and naming of binary compounds. For example, I now know that a positively charged ion can only form a compound with a negatively charged ion, and the positively charged ion must be a metal ion while the negatively charged ion must be a non-metal ion so that the compound formed will be electrically neutral*".

Bonza also stated that:

> "*Sir, I have now understood how the writing and naming of binary compounds work better than how we were taught at first. Now, I understand that, it is the charge and valency of the atoms that determine the nature of compound to be formed. For example, if we have Aluminium (Al) which is positively charged and has three valence electrons, it can only form a compound with a negatively charged atom with any valence electron, let's say Chlorine (Cl). And when they combine, the ions* Al^{3+} *and* Cl^{-} *will exchange their charges and be written as subscripts*".

Aziz also expressed that:

> "*Oh sir, that object you used to teach us writing and naming of binary compounds made me now understand the topic better. What I did since we learned this topic last term is to chew the formulas and names of some common compound in the past questions that regularly appear in the BECE. But from today I think I need to stop. Sir, in fact what has opened my eye and I think that is the first step to understand how the binary compounds are formed is the formation of the charges and valency of the atoms. To me, this is the breakthrough; because I know that the valency is determined from the number of electrons in the last shell of the atom, and the charge is determined by how many electrons is lost or gained in the last shell to become stable, and I know that an ion with positive charge cannot form a compound with another ion with positive charge, but only negative charge. Because of this sodium ion cannot form a compound with calcium ion because they are all ions with positive charges*".

Theme 2: Improved Attitudes Towards Science

JHS students also noticed how the use of locally constructed Model Kits had a positive effect on their attitudes towards writing and naming of binary compounds. For instance, a transcribed perception from Don stated that:

> "*Sir, one important thing that I have realized since you used that model to teach us writing and naming of binary compounds is that, I now enjoy the topic of writing and naming of binary compounds. At first the topic was boring, because everything from the principles to the application had to be" chew and pour". But, of late, I know how the principles work using the model. I will try and*

design one so that anytime I am doing further studies on my own and I find any difficulty to understand, I will apply it again".

To add to student Didier and Afi also expressed that:

"*Sir, what I can say about using this model to teach writing and naming of binary compounds is that, I now like the topic. Nowadays, anytime I close from school or during breaktime, I try to find question and solve on my own. And because I did not pay much attention at first, this time I want to understand everything under that topic so that I can perform well in my exams*".

Furthermore, Emefa stated concerning a change in attitude towards writing and naming of binary compounds using locally constructed Model Kits that:

"*…now I am beginning to like how to write and name binary compounds. I thought it was too difficult, not knowing they are easy principles to apply. I think it will be good if all science teachers use it to teach students how to write and name binary compounds*".

Theme 3: Better Retention of Concepts

JHS students further expressed the importance of the use of locally constructed Model Kits in helping them retain the application of principles of writing and naming of binary compounds. For instance, Deka stated that:

"*Sir, using the model to teach us was very good for me. If there is anything I remember more this term, it is writing and naming of binary compounds. Since the time you taught us this topic for about one month now, I still remember that, it is the ions of the atoms that are involved in forming the compounds and not* *the elements. So, if I want to form a compound involving potassium and Chlorine, I need to determine the ions of those elements first before I can form the compounds. And I know that the ions are formed using the electrons on the last shell, which is whether they gain or lose electrons for them to be stable*".

Zamza also stated that:

"*… sometimes I revise my notes but I almost remember whatever we did in the classroom during the writing and naming of binary compounds. And because of that, I even used the principle of positively charged ion to match negatively charged ion, and also the principle of outer shell electrons to practice on the other elements we did not practice in class. Now I do not need to chew and pour*".

Concerning retention of principles and concepts, student Novi uttered that:

"*Sir, I think it is good that you used this model to teach us writing and naming of binary compounds. It was very practical and that helped me to understand and remember all the principles and their applications involved in writing and naming of binary compounds. Especially, in the naming, I remember that binary compounds formulas start with the metal ions which is mostly the positively charged ion, followed by the non-metal ion which is mostly the negatively charged ion. Also, I remember that, when the compound is formed, the ions exchange their charges, and they are written as subscripts, but the subscripts should be written in their simplest ratios*".

Theme 4: Active Participation and Interest in Lessons

During the semi-structured interview, JHS students highlighted how happy they were with their participation in lessons using the locally constructed Model Kits. Students acknowledged the fact that being actively involved in the lessons during the use of the model was a major factor that made them understand the principles and concepts better, as well as developing interest in lessons.

In a transcribed view, student Bonfra stated that:

> "*…sir, what made me like the use of this model was that, I saw that almost everyone was involved in the activities we were doing in class. That even made me ask questions from my classmates when I did not understand some aspects. And I was also happy that my classmates helped me when I went to them to ask them questions*".

In another transcribed view, student Tevi also stated that:

> "*Sir, the use of this model is very interesting. I enjoyed every class because I saw that I was learning. I did not miss any class because how you were teaching us using the model made me gain more interest in science class. I felt that we were more involved during science lessons, and every student could ask or discuss with the other. That was good for me*".

In addition, from the voice of student Nana, it was stated that:

> "*Sir, I remember that I did not miss any science class when you taught us writing and naming of binary compounds. The use of the model made classes enjoyable, because we always took part in how the model was used. That made me get more interested in the lessons*".

4.7 Discussion of Results

The findings in this study are discussed in this section, which was done based on the research questions.

4.7.1 Discussion of Results for Research Question 1

Research question 1 sought to determine the challenges JHS integrated science teachers encounter in teaching writing and naming of binary compounds. Through a semi-structured interview, JHS teachers' views were sought and their responses were analysed in themes including large class size, inadequate support from authorities, unavailability or outmoded teaching and learning materials (TLMs), insufficient time to complete the syllabus, and lack of improvisational skills. This finding agrees with the findings of Dorsah et al. (2024), Handur et al. (2017), Mgbomo (2021) and Musharrat (2020). For instance, Musharrat (2020) and Handur et al. (2017) found that teachers do not get enough time to prepare for their classes properly, as well as huge student numbers in the classroom also prevent teachers from using hands-on activities. Mgbomo (2021) revealed the lack of support such as financial and incentive to motivate the teachers to improvise instructional materials. Dorsah et al. (2024), also reported that teachers experienced limited teaching and learning resources preventing them to use hands-on activities in teaching science. However, according to Uzor et al. (2022), despite these difficulties, science classroom hands-on activities are nevertheless incredibly beneficial for grabbing students' attention, encouraging critical thinking, and improving comprehension of scientific ideas. Therefore, through innovation, teamwork, and professional development, teachers who are passionate about adding hands-on learning frequently find solutions to these difficulties.

4.7.2 Discussion of Results of Research Question 2

Research question 2 also aimed to determine the effectiveness of locally constructed model kit on JHS students' performances in writing and naming of binary compounds. As a result, this research question was answered quantitatively using mean, standard deviation, mean difference and effect size on the pretest and posttest scores of the experimental group (JHS students taught using locally constructed Model Kit and control group (JHS students taught using the conventional teaching method). It was found that after exposure to the intervention, the experimental group had obtained a higher mean score than the control group (producing a significant mean difference between the experimental and control groups with a large effect size.

Moreover, in terms of their gain scores, using Hake's (2002) normalized gain, the experimental and control groups had low gains. Nevertheless, the experimental group (taught using locally constructed Model Kit) obtained a higher gain than the control group. This finding also agreed with the findings of Lombardi et al. (2014), Twizeyimana et al. (2020), Mushimiyimana et al. (2022), and Ibe et al. (2021), who all used locally constructed materials and found their potential impact to improve students' academic performances. The use of locally constructed Model Kits was effective because, Onuh (2022) suggests that when teaching with locally made objects, students are better able to relate abstract ideas being taught to experiences they have had in real life. Additionally, it supports scientific inquiry, discovery, and investigative approaches among students and fosters the growth of their creative faculties. Obiyo (2019) also asserts that the greatest way to learn a science subject is through active learning because this method helps students readily comprehend the material and perform well on tests and exams. This is because instructional materials make sure students see, hear, feel, identify, and enjoy as they study and use practically all five senses at once.

4.7.3 Discussion of Results of Research Question 3

What is the effect of locally constructed Model Kit on JHS students' abilities to retain the concepts in the writing and naming of binary compounds?

Models' tactile engagement and use of spatial imagery can significantly enhance students' memory and application of the guidelines for writing and naming binary compounds (Mushimiyimana et al., 2022; Udu et al., 2022). As a result, this study demonstrated that, in line with previous research (Mushimiyimana et al., 2022; Udu et al., 2022), using locally made Model Kits to teach writing and naming binary compounds in the context of teaching science in junior high schools in Ghana enhanced students' learning outcomes and increased retention of the underlying concepts. The present study's results are consistent with those of Lombardi et al. (2014), Horikoshi (2020), Obodo et al. (2020), Rivera and Sanchez (2020) and Quayson et al. (2022), who also discovered that the implementation of improvised models in the classroom fosters interactive learning experiences, thereby improving students' conceptual retention.

Because they were interactive and visually appealing, the Valency Arm and Y-shaped Model Kits were useful resources for improving students' recall in naming and writing binary compounds. (Stull et al., 2016) claim that by using Model kits, students may physically change and investigate atom-to-atom interactions, providing them with a tangible representation of the concepts involved in naming and writing compounds. For example, the Valency Arm allowed students to attach parts of different valencies, which improved their understanding of valency and the process by which elements come together to form a binary compound.

Additionally, as also discovered by Nsabayezu et al. (2023), by actively including students in the development and manipulation of models, these kits aid students in developing their knowledge of the ideas and procedures involved in writing and naming binary compounds. The use of models in the classroom aligns well with Constructivism and Kolb's Experiential Learning Theory, which promote problem-solving and critical thinking in students as they work through hands-on activities (Andres, 2017). This leads to a deeper and more permanent understanding of the concepts underlying the creation of binary compounds. This is consistent with theories of education that emphasize the importance of students' engagement and active learning in order to promote knowledge retention and application over the long term (McCarthy, 2016).

It is also important to note that students have different preferred learning styles, and these kits offer a multimodal approach that caters to those needs (Suprayogi et al., 2017). Some students could benefit more from employing visual aids, while others might acquire concepts more rapidly through practical exercises. Consequently, Mushimiyimana et al. (2022) state that a more flexible approach to learning is made possible by combining tactile engagement with the models that visually represent atomic and ionic structures. This ensures that a diverse range of learners can successfully assimilate the concepts of writing and naming a binary compound.

4.7.4 Discussion of Results of Research Question 4

What perception do JHS students have on the effectiveness of locally constructed Model Kit in the writing and naming of binary compounds?

The semi-structured interview with students showed that junior high school students were largely in favour of using locally built Model Kits to teach binary compound writing and naming. The research participants claimed that “we do it ourselves, it is more meaningful and more enjoyable” they had gained positive perceptions and attitudes towards the writing and naming of binary compounds, which is consistent with the findings of Teng and Jingjing’s (2023) and Turner’s (2019) and Sarkodie and Adu-Gyamfi's (2015) study. This good response could be partially explained by the claim made by Zhuo and Liang (2023), Cipolla and Ferrari (2016), who asserted that active participation in the classroom through model kits are helpful in deepening the understanding of students and arouses their interested (Zhuo & Liang 2023; Cipolla &Ferrari 2016). This perception aligns with the significant gains in performance and retention observed in the quantitative data, indicating that the tactile experience of assembling and using the kits contributed to deeper learning. The students' positive perceptions of the model kits, particularly their ability to make learning more engaging and concrete, likely played a crucial role in the enhanced learning outcomes. Furthermore, some students mentioned that the collaborative nature of using the kits in groups fostered a more active learning environment, which could have contributed to the higher performance and retention rates observed.

The results of this study therefore support the notion that improvisation is a valuable teaching and learning tool for science concepts, including writing and naming binary compounds. The findings show that using locally made model kits in an improvisational setting improves students' comprehension of the fundamentals of writing and naming of binary compounds, resulting in high retention rates. The results of this investigation corroborate that of Horikoshi (2020). According to Horikoshi (2020), students' understanding of writing chemical formulae, chemical equation and the balancing of chemical equations were enhanced by the use of improvised model kits.

CHAPTER FIVE

SUMMARY, CONCLUSIONS RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

5.0 Overview

A summary of the study's findings is presented in this chapter. Based on the results, conclusions, recommendations, and suggestions were made for further investigation.

5.1 Summary of Findings

The study assessed the challenges JHS integrated science teachers encounter in the teaching and learning of writing and naming of binary compounds, and determine how using locally constructed Model Kits would be beneficial in improving JHS students' academic performance, retention and perception in the writing and naming of binary compounds. Multiphase mixed-method design was adopted, allowing the research questions to be answered using quantitative and qualitative data.

After data collection and analyses, it was found that large class size, unavailability or outmoded teaching and learning materials (TLMs), inadequate support from authorities, insufficient time to complete the syllabus, and lack of improvisational skills were the challenges facing JHS integrated science teachers in the teaching and learning of writing and naming of binary compounds. Also, the study revealed that the use of locally constructed Model Kits enhanced JHS students' academic performance and retention of writing and naming of binary compounds. JHS students also perceived that using locally constructed Model Kits to learn writing and naming of binary compounds provided better understanding of the principles of writing and naming of binary compounds, improved attitude towards science, provided better retention of concepts, and active participation during lessons delivery.

5.2 Conclusions

Based on the findings of this study, it can be concluded that locally constructed Model Kits employed were effective in improving the performance and retention of writing and naming of binary compounds among JHS students in the Sekyere Central District. This is because, the use of locally constructed Model Kits provided students the opportunities to learn through hands-on activities, the various principles involved in writing and naming of binary compounds. This presented the concepts in a concrete form, which increased the interest of students to actively participate in lessons as articulated by students in the semi-structured interview.

5.3 Recommendations

The findings of this study have led to the following recommendations specified to be considered in making major educational decisions:

1. It is recommended that educational stakeholders in the Sekyere Central District should turn attention to the challenges JHS integrated science teachers encounter in the teaching and learning of writing and naming of binary compounds.
2. Additionally, when standard materials are unavailable or too expensive, Junior High School integrated science teachers in the Sekyere Central District are encouraged to teach the writing and naming of binary compounds by using improvised Y-Shaped Model Kit and the Valency Arm Model Kit in order to

improve junior high school students' performance in writing and naming binary compounds.

3. Furthermore, in order for junior high school to retain the concepts and principles in writing and naming binary compounds which is needed for the learning of writing and balancing of chemical equations JHS integrated science instructors in Sekyere Central District can make use of the improvised Y-shaped Model Kit and the Valency Arm Model Kit.
4. Lastly, Junior High School students have expressed the positive influence of Y-Shaped Model Kit and the Valency Arm Model Kit in the teaching and learning of writing and naming of binary compounds therefore junior high school integrated science instructors in the Sekyere Central District are to employ them during instructional delivery.

5.4 Suggestion for Further Research

Future studies should consider using randomised assignment of participants to experimental and control groups to enhance the validity of the findings. Randomisation would help in minimising selection bias and enable more robust conclusions that can be generalised to a broader population. Also, future research could explore the possibility of combining elements of both the Valency Arm Model Kit and the Y-shaped Model Kit into a single hybrid model. Such an approach could provide a more comprehensive tool for teaching chemical nomenclature, particularly in illustrating compounds involving elements with diverse valencies.

REFERENCES

Abban-Acquah, F., & Edusei, J. A. (2023). The impact of 3-dimensional molecular model on the elucidation of structure of aliphatic hydrocarbon. *International Journal of Research and Innovation in Social Science,* 7(3), 764-776. https://doi.org/10.47772/ijriss.2454-6186

Adesoji, F. A., & Babatunde, A. G. (2016). Investigating Gender Difficulties and Misconceptions in Inorganic Chemistry at the Senior Secondary Level. *International Journal of African & African American Studies,* 7(1), 1–6.

Adkins, D. G. (2020). Effects of Hands-On Experiences on Student Achievement, Interest, and Attitude in Chemistry. Stephen F. Austin State University.

Adu-Gyamfi, K., Ampiah, J. G., & Appiah, J. Y. (2017). Students' Difficulties in IUPAC Naming of Organic Compounds. *Journal of Science and Mathematics Education*, 6(2), 77–106.

Ajayi, V. O. (2017). Effect of Hands-on Activities on Senior Secondary Chemistry Students' Achievement and Retention in Stoichiometry in Zone C of Benue State [Benue State University]. https://doi.org/10.13140/RG.2.2.18058.57282

Ajayi, V. O., & Ogbeba, J. (2017). Effect of Gender on Senior Secondary Chemistry Students' Achievement in Stoichiometry Using Hands-on Activities. *American Journal of Educational Research, 5*(8), 839–842. https://doi.org/10.12691/education-5-8-1

Akella, D. (2010). Learning together: Kolb's experiential theory and its application. *Journal of Management & Organization,* 16(1), 100–112. https://doi.org/10.1017/s1833367200002297

Akpan, V. I., Igwe, U. A., Mpamah, I. B. I., & Okoro, C. O. (2020). Social Constructivism: Implications on Teaching and Learning. *British Journal of Education*, 8(8), 49–56.

Akuma, F. V., & Callaghan, R. (2016). Framework for reducing teaching challenges relating to improvisation of science education equipment and materials in schools. *Eurasia Journal of Mathematics, Science & Technology Education,* 12(10), 2697–2717. https://doi.org/10.12973/eurasia.2016.1305a

Albadi, A. (2019). The Impact of Activity Based Learning on Students' Achievement: A Study Among 12th Grade Science and Environment Students in a Public School in Oman. The British University in Dubai.

Alkan, F. (2016). Experiential Learning: Its Effects on Achievement and Scientific Process Skills. *Turkish Journal of Science Education*, 14(2), 15-26. https://doi.org/10.12973/tused.10164a

Amin, H. U., & Malik, A. S. (2014). Memory Retention and Recall Process. 219–237. https://doi.org/10.1201/b17605-11

Andres, H. P. (2017). Active teaching to manage course difficulty and learning motivation. *Journal of Further and Higher Education,* 43(2), 220–235. https://doi.org/10.1080/0309877X.2017.1357073

Anne H. (2021). Science Notes: Learn Science, Do Science. Retrieved from https://sciencenotes.org/what-is-a-binary-compound-definition-and-examples/. Accessed 4 March 2023.

Ansquer, R., Mesnier, T., Farampour, F., Oriot, D., & Ghazali, D. A. (2019). Long-term retention assessment after simulation-based-training of pediatric procedural skills among adult emergency physicians: A multicenter observational study. *BMC Medical Education*, 19(1), 1–10. https://doi.org/10.1186/s12909-019-1793-6

Applefield, J. M., Huber, R., & Moallem, M. (2001). Constructivism in Practice and Theory: Toward a Better Understanding. The High School Journal, 84(2), 35–53.

Ateş, Ö., & Eryilmaz, A. (2011). Effectiveness of hands-on and minds-on activities on students' achievement and attitudes towards physics. Asia-Pacific Forum on Science Learning and Teaching, 12(1), 1–22.

Baah, R., & Anthony-Krueger, C. (2012). An Investigation into Senior High School Students' Difficulties and Understanding in Naming Inorganic Compounds by IUPAC Nomenclature. International *Journal of Scientific Research in Education*, 5(3), 214–222.

Bloom, B., Krathwohl, D., & Masia, B. (1973). Taxonomy of Educational Objectives. The Classification of Educational Goals: Handbook 2: Affective Domain (pp. 1–196). Longmans Green and Co. Ltd.

Bostley, M. A. (2019). Basics of research design: A guide to selecting appropriate research design. *International Journal of Contemporary Applied Researches*, 6(5), 76–89. https://www.researchgate.net/publication/342354309.

Botes, W. (2021). The Development and Use of Improvised Science-Teaching Models: A Case of Natural Science Pre-Service Teachers, 20(5), 18–37. https:/ /doi .org/10.26803/ijlter.20.5.2

Bullock, A. (2021). Improving Long-Term Memory in Students in Early Childhood Education Through the Use of Multi-Sensory Interventions. In Frontiers in Neuroscience. Goucher College.

Burgin, S. R., Oramous, J., Kaminski, M., Stocker, L., & Moradi, M. (2018). High School Biology Students Use of Visual Molecular Dynamics as an Authentic Tool for Learning About Modeling as a Professional Scientific Practice. Biochemistry and Molecular Biology Education, 46(3), 230–236. https://doi.org/10.1002/bmb.21113

Cipolla, L., & Ferrari, L. A. (2016). Big Atoms for Small Children: Building Atomic Models from Common Materials to Better Visualize and Conceptualize Atomic Structure. *Journal of Chemical Education*, 93(6), 1068-1072.

Clearwater, L. (2022). Understanding the Science Behind Learning Retention. Retrieved from https:// resource.indegene.com/indigene/pdf/article/understanding-the-science-behind-learning-retention.pdf.Accessed on 5th November 2023.

Coffie, I. S., Frempong, B. B., & Appiah, E. (2020). Teaching and Learning Physics in Senior High Schools in Ghana: The Challenges and the Way Forward. *Advances in Research*, 21(3), 35–42. https://doi.org/10.9734/air/2020/v21i330192

Cohen, L., Manion, L., & Morrison, K. (2007). Research Methods in Education (6th ed.). Routledge.

Cohen, L., Manion, L., & Morrison, K. (2018). Research Methods in Education (8th ed). Routledge.

Coletta, V. P., & Steinert, J. J. (2020). Why Normalized Gain Should Continue To Be Used in Analyzing Preinstruction and Postinstruction Scores on Concept Inventories. *Physical Review Physics Education Research*, 16(1), 1–7. https://doi.org/10.1103/PhysRevPhysEducRes.16.010108

Coleman, H. (2022). Learning Retention – How to Make Information Stick. Retrieved from https://www.ispringsolutions.com/blog/learning-retention. Accessed on 6th November, 2023.

Comba, P., Hambley, T. W., & Martin, B. (2009). Molecular Modeling of Inorganic Compounds. John Wiley & Sons.

Creswell, J. W. (2014). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (4th ed.). SAGE Publications, Inc.

Davis, S. E. (2007). Learning Styles and Memory. *Institute for Learning Styles Journal*, 1, 46–51.

Davis, E. K., Ntow, D. F., & Beccles, C. (2022), Factors Influencing Ghanaian Public Junior High School Students' Performance in English Language, Mathematics and Science and its Implication on the Nation Policy on progression. *SAGE Open*, 12(3), 215-223. Retrieved fromhttps://doi.org/10.1177/21582440221123912. On July,5,2023.

Divoll, K., & Browning, S. (2010). The "Classroom Ticket" to Concept Retention. *International Journal for the Scholarship of Teaching and Learning,* 4(2). https://doi.org/10.20429/ijsotl.2010.040210

Djami, C. B. N., & Kuswandono, P. (2020). Teachers' Strategies to Implement Higher-Order Thinking Skills in English Instruction. Metathesis: *Journal of English Language, Literature, and Teaching,* 4(1), 25–40. https://doi.org/10.31002/metathesis.v4i1.2048

Djoumbou F, Y., Eisner, R., Knox, C., Chepelev, L., Hastings, J., Owen, G., & Wishart, D. S. (2016). ClassyFire: Automated Chemical Classification with a Comprehensive, Computable Taxonomy. *Journal of Cheminformatics*, 8, 1-20.

Dori, Y. J., & Barak, M. (2001). Virtual and Physical Molecular Modeling: Fostering Model Perception and Spatial Understanding. *Journal of Educational Technology & Society*, 4(1), 61-74.

Dorsah, P., Awini, G., Okyer, M., Alhassan, A.-G., Shahadu, I. and Kpemuonye, A.K.N. (2024) Challenges in Teaching Integrated Science in Junior High Schools. *Open Access Library Journal,* 11: e11101. https://doi.org/10.4236/oalib.1111101

Egorova, K. S., & Ananikov, V. P. (2017). Toxicity of metal compounds: Knowledge and myths. Organometallics, 36(21), 4071-4090.

Ekenobi, T. N., Mumuni, A. A., & Nwanekezi, A. U. (2016). Enhancing Chemistry Students' Retention of Redox Reaction Concept Through Intervention with Advance Organizers. European Centre for Research Training and Development, 4(4), 34–46. www.eajournals.org

Ekwueme, O. C., Ekon, E. E., & Ezenwa-Nebife, C. D. (2015). The Impact of Hands-On-Approach on Student Academic Performance in Basic Science and Mathematics. *Higher Education Studies,* 5(6), 47. https://doi.org/10.5539/hes.v5n6p47

Elangovan, N., & Sundaravel, E. (2021). Method of preparing a document for survey instrument validation by experts. https://www.researchgate.net/publication/350747699. DOI:10.1016/j.mex.2021.101326

Erlina, E., Eny, E., & Rahmat, R. (2021). Using Simple Molecular Model to Enhance Students' Understanding on Molecular Geometry Based on VSEPR Theory. Jurnal Pendidikan Dan Pembelajaran Kimia, 10(1), 24–33. https://doi.org/10.23960/jppk.v10.i1.April2021.04

Essiam, C., Osei-Antwi, D., & Quayson, C. (2023). Are Chemistry Topics Difficult To Learn? The Stance of Ghanaian Senior High School Students. *International Journal of New Trends in Arts, Sports & Science Education*, 12(2), 112–121.

Faught, B. E., Law, M., & Zahradnik, M. (2016). How Much Do Students Remember Over Time? Longitudinal Knowledge Retention in Traditional versus Accelerated Learning Environments. Higher Education Quality Council of Ontario.

Feng, X., Cheng, L., Chen, J., & Zeng, Y. (2023). Application of DNA Molecular Model Printed by 3D Printing Technology in Biology Class of Senior High School. Proceedings of the 2022 3rd International Conference on Big Data and Informatization Education (ICBDIE 2022), 3, 13–22. https://doi.org/10.2991/978-94-6463-034-3.

Fisher, N., Gerdes, K., Logue, T., Smith, L., & Zimmerman, I. (1998). Improving Students' Knowledge and Attitudes of Science through the Use of Hands-On Activities. [Saint Xavier University]. In Dissertations. https://eric.ed.gov/?id=ED417056.

Flick, L. B. (1993). The meanings of hands-on science. *Journal of Science Teacher Education*, 4(1), 1–8. https://doi.org/10.1007/BF02628851.

Gardner, H. (1983). Frames of Mind: The Theory of Multiple Intelligences (2nd edition). Basic Books.

Gakuba, E., Kibga, E. S., & Sentongo, J. (2021). Effectiveness of Hands-On Activities to Development Chemistry Learners' Curiosity in Community Secondary Schools in Tanzania. *Journal of Turkish Science Education*, 18(4), 605-621. https://doi.org/10.36681/tused.2021.93.

Golder, J. (2018). Constructivism: A Paradigm for. International Journal of Research and Analytical Reviews, 5(3), 678–686.

Gyasi, H., Ofoe, E. O., & Samlafo, V. B. (2018). The Effect of Molecular Model Sets on Students' Academic Performance in Naming Organic Compounds. Education, 8(3), 37–41. https://doi.org/10.5923/j.edu.20180803.01.

Hake, R. R. (2002). Relationship of Individual Student Normalized Learning Gains in Mechanics with Gender, High-School Physics, and Pretest Scores on Mathematics and Spatial Visualization. Physics Education Research Conference, 8, 1–14.

Handur, V., Kalwad, P. D., Patil, M. S., Garagad, V. G., Yeligar, N., Pattar, P., Mehta, D., Baligar, P., & Joshi, G. H. (2017). Integrating Class and Laboratory with Hands-On Programming: Its Benefits and Challenges. In Proceedings - 2016 IEEE 4th International Conference on MOOCs, Innovation and Technology in Education, MITE 2016 (pp. 163–168). https://doi.org/10.1109/MITE.2016.47

Hanson, R. (2017). Enhancing Students' Performance in Organic Chemistry Through Context-Based Learning and Micro Activities - A Case Study. *European Journal of Research and Reflection in Educational Sciences,* 5(6), 7–20. www.idpublications.org

Hartshorn, R. M., & Yerin, A. (2019). The Past, Present, and Future in the Nomenclature and Structure Representation of Inorganic Compounds. Dalton Transactions, 48(26), 9422–9430. https://doi.org/10.1039/c9dt00352e

Haury, D. L., & Rillero, P. (1994). Perspectives of Hands-On Science Teaching. The ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Healey, M., & Jenkins, A. (2000). Kolb's experiential learning theory and its application in geography in higher education. Journal of Geography, 99(5), 185–195. https://doi.org/10.1080/00221340008978967

Hertzog, M. A. (2008). Considerations in Determining Sample Size for Pilot Studies. Research in Nursing & Health, 31, 180–189. https://doi.org/10.1002/nur.20247

Horikoshi, Ryo. (2020). Teaching Chemistry with Lego bricks. *Chemistry Teacher International*, 3(3), 239-255. https://doi.org/10.1515/cti-2020-0017

Ibe, F. N., Obikezie, M. C., & Chikendu, R. E. (2021). Effect of Improvised Instructional Materials on Chemistry Students' Academic Retention in Secondary School. International Journal of Research in Education and Sustainable Development, 1(5), 19–31. https://doi.org/www.doi.org/10.46654/IJRESD.1520

Kaumal, N. M., & Wijayawardana, D. N. U. (2017). Build-it-Yourself Atomic Modeling Kit: Development of a Low-Cost Atomic Modelling Kits Using waste material for Middle and Upper Level of School Students. *International Journal of Environmental & Science Education,* 12(8), 1737-1742.

Kaur, J. (2016). Methodology of Research and Statistical Techniques. Lovely Professional University.

Keshavarz, E. (2018). Hand -made, three-dimensional molecular model for active inorganic chemistry learning. Creative Education, 09(07), 1168-1173. https://doi.org/10.4236/ce.2018.97086.

Kivunja, C., & Kuyini, A. B. (2017). Understanding and Applying Research Paradigms in Educational Contexts. *International Journal of Higher Education*, 6(5), 26. https://doi.org/10.5430/ijhe.v6n5p26

Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (1999). Experiential learning theory: Previous research and new directions. 1–40.

Kovács, E., Jenei, Z. M., Csordás, K., Fritúz, G., Hauser, B., Gyarmathy, V. A., Zima, E., & Gál, J. (2019). The Timing of Testing Influences Skill Retention After Basic Life Support Training: A Prospective Quasi-Experimental Study. BMC Medical Education, 19(1), 1–7. https://doi.org/10.1186/s12909-019-1881-7

Kwak, S. G., & Park, S. H. (2019). Normality Test in Clinical Research. Journal of Rheumatic Diseases, 26(1), 5–11. https://doi.org/10.4078/jrd.2019.26.1.5

Lombardi, S. A., Hicks, R. E., Thompson, K. V., & Marbach-Ad, G. (2014). Are all hands-on activities equally effective? Effect of using plastic models, organ dissections, and virtual dissections on student learning and perceptions. *American Journal of Physiology - Advances in Physiology Education,* 38(1), 80–86.
https://doi.org/10.1152/advan.00154.2012

Lorenzo, M., Crouch, C. H., & Mazur, E. (2006). Reducing the Gender Gap in the Physics Classroom. *American Journal of Physics*, 74(2), 118–122.
https://doi.org/10.1119/1.2162549

Marczyk, G., DeMatteo, D., & Festinger, D. (2005). Essentials of Research Design and Methodology. *International Journal of Geography and Geology*, 6(3). John Wiley & Sons, Inc.

Mayeem, B. P., Naa, A. M., & Adjei, A. (2018). Enhancing Senior High School Students Understanding of Chemical Formulae and Nomenclature of Inorganic Compounds by the Use of Improvised Conceptual Models. *Journal of Education and Practice*, 9(6), 22–45.

Mboto, F. A., Udo, N. N., & Stephen, U. (2011). Effects of Improvised Materials on Students' Achievement and Retention of the Concept of Radioactivity. *International Multi-Disciplinary Journal,* 5(18), 342–353.

McCarthy, M. (2016). Experiential Learning Theory: From Theory To Practice. *Journal of Business & Economics Research* (JBER), 14(3), 91–100. https://doi.org/10.19030/jber.v14i3.9749

Mchugh, M. L. (2012). Lessons in biostatistics Interrater reliability: the kappa statistic. Biochemia Medica, 22(3), 276–282.

Mgbomo, Tubonemi. (2021). Teacher Attribute and Problem of Problems of Improvisation of Instructional Resources among Biology Teachers in Secondary School in Oyigbo Local Government Area. *Direct Research Journal of Education and Vocational Studie*, 3(1), 127-132. DOI: https://doi.org/10.26765/DRJEVS250184653

Ministry of Education. (2020). Science Common Core Programme Curriculum (Basic 7 - 10). National Council for Curriculum and Assessment. www.nacca.gov.gh

Munyaradzi, E. (2013). Teaching Methods and Students' Academic Performance. *International Journal of Humanities and Social Science Invention,* 2(9), 29–35.

Musharrat, T. (2020). Teachers' Perceptions About Use and Challenges of Hands-on Activities in Secondary Science Classroom. *European Journal of Education Studies*, 7(12), 20–27. https://doi.org/10.46827/ejes.v7i12.3384

Mushimiyimana, D., Kampire, E., & Dushimimana, E. (2022). Impacts of Improvised Instructional Materials on Grade Nine Learners' Performance in Chemistry. *African Journal of Educational Studies in Mathematics and Sciences,* 18(1), 127–135. http://creativecommons.org/licenses/by-nc-nd/4.0. DOI: https esms.v18i1.10

Nahimana, J. P., Karegeya, C., Nkurunziza, J. B., Gakuba, E., and Ntihabose, R. (2023). Impact of LowCost Atomic Models on Upper Secondary School Students' Comprehension of Electronic Configuration and Chemical Bond Concepts in Nyarugenge, Rwanda. *East African Journal of Education and Social Sciences* 4(3)240-245.DOI: https://doi.org/10.46606/eajess2023v04i03.0295.

Ndihokubwayo, K., Uwamahoro, J., & Ndayambaje, I. (2018). Use of Improvised Experiment Materials to Improve Teacher Training College Students' Achievements in Physics, Rwanda. *African Journal of Educational Studies in Mathematics and Sciences*, 14(1), 71–85.

Nsabayezu, E., Uwihanganye, A., & Nsengiyumva, P. (2023). Examining Teachers' and Students' Perceptions on the Use of Science Kits to Improve Chemistry Performance in Lower Secondary Schools. *Journal of Classroom Practices*, 2(2), 1–17. https://doi.org/10.58197/prbl/aori1073

Obiyo, N. (2019). Underutilization of Instructional Materials for Teaching and Learning of Chemistry in Nigerian Secondary Schools: Ohafia Education Zone, Abia State. African *Journal of Teacher Education*, 8(1994), 261–280. https://doi.org/10.21083/ajote.v8i0.5047

Obodo, A. C., Ani, M. I., & Thompson, M. (2020). Effects of Improvised Teaching-Learning Materials on the Academic Performance of Junior Secondary School Student. IOSR *Journal of Research & Method in Education,* 10(4), 23–30. https://doi.org/10.9790/7388-1004062330

Ogbeba, J., & Ajayi, O. V. (2017). Effect of Hands-on Activities on Achievement and Retention of Senior Secondary Chemistry Students in Stoichiometry. *International Centre for Science, Humanities and Education Research,* 2(2), 54–59.

Okori, O. A., & Jerry, O. (2017). Improvisation and utilization of resources in the teaching and learning of science and mathematics in secondary schools in Cross River state. *Global Journal of Educational Research,* 16(1), 21. https://doi.org/10.4314/g jedr. v16i1.4

Onuh, O. (2022). Effect of Improvised Chemical Models in The Teaching and Learning of Chemistry Among Senior Secondary Student Achievement in Makurdi Local Government Area Omale. *International Journal of Education, Learning and Development*, 10(7), 52–61.

Onwuegbuzie, A. J., & Collins, K. M. T. (2007). A Typology of Mixed Methods Sampling Designs in Social Science Research. *The Qualitative Report*, *12*(4), 281–316. http://www.nova.edu/ssss/QR/QR12-2/onwuegbuzie2.pdf

Osei-himah, V., Parker, J., & Asare, I. (2018). The Effects of Improvised Materials on the Study of Science in Basic Schools in Aowin Municipality - Ghana. *Research on Humanities and Social Sciences,* 8(8), 20–23.

Owo, J. O., (2022). Effects of Using Molecular Model Kits, Charts and Board Drawings in Teaching Chemical Bonding to Secondary School Chemistry. *International Journal of Discoveries and Innovations in Applied Sciences,*2(12),42-49.

Pallant, J. (2011). SPSS Survival Manual: A Step-by-step guide to data analysis using SPSS (4th ed.). Allen & Unwin.

Penny, M. R., Cao, Z. J., Patel, B., Sil dos Santos, B., Asquith, C. R., Szulc, B. R., ... & Hilton, S. T. (2017). Three-Dimensional Printing of a Scalable Molecular Model and Orbital Kit for Organic Chemistry Teaching and Learning. *Journal of chemical education*, 94(9), 1265-1271.

Petrucci, R. H., Herring, G. F., Madura, J. D., & Bissonette, C. (2011). General Chemistry: Principles and Modern Applications (10th edition). MacMillan Publishing Company.

Piaget, J. (1976). Piaget and His School: A Reader in Developmental Psychology. *Physical Therapy, 5*8(3), 375–375. https://doi.org/10.1093/ptj/58.3.375a

Pillado, I. A., Futalan, M. C. Z., & Comighud, S. M. T. (2020). Factors on Memory Retention: Effect to Students' Academic Performance. *International Journal for Research In Mathematics And Statistics,* 6(4), 1–24.

Pirttimaa, M., Husu, J., & Metsärinne, M. (2017). Uncovering procedural knowledge in craft, design, and technology education: A case of hands-on activities in electronics. *International Journal of Technology and Design Education*, 27, 215-231.

Powell, K. C., & Kalina, C. J. (2009). Cognitive and Social Constructivism: Developing Tools for an Effective Classroom. Education, 130(2), 241–250.

Quansah, R. E., Sakyi-Hagan, N. A., & Essiam, C. (2019). Challenges Affecting the Teaching and Learning of Integrated Science in Rural Junior High Schools in Ghana. *Science Education International,* 30(4), 329–333. https://doi.org/10.33828/sei.v30.i4.10

Quayson, C., Kwarteng, T. A., Koranteng, E., & Hanson, R. (2022). Chemistry Teacher Trainees' use of Molecular Models in Learning Spiro and Bicyclic Compounds. *Science Education International,* 33(3), 291–295. https://doi.org/10.33828/sei.v33.i3.4

Rahi, S. (2017). Research Design and Methods: A Systematic Review of Research Paradigms, Sampling Issues and Instruments Development. *International Journal of Economics & Management Sciences,* 06(02). https://doi.org/10.4172/2162-6359.1000403

Ramesh, B. V., Selvam, A. A. A., Kulkarni, S., Dattatreya M., A., & Bettadapur, K. R. (2020). Designing and using an atomic model kit with H, C, N, and O Model Atoms having a mass ratio of 1: 12: 14: 16 to teach the concept of mole and associated stoichiometric relationships. *Journal of Chemical Education*, 97(4), 986-991. https://doi.org/10.1021/acs.jchemed.9b00665

Rivera, G. M., & Sanchez, J. M. P. (2020). Use of Contextualized Instructional Materials: The Case of Teaching Gas Laws in a Public Uptown High School. *The Electronic Journal of Chemistry*, 12(4), 276–281. https://doi.org/http://dx.doi.org/10.17807/orbital.v12i4.1526

Saif, M., & Laszlo, K. (2020). Constructivist Theory as a Foundation for the Utilization of Digital Technology in the Lifelong Learning Process. Turkish Online *Journal of Distance Education,* 21(4), 90–109. https://doi.org/10.17718/TOJDE.803364

Samuel, N. N. C., & Ikwuka, O. I. (2017). Effect of computer animation on chemistry academic achievement of secondary school students in Anambra State, Nigeria. *Journal of Emerging Trends in Educational Research and Policy Studies*, 8(2), 98–102.

Sarkodie, P. A., & Adu-Gyamfi, K. (2015). Improving Students' Performance in Naming and Writing Structural Formulae of Hydrocarbons Using the Ball-and-Stick Models. *Bulgarian Journal of Science Education,* 24(2), 203–219.

Sekyere Central District Assembly. (2014). Sekyere Central District. http://sekyerecentral.ghanadistricts.gov.gh

Sousa, D. A. (2016). How the brain learns. Corwin Press.

Stull, A. T., Gainer, M., Padalkar, S., & Hegarty, M. (2016). Promoting Representational Competence with Molecular Models in Organic Chemistry. *Journal of Chemical Education,* 93(6), 994–1001. https://doi.org/10.1021/acs.jchemed.6b00194

Sulyman, H. T., Abubakar, A. O., & Oladoye, E. O. (2022). Effect of Hands-on Activities on Pupils' Academic Performance in Basic Science in Ilorin East Local Government Area, Kwara State.1-19.

Suprayogi, M. N., Valcke, M., & Godwin, R. (2017). Teachers and Their Implementation of Differentiated Instruction in the Classroom. Teaching and Teacher Education, 67(1), 291–301. https://doi.org/10.1016/j.tate.2017.06.020

Taber, K. S. (2011). Constructivism As Educational Theory: Contingency in Learning, and Optimally Guided Instruction. In J. Hassaskhah (Ed.), Educational Theory (pp. 39–61). Nova Science Publishers, Inc. https://doi.org/10.1525/aa.1912.14.2.02a00130

Taskin, V., & Bernholt, S. (2014). Students' Understanding of Chemical Formulae: A Review of Empirical Research. *International Journal of Science Education*, 36(1), 157-185.

Teng, W., & Jingjing, L. (2023). A portable, Low-Cost, and, and Easy-to-Construct Model for Teaching Packing Arrangements of Metallic Crystal. *J. of Chem. Educ.*100(3),3102-3106. https://doi.org/10,1021/acs.jcemed.3c00395.

Toheed, L., Ali, A., & Jabeen, F. (2017). The effect of mastery learning strategy on learning retention of secondary school students in the subject of mathematics. *Journal of Education and Practice,* 8(19), 46–51. https://core.ac.uk/download/pdf/234640657.pdf

Tondeur, J., Braak, J. van, Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*, 1–41.

Turner, K. (2019). Reasons to craft your own molecular models. Retrieved from https://edu.rsc.org/ideas/reasons-to-craft-your-own-molecular-models/3009984. Accessed 13 May 2023.

Twizeyimana, E., Renzaho, A., & Mujawimana, E. (2020). Effectiveness of Locally Made Instructional Materials on Students' Academic Performance and Retention in Science Education in Eastern Province of Rwanda. *International Journal of All Research Writings*, 1(11), 29–37.

Udu, D. A. (2018). Innovative Practices in Science Education: A Panacea for Improving Secondary School Students' Academic Achievement in Science Subjects in Nigeria. *Global Journal of Educational Research,* 17(1), 23–30. https://doi.org/https://dx.doi.org/10.4314/gjedr.v17i1.4

Udu, D. A., Nmadu, J., Uwaleke, C. C., Anudu, A. P., Okechineke, B. C., Attamah, P. C., Chukwuemeka, C. O., Nwalo, C. N., & Ogonna, O. C. (2022). Innovative Pedagogy and Improvement of Students' Knowledge Retention in Science Education: Learning Activity Package Instructional Approach. Pertanika *Journal of Social Sciences and Humanities*, 30(3), 1405–1426. https://doi.org/10.47836/pjssh.30.3.25

Uzor, O. F., Nwankwo, G. U., Obiefuna, G. C., & Oliobi, J. I. (2022). Challenges of Teaching Basic Science and Technology with Hands-on Activities During the Covid-19 Pandemic Era. *STEM Journal of Anambra State*, 3(2), 49–58.

Valderama, J., & Oligo, J. (2021). Learning Retention in Mathematics over Consecutive Weeks: Impact of Motivated Forgetting. *International Journal of Evaluation and Research in Education,* 10(4), 1245–1254. https://doi.org/10.11591/IJERE.V10I4.21577

VanderStoep, S. W., & Johnston, D. D. (2009). Research methods for everyday life: Blending qualitative and quantitative approaches (1st ed.). Jossey-Bass A Wiley Imprint.

Vilia, P. N., Candeias, A. A., Neto, A. S., Franco, M. da G. S., & Melo, M. (2017). Academic achievement in physics-chemistry: The predictive effect of attitudes and reasoning abilities. Frontiers in Psychology, 8(1064), 1–9. https://doi.org/10.3389/fpsyg.2017.01064

Vitoria, L., Mislinawati, M., & Nurmasyitah, N. (2018, September). Students' perceptions on the implementation of e-learning: Helpful or unhelpful? In *Journal of Physics: Conference Series* (Vol. 1088, p. 012058). IOP Publishing.

Vygotsky, L. (1978). Mind in Society: The Development of Higher Psychological Processes (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.; 1st edition). Harvard University Press.

WAEC. (2017). Chief Examiners' Reports for Integrated Science: BECE. https://www.ptonline.com/articles/how-to-get-better-mfi-results

WAEC. (2018). Chief Examiners' Reports for Integrated Science: BECE. https://www.ptonline.com/articles/how-to-get-better-mfi-results

WAEC. (2019). Chief Examiners' Reports for Integrated Science: BECE. https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482

WAEC. (2020). Chief Examiners' Reports for Integrated Science: BECE. https://waecgh.org/chief-examiners-report/#16796451841762-1a02dc69-adf2

WAEC. (2020). External Examiners' Reports on BECE Performance. Freetown.

Wenglinsky, H. (2002). How schools' matter: The link between teacher classroom practices and students' academic performance. Education Policy Analysis Archives, 10(12), 1–30.

Willingham, D. T. (2021). Why Don't Students Like School? A Cognitive Scientist Answers Questions About How the Mind Works and What It Means for the Classroom. John Wiley & Sons.

Wirtz, C. M., Kaufmann, J., & Hawley, G. (2006). Nomenclature Made Practical: Students Discovery of the Nomenclature Rules. *Journal of Chemistry Education*, 83(4), 595. https://doi.org/10.1021/edo83p595.

Yeboah, R., Abonyi, U. K., & Luguterah, A. W. (2019). Making Primary School Science Education More Practical Through Appropriate Interactive Instructional Resources: A Case Study of Ghana. *Cogent Education*, 6(1), 1–14. https://doi.org/10.1080/2331186X.2019.1611033

Zhuo, J., & Liang, J. (2023). Reusing Waste Plastic Caps to Build Inexpensive and Easily Changeable Crystal Structure Models. *J. Chem. Educ*.100 (7), 2793-2801. https://doi.org/10.1021/acs.jchemed.3c00007

Zumdahl, S.S., & Zumdahl, S. A. (2013). *Chemistry* (9th ed.) Cengage Learning Inc. Boston, USA

APPENDICES

Appendix A

Pretest

1. If magnesium (Mg) reacts with chlorine (Cl) to form a binary compound, what is the chemical formula of the compound formed?
2. Write the chemical formula for the compound formed between lithium and chlorine.
3. What is the chemical formula for the compound formed between aluminium and oxygen?
4. Write the chemical formula for the following binary compounds

a. Iron (II) chloride

b. Carbon (IV) oxide

c. Magnesium nitride

d. Hydrogen sulphide

Appendix B

Posttest

1. Determine the correct chemical formula for the binary compound formed by:

a. Aluminum and fluorine

b. Iron (II) and sulphur

c. Potassium and oxygen

d. Beryllium and nitrogen

2. Write the systematic names of the following chemical formulae:

a. NaCl

b. K_2O

c. MgH_2

d. CaS

3. In a reaction, aluminum (Al) reacts with chlorine (Cl) to form a compound. What is the name of the compound formed?

4. A student combines of magnesium (Mg) fluorine (F) to form a compound. Determine the chemical formula of the compound.

Appendix C

Delayed Posttest 1

1. Write the appropriate answer in place of the letters x and y

a. Al(s)+Cl(g) → AlxCly X =……. Y=……...

b. Mg(s)+N(g)→MgxNy(s), X =……. Y=……...

c. Si+Cl→SiClx, X=………

d. C+O→COx, X=……...

2. Write chemical formulae for the compounds below:

   i. Sodium chloride

   ii. Calcium fluoride

   iii. Nitrogen (II) oxide

3. The element X is in group 7 what is its valency?

4. Write the formula for the compound of each of the following pairs of ions.

   a. Fe^{3+} and O^{2-}

   b. K^{+} and Cl^{-}

   c. Li^{+} and F^{-}

   d. Ca^{2+} and S^{2-}

Appendix D

Delayed Posttest 2

1. Identify the correct chemical formula for the compounds formed by:

a. Aluminum and chlorine

b. Sodium and sulphur

c. Potassium and oxygen

d. Beryllium and nitrogen

2. If magnesium (Mg) reacts with chlorine (Cl) to form a binary compound, what is the chemical formula of the compound formed?

3. A student combines Silicon (Si) with oxygen (O) to form a compound. Determine the chemical formula of the compound.

4. Write the formula for the compound of each of the following pairs of ions.

a. $Mg^{2+}$and Cl^{-}

b. Li^{+} and N^{3-}

c. Al^{3+} and N^{3-}

d. Be^{2+} and O^{2-}

Appendix E

Hake's Gain (g) Formula

Gain, $g = \frac{Posttest\ mean - Pretest\ mean}{Maximum\ Score\ (30) - Pretest\ mean}$

Appendix F

Cohen's d Formular

$$d = \frac{M_1 - M_2}{\sqrt{\frac{S_1^2 + S_2^2}{2}}}$$

where $\sqrt{\frac{S_1^2 + S_2^2}{2}}$ = pooled standard deviation

M_1= Posttest mean of experimental group

M_2= Posttest mean of control group

S_1^2 = posttest standard deviation of experimental group

S_2^2 = posttest standard deviation of control group

d= calculated Cohen's *d*

Appendix G

Teachers' Challenges Interview Guide

1. Can you describe the types of teaching materials or resources you currently use when teaching the writing and naming of binary compounds?
2. When faced with a shortage of specific teaching materials or resources for teaching writing and naming binary compounds, how do you typically improvise or adapt your teaching methods?
3. Can you describe any instances where you sought support or assistance from authorities regarding teaching materials or resources for writing and naming binary compounds?
4. In your view, how does the lack of sufficient time impact students' understanding and retention of concepts of writing and naming binary compounds?
5. In your experience, how does the class size affect students' participation and engagement during lessons on writing and naming binary compounds?

Appendix H

Students' Perceptions Interview Guide

1. In what ways do you think the hands-on experience with the model kits has deepened your understanding on the writing and naming of binary compound?
2. In what ways do you think the model kits has helped to make learning about binary compounds a more engaging and positive experience?
3. In your opinion, what role do the hands-on activities with the model kits play in helping you remember and apply the principles of writing and naming of binary compounds?
4. Can you describe a specific instance when you felt actively involved in a lesson on writing and naming binary compounds because of the model kits?