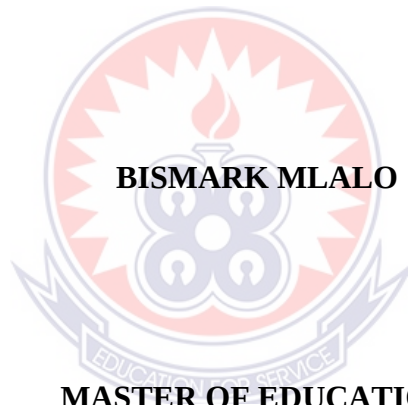


UNIVERSITY OF EDUCATION, WINNEBA

**Effect of hands-on activities on students' performance in acids, bases and salts a
study at Ye Senior High School**



BISMARCK MLALO

MASTER OF EDUCATION

UNIVERSITY OF EDUCATION, WINNEBA

**EFFECT OF HANDS-ON ACTIVITIES ON STUDENTS' PERFORMANCE IN
ACIDS, BASES AND SALTS: A STUDY AT VE SENIOR HIGH SCHOOL**



BISMARCK MLALO

(7241610014)

**A dissertation in the Department of Science Education,
Faculty of Science Education, submitted to the School of
Graduate Studies in partial fulfilment
of the requirements for the award of the degree of
Master of Education
(Science Education)
in the University of Education, Winneba**

AUGUST, 2024

DECLARATION

STUDENTS' DECLARATION

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

SIGNATURE:

DATE:

SUPERVISOR'S DECLARATION

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

SUPERVISOR'S NAME: PROF. JOHN K. EMINAH

SIGNATURE:

DATE:

DEDICATION

This research study is dedicated to my lovely wife, Agnes Kumasi. It is also dedicated to my my parents, Isaac Mlalo and Kafui Fiador.



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Glory and Honour be to God Almighty for His inspiration, strength and knowledge granted me to conduct this study.

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I wish to express my sincere gratitude to all lecturers of Integrated Science Education Department especially, Dr. Charles Koomson (HOD, Integrated Science Education).

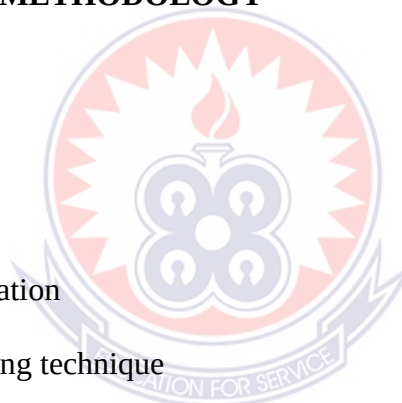
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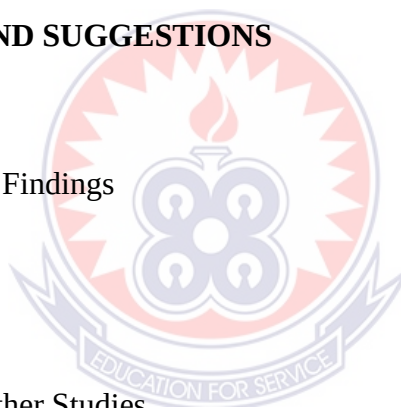
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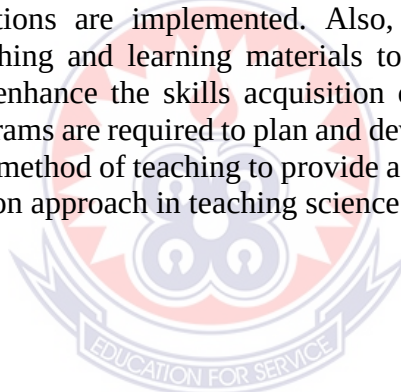
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ABSTRACT

The purpose of this study was to determine the effect of hands-on activities on the performance of students in acids, bases and salts. The design used for the study was action research. Fifty students were sampled using the purposive sampling technique. Teacher-made-test (pre-test and post-tests) and questionnaire were instruments used to collect the data. Four research questions guided the study. Pre-test and post-test were used to assess students' performance before and after the intervention respectively. The test was also used to determine students' acquisition of science process skills after the intervention. Furthermore, questionnaire were used to determine students' perceptions of hands-on instructional approach. Intervention strategies with regards to hands-on approach were implemented within 4 weeks. Findings obtained from the study revealed that senior high school students had conceptual difficulties in acids, bases and salts. It also came to light that students' performance was enhanced after the implementation of hands-on activities. It was also discovered that there was a significant improvement in students' science process skills (measuring, observation, manipulation, and recording). Majority of students found the hands-on method engaging, enhancing participation, understanding, and retention of scientific concepts. It was therefore, recommended that science teachers should make sure that students' difficulties in science concepts are identified before appropriate interventions are implemented. Also, the school authorities should provide enough teaching and learning materials to facilitate hands-on method of teaching science to enhance the skills acquisition of senior high school students. Further training programs are required to plan and develop for both teachers and their students in hands-on method of teaching to provide a better perception of students on the use of the hands-on approach in teaching science concepts.



CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter provides the background to the study, statement of the problem, purpose of the study, objectives of the study, research questions, significance of the study, limitations, delimitations, organization of the study and operational definition of terms.

1.1 Background to the Study

The repeated reliance on the lecture method in teaching Integrated Science at the senior high school level in Ghana has been identified as detrimental to effective learning (Kwami, 2024). Adeyemi (2008) and Lawal (2009) discovered that students tend to perform poorly when subjected to teacher-centered instructional strategies. This approach fails to foster creativity in the classroom (Nwosu, 2004). Bolaji (2007) has raised concerns about the preparedness of students for the demands of the 21st-century workforce, which emphasizes practical skills and the ability to independently solve problems.

To address these challenges, it is essential for educators to adopt teaching methods that stimulate creativity in the field of Integrated Science, and one such approach is hands-on approach of teaching. Ibe (2011) and Ornstein (2006) assert that science instruction should involve a lot of hands-on activities to enhance the acquisition of process skills and promote creativity among students.

The hands-on hands-on method is therefore an instructional method that encourages students to acquire knowledge through direct experience. In this method, students are provided with opportunities to interact with and manipulate the objects they are

studying, such as microscope, measuring cylinder, conical flask (Uyanik, 2018). This approach emphasises active participation of students in the learning process, turning them into engaged participants in the classroom (Ekwueme et al., 2015).

Ekwueme et al. (2015) also argued that hands-on method immerses students in a comprehensive learning experience that enhances their critical thinking abilities. Consequently, any teaching strategy geared towards this direction can be considered an hands-on method-oriented teaching method. This approach is advocated as a means to improving students' academic performance, enhance their engagement levels and comprehension of scientific concepts (Kontra et al., 2015). By physically interacting with objects, it can make abstract knowledge more tangible and easier to grasp. Through the hands-on activities, students are able to connect with real-life examples and witness the effects of varying variables, providing them with concrete illustrations of abstract concepts (Babb & Stockero, 2020).

Furthermore, the hands-on method is learner-centred, enabling students to see, touch, and manipulate objects as part of their learning process. This is particularly important in science education, as this subject is best understood through visual and hands-on engagement, rather than solely through auditory means. In essence, the hands-on approach aligns with the principle of "learning by doing" in science education (Ekon, 2013). In the classroom environment at Ve Senior High School, students primarily receive instruction through lectures, with limited engagement in practical experiments related to acids, bases and salts. Yet, it is crucial that the lecture method in science classroom, particularly when addressing topics like acids, bases and salts, integrates hands-on demonstrations and experiments. Without this practical exposure to acids, bases and salts, students' growth in experimental skills within science is hindered,

consequently affecting their overall academic performance in senior high school (Sadi & Çakıroğlu, 2011).

Obanya (2012), in his convocation address, supported the aforementioned statement by asserting that traditional lectures yield a mere 5 % retention rate, whereas engaging in practical, hands-on method-oriented learning results in an impressive 75% retention rate. This clearly demonstrates that as teaching shifts towards more interactive and hands-on -based activities, retention rates consistently improve. Also, science education research has consistently demonstrated the significant benefits associated with the use of hands-on and minds-on activities. These approaches have a track record of positively impacting students in various ways, such as fostering improved attitudes towards science (Gormally et al., 2009), improving students' performance in examinations (Abdi, 2014), enhancing proficiency in scientific process and experimental skills (Ergul et al., 2011; de Jong et al., 2013; Uzal et al., 2010), and even potentially inspiring a greater number of students to pursue careers in STEM fields (Van den Hurk et al., 2019).

1.2 Statement of the Problem

Sakyi-Hagan and Hanson (2019) assert that science appears to be primarily taught in Ghanaian senior high schools through lectures, note-taking, chalkboard illustrations and other teacher-centered techniques that only allow students to form mental models of the topics that are being presented to them, and this type of concept presentation may cause students to forget what they learn quickly.

At numerous points in time of teaching at Ve Senior High School, the researcher noticed that when the concept of acids, bases and salts was taught without incorporating practical activities, the students struggled to grasp the concept and appeared

disinterested in the lesson. A particular lesson on the review of acids, bases and salts in Integrated Science revealed the students' difficulties with understanding the nature and functions of acids, bases and salts and their applicability in real-life situations. This issue was evident during a question-and-answer session. Additionally, when a test was administered on the acids, bases and salts, the results indicated that the students encountered difficulties explaining some concepts associated with acids, bases and salts. Furthermore, upon closer observation by the researcher, it became evident that many students had never encountered most of the laboratory equipment and materials used in acid-base titrations, and therefore have not been exposed to proper teaching and learning experiences during science lessons. These shortcomings stem from the instructional strategies employed in science classrooms, which are significant contributors to students' failure in the subject (Ekon, 2013). A study conducted by Alkan (2016) suggested that hands-on activities provide students with tangible, real-world examples and enables deeper understanding of abstract concepts by allowing students to directly observe and interact with materials and equipment in science. For this reason, this study was designed to investigate the effect of hands-on activities on students' performance in acids, bases and salts.

1.3 Purpose of the Study

The purpose of the study was to determine the effect of hands-on activities on the performance of students in acids, bases and salts in Ve Senior High School.

1.4 Objectives of the Study

The objectives of the study were to;

1. Determine the difficulties the students encounter during lessons on acids, bases and salts

2. Assess the effect of the hands-on approach of teaching on students' performance in acids, bases and salts.
3. Determine the effect of hands-on approach of teaching on students' science process skills.
4. Determine the perception of students about the use of hands-on method of teaching in the Integrated Science classroom with reference to acids, bases and salts.

1.5 Research Questions

The following research questions were addressed in the study;

1. What difficulties do the students encounter during lessons on acids, bases and salts?
2. What is the effect of the hands-on teaching and learning approaches on the students' performance in acids, bases and salts?
3. What is the effect of hands-on teaching and learning on the students' science process skills?
4. What are the perceptions of the students about the use of hands-on instructional approaches for science lessons?

1.6 Significance of the Study

The result of this study helps educators identify effective teaching strategies. A positive correlation between hands-on method and academic success, can encourage the adoption of this method in Integrated Science classrooms, potentially leading to improved learning outcomes for students. The results of the study also help policymakers and education administrators to inform decisions about curriculum development and resource allocation. This may lead to the allocation of funds and

resources for the development of laboratory facilities and teacher training programs that facilitate hands-on method of teaching and learning in Integrated Science. Moreover, the findings of the study provide valuable insights for curriculum designers and Integrated Science teachers into the types of activities that are most effective for skill development.

1.7 Limitations of the Study

It would have been very appropriate and important to include all the students in Ve Senior High School but this could not materialize due to inadequate resources, funds and constraints of time. Few students were selected as the sample size which may not accurately represent the larger population from which it is drawn.

1.8 Delimitations of the Study

The study was delimited to Ve Senior High School in the Afadzato South district in the Volta region of Ghana and only 2 Business 2 class was selected. The study was also delimited to only the concepts, acids, bases and salts in Integrated Science.

1.9 Operational definition of terms

1. **Lecture Method:** This refers to a teaching approach where the teacher presents information to students verbally, often in a one-way communication format, without much interaction or hands-on activities.
2. **Integrated Science:** This is a subject that combines various scientific disciplines such as science, chemistry, physics, and earth science into a unified curriculum.
3. **Hands-on Approach/Hands-on method:** This instructional method involves students directly engaging with materials, equipment, or experiments as part of

the learning process. It emphasizes active participation and manipulation of objects to enhance understanding.

4. **Process Skills:** These are the fundamental abilities required for scientific inquiry and problem-solving, such as observation, measurement, data interpretation, and experimentation.
5. **Content Retention:** Refers to the ability of students to remember and recall information or concepts learned over a period of time.
6. **Real-life Situations:** These are practical scenarios or applications where the concepts learned in the classroom can be applied or observed in everyday life.
7. **Acids, Bases, and Salts:** These are categories of chemical substances defined by their properties and behaviour in solution. Acids release hydrogen ions (H^+) when dissolved in water, bases release hydroxide ions (OH^-), and salts are compounds formed from the neutralization of an acid and a base.
8. **Instructional Strategies:** These are the approaches or methods employed by teachers to facilitate learning, including but not limited to lecture, demonstration, discussion, and hands-on activities.

1.10 Organisation of the Study

The study was organized into five chapters; Chapter one to Chapter five. Chapter one provides information on the introduction of the study. It contains the background to the study, statement of the problem, purpose of the study, objectives, research questions, significance of the study, limitations and delimitations of the study. Chapter two reviews related literature on the study. Chapter three outlines how the research was conducted. It contains the research area, the design of the study, research instrument, population, sample and sampling technique, validity and reliability of the instruments, data collection procedure, data analysis and ethical consideration. Chapter four explains

the analysis and interpretations of the research findings. Chapter five presents the summary, conclusions, recommendations of the study and suggestions for further studies.



CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter deals with the review of the works of other researchers in relation to the use of hands-on activities in teaching acids, bases and salts in science. Firstly, this study explored the theoretical and conceptual framework of the study. It also looked at students' difficulties in acids, bases and salts, the hands-on method of teaching science highlighting its characteristics and strategies for implementation. Moreover, the study also explored students' academic performance in science and the factors influencing students' performance in science. Furthermore, empirical study of this research was also investigated. Moreover, students' perception of hands-on method in science lessons was examined as well as the challenges in using hands-on activities in teaching and learning science concepts. Lastly, the study explored the effect of hands-on activities on the development of science process skills and the role of students' prior knowledge in teaching and learning.

2.1 Theoretical framework

The idea that learning is an active process in which students generate new ideas or concepts based on their existing or prior knowledge is a crucial one in Bruner's theoretical framework. The learner uses a cognitive structure to choose and modify information, generate hypotheses, and come to judgments. This is the constructivist method, or the process by which we create meaning for ourselves, according to American cognitive psychologist Jerome Bruner, who coined the term in the 1960s. One of the most influential philosophies in today's education and learning is constructivism (Cohen et al., 2006). According to Bruner, "excellent teachers will plan

classes that assist pupils uncover the connections between different pieces of information. In order to accomplish this, a teacher must provide pupils with the data they require without organizing it for them (McLeod, 2019). In essence, rather than providing methods and procedures, we offer the tools, the initial work, the questions, and the chance for exploration and discovery.

Jerome Bruner's involvement with the national science foundation curriculum development project in the 1960s and 1970s had a significant impact on methods for teaching science. According to Bruner, learning occurs best through exploration, and the learner is a problem-solver who engages with the world to test ideas and form generalizations. According to Bruner, the purpose of education should be intellectual development, and the science curriculum should encourage the growth of problem-solving abilities through inquiry and discovery. Rather than the cumulative knowledge of science as it is given in textbooks, according to Bruner, knowing is a process. Students should be given challenging scenarios in order to help them grasp science ideas and find solutions. The learner in this scenario will be driven by intrinsic motivation to find the answer. The basis for developing discovery learning activities is offered by this straightforward idea.

Hands-on method theory also provides a theoretical framework for understanding human behaviour (Engeström, 2007; Leont'ev, 2008) and a lens for analyzing the interactions between district and classroom systems to mediate teachers' practices for integrating technology. A hands-on method system is a way to conceptualize confines the interaction between social and material resources that supports and limits what people and social groupings can achieve (Engeström, 2009a). Subject, object, mediating artifacts or tools, norms, community, and division of labor are the

fundamental components of hands-on method system (Engeström, 2007). The individual or individuals participating in the hands-on method are the subject. The subject's motivation to participate in the hands-on method is driven by the item. Symbols, signs, and conceptual understandings that work as both physical and psychological instruments to mediate interaction between the subject and the object are referred to as mediating artifacts or tools. The social and cultural group that subjects are a part of has established norms and rules that govern and guide behavior. As system members participate in hands-on method, the division of labor specifies how tasks and obligations are distributed among them (Cole & Engeström, 2013). The system may alter during action in response to modifications in the underlying motives and underlying demands (Engeström, 2009a).

Because of its capacity to handle differences between individual and collective action, hands-on method theory has influenced educational research (Kaptelinin, 2005). It has been characterized as a flexible and developing theoretical framework (Roth & Lee, 2007). The mediation study has been influenced by this framework. Researchers in human computer interaction (HCI) have used hands-on method theory to broaden analysis beyond user-computer interactions to also take into account the use of computers in social, organizational, and cultural contexts when researching tool mediation (Kaptelinin, 2006). Researchers in HCI have been able to develop solutions that support computer-mediated hands-on method thanks to hands-on method theory (Gay & Hembrooke, 2014; Hardman, 2007). The framework, for instance, has influenced the creation of instructional software that aims to mediate learning by giving kids access to resources and procedures that are similar to those found in the adult world (Bellamy, 2016). Hands-on method theory has contributed to a better understanding of how teachers employ classroom discourse, such as discussion, argumentation, and

clarification, to enhance student learning beyond software design (Walshaw & Anthony, 2008).

Third-generation hands-on method theory, which provides conceptualizations of interconnected hands-on method systems that can be arranged as networks for studying micro- or macro-level clusters of hands-on method, such as instances of teamwork, an organizational system, or human society, is one of Engeström's contributions to the representation and analysis of human hands-on method (Engeström, 2007; Roth & Lee, 2007).

2.2 Conceptual Framework

The diagram summarises the conceptual framework of the study

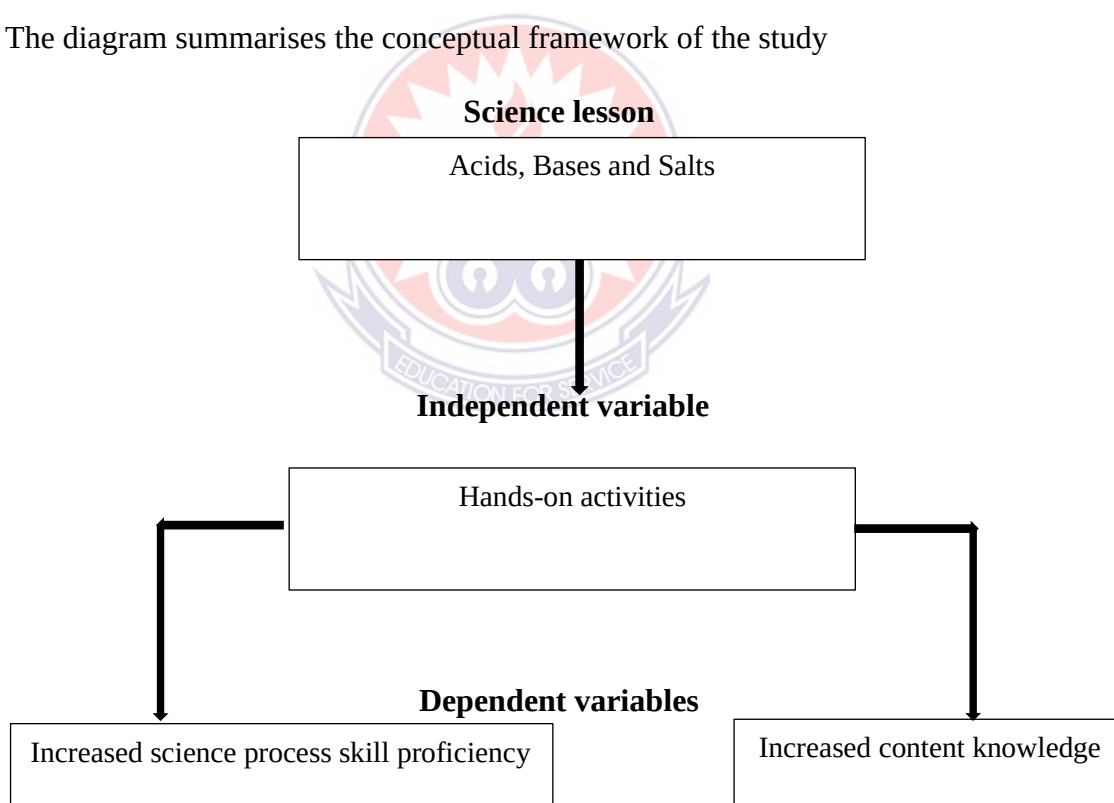


Figure 1: The Conceptual Framework of the Study

2.3 Students' Difficulties in Acids, Bases and Salts

The study of acids, bases, and salts constitutes a fundamental part of chemistry education at both the junior and senior high school levels. Despite its importance, numerous studies have documented persistent difficulties students face in understanding these concepts. These difficulties stem from a combination of abstract theoretical content, misconceptions carried from everyday life, instructional challenges, and cognitive overload. Addressing these challenges is essential to improving students' conceptual understanding and academic performance in chemistry. One major area of difficulty for students lies in the conceptualization and differentiation of acids and bases. Several researchers have identified that students often struggle to distinguish between the Arrhenius, Brønsted-Lowry, and Lewis definitions of acids and bases, leading to confusion in classroom settings (Demircioğlu et al., 2020; Chandrasegaran et al., 2007). For instance, while the Arrhenius definition limits acids and bases to aqueous solutions producing hydrogen and hydroxide ions respectively, the Brønsted-Lowry and Lewis definitions broaden these categories. Students' failure to reconcile these definitions often leads to fragmented understanding and the inability to apply the concepts in varied contexts (Özmen, 2021).

Additionally, misconceptions arising from everyday language usage contribute significantly to students' difficulties. Acids are often associated with substances that are corrosive or sour-tasting, while bases are linked to soapiness or bitterness. These associations, although sometimes useful, are limited and often misleading in scientific contexts. Research by Cevik et al. (2019) found that many students consider all acidic substances dangerous and overlook the presence of weak acids in food items. Similarly, bases are frequently perceived merely as cleaning agents, which narrows students' understanding of their roles in chemical reactions and titration processes. Another area

of difficulty involves the pH scale and the concept of concentration. Many students incorrectly interpret the pH scale as a linear rather than a logarithmic scale, leading to misunderstandings about the strength and concentration of acids and bases (Ayas & Demirbaş, 2018). According to Schmidt and Brown (2019), students often believe that an acid with a pH of 2 is only twice as strong as one with a pH of 4, rather than 100 times more concentrated in hydrogen ions. This misunderstanding impacts their ability to accurately calculate or compare the acidity or basicity of solutions.

Furthermore, the neutralization reactions between acids and bases are another source of confusion. Although the idea of an acid neutralizing a base (or vice versa) seems simple, students often fail to understand the ionic processes behind these reactions (Chiu et al., 2020). For instance, in titration experiments, students may struggle to identify the role of indicators, the concept of equivalence points, or the ionic equations that underpin the observable changes. A study by Nyachwaya and Gillaspie (2016) showed that students often memorize procedures without comprehending the underlying concepts, resulting in superficial learning and difficulty transferring knowledge to new situations. Salt formation and hydrolysis also pose significant learning obstacles. The concept that salts can be acidic, basic, or neutral depending on the strength of the parent acid and base is often misunderstood. In a survey by Banerjee and Yager (2021), students demonstrated difficulty predicting the nature of salts formed from weak acid-strong base or strong acid-weak base reactions. These challenges are compounded by the lack of adequate visual or experimental representations in many classrooms, particularly in under-resourced settings.

Instructional strategies and curriculum design also play a role in students' difficulties. Traditional lecture-based methods dominate in many schools, limiting opportunities for

hands-on learning or conceptual engagement. Taber (2019) argues that without guided inquiry, visual aids, and active student participation, abstract concepts such as acid dissociation constants, conjugate acid-base pairs, and salt hydrolysis remain inaccessible to most learners. Moreover, textbooks often present the topic in a fragmented manner, failing to adequately link concepts across subtopics, which further hinders students' ability to build a coherent conceptual framework (Nakhleh, 2020). Gender and language of instruction have also been noted to influence students' performance in acids, bases, and salts. In some contexts, female students tend to perform poorly in acid-base questions due to limited classroom participation, while students learning in a second language face challenges in grasping complex scientific terminology (Kibirige & Tsamago, 2022). Language-related issues may lead to incorrect interpretations of terms such as "strong" and "weak," which in science refer to the degree of dissociation, not concentration or danger as they do in everyday usage. Efforts to address these learning difficulties have included the integration of multiple teaching strategies such as concept mapping, computer simulations, and inquiry-based learning. For example, a study by Aidoo et al. (2020) demonstrated that students taught using computer simulations showed a statistically significant improvement in understanding acid-base reactions compared to those taught using conventional methods. Similarly, peer instruction and formative assessment strategies have been shown to encourage deeper engagement and improve conceptual retention (Mensah & Ampiah, 2021).

2.4 Hands-on Method of Teaching Science

According to Latip and Supriatna (2023), hands-on teaching approach is an instructional approach that seamlessly integrates various activities relevant to specific subjects into regular teaching methods. This method actively involves students in the

teaching-learning process, fostering fruitful engagement. Illeris (2004) further characterizes hands-on learning as a holistic process that combines cognitive, emotional, and environmental influences, providing experiences for acquiring, enhancing, and reshaping knowledge, skills, and worldviews. The key to effective learning lies in students comprehending and engaging with educational materials. For learning to occur successfully, students must process information through higher-order thinking skills such as synthesis, application, comprehension, analysis, and metacognition. Kaya and Kesan (2023) emphasize the importance of students being able to apply higher-level thinking to relate information to real-life situations, connect it with prior learning, and construct their knowledge. This, in turn, shapes them into knowledgeable and contributing citizens in adulthood.

Through a series of activities, students actively engage with educational materials, facilitating a deeper understanding and longer retention of information (Manor, 2002). Unlike traditional textbook study, hands-on learning emphasizes direct experiences, allowing students to learn effectively and apply acquired knowledge. Hands-on learning is designed to empower students to actively participate in the learning process, enabling them to comprehend information and construct their understanding of specific subjects. Rooted in the constructivist educational theory and characterized by a child-centered pedagogy, this approach aligns with the cognitive perspective, which focuses on learning, memory, problem-solving skills, and intelligence. According to Li et al. (2013), cognitivism involves individuals consciously engaging in the construction of a product. Under the constructivist framework, the utilization of constructionism in educational settings has been found to foster higher-order thinking skills such as problem-solving and critical thinking (Li et al., 2013). This approach creates an

enriching environment with various tools that students can manipulate to develop their skills.

The hands-on approach, as a teaching technique, emphasizes the teacher's involvement in the learning process through rigorous student participation, aiming to facilitate efficient learning experiences. Lunetta et al. (2007) describes the hands-on method-based method as a teaching strategy that encourages students to discover knowledge through engaging activities. Furthermore, this method not only facilitates knowledge acquisition but also cultivates process skills such as measuring, recording, analyzing, and interpreting data (Lunetta et al., 2007). Hands-on method is inherently child-centered, suggesting that students may learn more effectively and rapidly when instruction is delivered through activities. According to Gray and DiLoreto (2016), individual engagement in activities enhances understanding and promotes lasting retention of information.

The pedagogy of teaching Science through hands-on method extends beyond merely providing hands-on experiences for students. The hands-on method employed in science education positions the students at the core of the learning process, allowing them to actively manipulate materials and directly experience concepts (Lunetta et al., 2007). Brown and Ciuffetelli (2009) suggest that while not all teaching strategies must be inquiry-based, educators should involve students by posing open-ended questions, encouraging hypothesis formation, actively listening to students, supporting hypotheses with data, and facilitating discussions in small groups or pairs. However, a contrasting perspective arises from an article in the "Educational Psychologist" by Kirshner et al. (2006), which challenges the efficacy of the hands-on method method. The study contends that unguided activities may lead to memory loss, emphasizing the need for

strong guidance. The authors caution that unguided instruction is generally less effective and may result in negative outcomes, such as students acquiring misconceptions or incomplete knowledge.

In light of this, Demiralp and Ozudogru (2023) argue that education focused on in-depth knowledge surpasses the value of "curriculum coverage," which provides superficial exposure with limited opportunities for topic mastery. Depth in learning is seen as promoting lasting retention and facilitating knowledge transfer. Agboola and Ojo (2007) outline the multifaceted roles of practical or hands-on method-based methods in science, including fostering accurate observation, meticulous recording, promoting common-sense and scientific thinking, developing manipulative skills, providing training in problem-solving, verifying previously taught facts and principles, aiding comprehension through theoretical work, and actively engaging students in the investigative process to discover facts and principles. The hands-on method method of teaching places students at the focal point of the teaching and learning process, requiring them to interact with educational materials independently to discern scientific facts, concepts, or principles, whether or not guided by a teacher. Khan and Iqbal (2011) define an inquiry-based science lesson as a student-centered approach that encourages questioning and instructs students to arrive at new knowledge, fostering critical thinking and reasoning skills in a science class.

McBride et al. (2004) assert that employing hands-on method-based lessons, such as inquiry-based Physics teaching, has positively impacted students' performance, particularly those admitted to universities. Ergul et al. (2011) discovered that a combination of hands-on activities and inquiry-based science teaching enhances students' attitudes toward the study of science. This improvement in attitude was

evident in the experimental group compared to the control group, suggesting the efficacy of this teaching approach. In hands-on method lessons, the materials utilised are either provided by the teacher or the students themselves (Ministry of Education, Youth, and Sports [MOEYS], 2006). As outlined by Khan and Iqbal (2011) and the Ministry of Education Youth and Sport (2006), in a hands-on lesson, the teacher introduces the topic, distributes teaching-learning materials, and provides instructions for students to independently carry out the hands-on method. The teacher assumes the role of a co-learner, demonstrating interest in students' activities, circulating to monitor their progress, and offering guidance as needed. Through active engagement in the learning process, students develop a deeper understanding of scientific concepts and exhibit improved retention of acquired knowledge.

Cooke et al. (2023) emphasize that active engagement in science activities enhances learners' comprehension of scientific principles, promotes better retention, and fosters a more enjoyable learning experience compared to passive teaching techniques. The North Central Region Education Laboratory (NCREL, 1993) cites this perspective, highlighting the emergence of a new vision for science learning that calls for innovative instructional approaches. In the context of teacher training for science instruction through inquiry, McBride et al. (2004) note that instructors in the program adopt a co-learner role. They actively monitor participating teachers during activities, providing guidance when necessary. According to the Ministry of Education, Youth, and Sports (MOEYS, 2006), the hands-on method is the preferred choice for teaching and learning science at the basic school level. This preference is rooted in Piaget's concrete operational developmental stage, where students, by nature, exhibit distinct behaviors when engaged in play or using materials within their environment. The hands-on

method capitalizes on this stage, allowing individual students to construct concepts at their own pace, facilitating easy retention of learned concepts.

At their formative ages, students learn effectively when tangible objects that appeal to their senses are incorporated into teaching and learning. The use of concrete materials among students enhances skills in logical reasoning, symbol manipulation, and generalization (Baroody, 2017). Observing a primary school science lesson, Clark (2003) notes that students engage in activities based on simple and familiar materials, contributing to a meaningful and relatable learning experience. Baroody (2017) reaffirms that the hands-on method in science teaching affords students ample time to engage in activities, facilitating the discovery of new knowledge. The approach advocated by Baroody (2017) emphasizes that science education should allow students sufficient time for exploration, observation, data collection, sorting, idea testing, measurement, recording, drawing, interviewing, surveying, computation, and skillful use of scientific equipment. This approach enhances students' retention of scientific concepts, thereby improving their performance in science. There is a historical shift from a theoretical approach in science education, driven by limited knowledge among pupils, to a contemporary emphasis on practical, hands-on learning. In modern times, the enjoyment of science lessons is heightened when students actively participate in activities related to the topic. Thus, there is a compelling need to adopt hands-on and inquiry methods in science teaching, especially at the basic and secondary levels (Chikaluma et al., 2023).

However, concerns about practical work in school science have persisted. Some argue that teachers often spend a considerable amount of time organizing such activities, hindering their ability to complete the syllabus. It was therefore cautioned that practical

work, often conducted under the guise of enhancing learning, can be a relatively ineffective use of teaching time. They argue that it has repeatedly failed to equip students with the necessary science skills for the 21st century and has not provided a sufficient understanding of scientific theories or the scientific process. Ofsted (HMI/Ofsted, 2004a, 2004b) further notes the variability and vulnerability of scientific inquiry in primary schools and the narrow range of investigations at the secondary level, dominated by the perceived demands of assessed coursework beyond Year eight. These concerns have gained support from various sectors, including the science community, educators, industries, businesses, students, and some teachers.

Arguments both for and against practical work or hands-on activities need careful consideration by those involved in science education, taking into account the purpose of science education and the specific aims and objectives of practical work. Authors like Bennett and Kennedy (2001) highlight the challenge of assessing practical work due to the diverse aims attributed to it. There is a suggestion that viewing the laboratory as an aide-de-camp rather than a necessity might be a worthwhile perspective, emphasizing that the learning of science does not necessarily depend on a practical component for every lesson. On a broader scale, teachers and students exhibit a positive attitude toward hands-on learning. According to a NESTA survey involving 510 UK science teachers, 99% believed that inquiry learning had a positive impact on student performance and attainment, with 83% expressing a strong positive impact (NESTA, 2005b). Lunetta et al. (2007) acknowledge the considerable variability in the quality of practical work but assert that well-planned and effectively implemented laboratory and simulation experiences in science education can engage students both mentally and physically, providing inquiry-based learning opportunities that are not feasible in other science education experiences.

2.5 Students' Academic Performance in Science

Researchers emphasise that academic performance is the culmination of the learning process, shaped by both instructional efforts and the student's engagement (Martínez-Otero, 2007). From a humanistic viewpoint, academic success is commonly demonstrated through school grades, reflecting an individual's acquired knowledge, critical thinking, problem-solving skills, and practical application of learned concepts (Lamas, 2015). According to Caballero et al. (2007), good academic performance involves meeting specific goals and objectives within a course or program, as reflected in grades attained through assessments. Willcox (2011) defines academic performance as the demonstration of knowledge relative to the norm, often evaluated by the grade point average. The pursuit of academic success aims to achieve specific learning goals, with performance encompassing various interconnected components. These components involve educational processes within a cognitive and structural unit, subject to influences from internal, external, and environmental factors. Variables such as intellectual capacity, personality, motivation, aptitude, study habits, and the teacher-student relationship impact academic achievement. Biggs It is crucial to recognise that students' learning approaches are flexible, influenced by both individual traits and contextual factors (Biggs et al., 2011). Barca et al. (2013) highlight that learning approaches, combining goals and strategies, significantly influence academic performance. For instance, using a surface approach with effective memorization techniques to attain high grades may yield satisfactory performance. Learning approaches involve the strategies students employ based on their perceptions of the task and self-identity (Entwistle & Peterson, 2004). This concept includes situational and individual components, with students considering goals, motivations, tactics, and

resources when faced with a task (McCune & Entwistle, 2011). Consequently, learning strategies are goal-motivated and employ distinct techniques.

2.6 Factors Affecting Students' Performance in Science

In order to discuss the elements influencing students' academic achievement, the idea of bad performance should be examined. According to Aremu (2010), a poor performance is one that was determined by the test takers to be significantly below the expected standard. Because of the performance evaluator's ongoing cognitive ability, it is easier to understand how to interpret this expected or desired standard. Therefore, based on certain criteria, the evaluator or assessor may offer various interpretations. As opposed by Bakare (2007) as cited in Abdullahi (2013) who defined bad academic performance as any performance that is below a desired standard.

The academic pursuits of students are influenced by numerous factors. The accomplishments of students are mostly a result of them. Parents, siblings, instructors, peers, and other social groups (such as the clergy, famous people, and social organizations) can also be thought of as having an impact on a student's achievement (Sirin, 2005; Dankenda & Sooriyapathirana, 2011; Gupta & Mili, 2015). To improve student achievement, adequate resources are also required. According to Kalita (2016), there is a strong association between a student's academic success and emotional stability. Therefore, it is crucial to motivate parents, educators, and decision-makers to take the required steps to foster children's emotional stability. When used effectively, student self-assessments can also foster intrinsic drive (James & Jessica, 2016). According to James (2006), influences from family, friends, and pre-secondary teachers have an impact on a student's success in post-secondary school.

According to studies by Blooms (2014), Fehrmann (2017) and Eisner (2010), parental involvement in their children's education is positively correlated with student outcomes. Steinberg et al. (2009) did not discover any differences when comparing the parenting styles of successful and unsuccessful students. The degree and kind of parental involvement in their children's education depends on a variety of factors, including the parents' gender, educational background, amount of income, and place of residence (Dankenda & Sooriyapathirana, 2011). Branch (2013) recognized school-sponsored extracurricular activities and teacher effectiveness as factors influencing students' academic success in science.

Additional characteristics that may affect students' achievement in science include gender, family structure, parents' educational attainment, socioeconomic status, parent and student attitudes toward school, and parental participation, according to a growing body of research (Campbell et al., 2010; Epstein & Voorhis, 2011; Fennema & Sherman, 2006, 2008; Fluty, 2017). Ethiopia's education policies and sector development plans place a strong emphasis on the value of science and technology in ensuring the nation's growth and development. By using science and technology as tools to generate wealth, Ethiopia must restructure its economy in order to realize its goal of being a middle-income nation by 2025. According to the main objectives of the present growth and transformation strategy, there will be a high demand for qualified people who can help the nation compete in the increasingly knowledge-based global economy. This should be also be considered and prioritized in Ghana to promote scientific literacy in the communities.

2.7 Empirical Study

A number of studies carried out using hands-on instructional approaches came out clearly that students learned and performed better when they were actively involved in their learning process (Usman, 2000). A study by Shah and Rahat (2014), reported that performance of experimental group was better than the performance of the controlled group when hands-on method-based teaching was used on the students. The study further stated that there was significant difference between the performance of the experimental group as compared to the control group with reference to knowledge, comprehension, and application skills. Overall, the findings of the study showed that the hands-on method-based teaching was much effective than the lecture method teaching of Integrated science. Fifteen years of study by Luecke et al. (2023), reported that the students in hands-on program performed 20 percentile units higher than the comparison groups. The students in these programs scored higher than the control groups.

The hands-on method of teaching could improve students' creativity in problem solving, promote students' independence and help low ability students to overcome initial handicaps (Anwer, 2019). This meant that students who were even below average could improve tremendously when they are given the chance to manipulate items during the teaching and learning process. Chikuni (2003), backed the use of hands-on method of teaching and learning as it yields a lot of benefit to learners. They argued that the hands-on method marks active involvement of students and focuses on the needs of learners which enables them to be more creative, think critically and be innovative. They further stated that the hands-on method-based approach should be employed mostly in teaching and learning of science due to its feasibility to involve learners

actively in the lessons. This will therefore enable teachers and learners to achieve general and specific objectives in the teaching syllabus.

A study was conducted by Kırılmazkaya and Dal (2022) on the effect of hands-on method on student's academic achievement and scientific attitude. The study was a quasi-experimental model with pretest-posttest control group as a design. The study group of this research consists of a total of 40 students, 21 (52.5%) girls and 19 (47.5%) boys, studying in a secondary school in the southeast of Turkey in the 2021-2022 academic year. The "Force and Energy achievement test" was used to determine the effect of science activities with simple tools on the academic achievement of students. the "Attitude towards Science Scale" was used in order to determine students' attitudes towards science. The data obtained from the data collection tools used in the study were analyzed with the SPSS program. The results of the study indicated that the activities performed with simple tools were effective in student success. This shows that the activities made with simple equipment are more effective on the academic success of the student than the traditional method. In the study, a significant difference was found in favour of the experimental group when the scientific attitude scale results of the control group taught with the traditional approach and the science activities performed with simple tools and the experimental group were compared.

Another study was also conducted by Ekwueme et al. (2015) on the effectiveness of hands-on activities on the academic performance of students in science and mathematics. This study aimed to examine the influence of a hands-on approach on students' academic achievements and their perspectives on this hands-on method-based teaching method. The primary goal was to evaluate the effects and offer an alternative platform for students to demonstrate their comprehension beyond traditional written

exams focused on memorization of formulas. The hands-on activities specifically targeted Mensuration and Geometry, allocating 25% of the questions to each area, and the separation of mixtures involving pure and impure substances. This paper involved an analysis of students' feedback through pre-test and post-test scores before and after the implementation of the hands-on approach, as well as insights gathered from student interviews. The findings indicated a positive enhancement in both student performance and engagement in mathematics and basic science activities. Additionally, teachers express a willingness to incorporate the hands-on approach to effectively communicate mathematical and scientific concepts to their students.

2.8 Students' Perception of Hands-on method in science lessons

There are sense organs like the nose, ear, and eyes to help us take in information from our surroundings. A sensory system, which accepts sensory inputs and relays sensory data to the brain, is made up of each sense organ. How to describe the mechanism by which the physical energy received by sense organs serves as the foundation of perceptual experience is a specific challenge for psychologists. Sensory inputs are somehow transformed into perceptions of computers and desks, flowers and buildings, automobiles and planes, and into experiences with sights, sounds, smells, tastes, and touches (MacLoed, 2007). Around the world, it is common practice to use student perspective to examine instructional strategies and create efficient teaching approaches. In order to determine which instructional practices students believe to be the most effective for promoting learning in the classroom, student perception is used (Abdulghan & Al-Nagger, 2015). They claimed that using student feedback was a successful strategy for changing the undergraduate curriculum and enhancing the appeal and applicability of pharmacology. They also showed that numerous research on students' views of learning pharmacology demonstrated how better teaching and

learning procedures lead to improvements in students' performance. Thus, when suggestions received from students are put into practice, student feedback is regarded as an excellent instrument for enhancing students' performances.

They also noted that student feedback could offer a variety of practical suggestions for enhancing the quality of instruction. In response, they stated that they would contribute significantly to the curriculum review processes, aid in the development of a knowledge-building process that is learner-centered, improve the application of contemporary pharmacology teaching methods, and improve the learning environment's overall quality (Abdulghani & Al-Nagger, 2015). A person's capacity for perceiving and comprehending things that are not immediately apparent to others is referred to as perception. From a physical, psychological, and physiological standpoint, perception can be defined. Perception is important because it affects the information that gets stored in working memory (Davis, 2010).

According to Gerstner and Bogner (2010), hands-on method is a style of playing or working that involves research, experience, or study and allows the student to express and develop his or her own ideas, thoughts, and problem-solving and manipulating skills. The learner-centered nature of the hands-on method technique, which places more focus on students' active participation, was reaffirmed by Gerstner and Bogner (2010). It has been suggested that using hands-on science will improve student performance in scientific classes. To explain why students learn science better when they engage in hands-on activities, several theories have been put forth. Content knowledge and process skills are two broad categories of scientific knowledge that are identified by science educators (Kugamoorthy, 2012). The facts, ideas, conceptual frameworks, theories, and rules that students are required to comprehend and remember

are included in content knowledge, which is sometimes referred to as declarative knowledge. The methods utilized in science are called process skills, often known as procedural knowledge. The subject of this conversation is education in the sciences. Other justifications for hands-on science include enhancing laboratory practices and boosting student motivation. The four skills that students must master are illustration, observation, measuring, and constructing hypotheses. For students to completely comprehend science and be able to apply it, both domains are seen to be important (Kugamoorthy, 2012). It has been suggested that teaching science through hands-on activities will help students understand both types of information better.

Knowledge of scientific subjects is frequently complex and abstract. This abstract information may become more concrete and obvious through the examination and manipulation of objects. Students can experience real-world examples of the information and observe the impact of changes in many factors through hands-on science. These examples serve as debate points as well (Ergul et al., 2011). Promoting students' ability to combine all of the distinct process skills for problem-solving and conducting scientific research independently is another issue with process skills. This objective has occasionally been set for only the top students who are expected to pursue careers in science, while other times it has been tailored to all students through applications in daily life, whether they are personal or professional.

2.9 Effect of Hands-on Activities on the Development of Science Process Skills

Science process skills encompass a collection of cognitive and manipulative abilities that empower individuals to participate in scientific inquiry and problem-solving. These skills play a crucial role in comprehending and employing scientific principles, carrying out experiments, and thoughtfully assessing information (Sideri & Skoumios, 2021).

The cultivation of science process skills is fundamental to both the scientific method and the broader process of scientific investigation. In our rapidly advancing world, possessing science literacy has become indispensable for individuals navigating the landscape of ongoing scientific research. It is essential for everyone to actively participate in discussions surrounding the significant technological and scientific endeavors shaping our society. The demand for advanced knowledge, skills, and effective communication with the community underscores the crucial role of science in our lives. According to Soylu (2004), science and scientific process skills play a pivotal role in acquiring these competencies. Sideri and Skoumios (2021) highlights that when scientific process skills are explicitly designated as a targeted outcome within a science program, students tend to grasp them more effectively. Consequently, educators should opt for curricula that emphasize the development of scientific process skills. Western societies, with their advanced educational systems, have long recognized the importance of incorporating scientific process skills into curricula. In Turkey, recent changes in educational frameworks for chemistry, physics, and biology aim to elevate the quality of science education. Notably, scientific process skills have gained increased prominence in secondary science education programs over the past few years.

In the contemporary era marked by rapid technological advancement and easy access to information, students should prioritize gaining an understanding of the essence of science, generating scientific knowledge, identifying and interpreting issues, and proficiently solving problems. Merely imparting existing knowledge and equipping students with problem-solving skills limited to everyday scenarios is insufficient for adequately preparing them for the future (Gozli, 2023). Therefore, the primary objective of science education is to enhance science literacy. To realize this objective, the key aims of chemistry, physics, and biology curricula should be to educate

individuals capable of comprehending the nature of scientific inquiry. These individuals should be adept at producing scientific knowledge by employing scientific process skills, solving problems, applying scientific knowledge and methodologies to explain phenomena, offering substantiated justifications through evidence and proof, analyzing and evaluating acquired or existing knowledge through practical experience, sharing scientific knowledge, and employing information technology as needed (Ministry of National Education [MONE], 2013a, 2013c).

Teaching science encompasses both the content and process aspects of the discipline, and it is imperative not to undervalue one over the other; both hold equal importance. Content involves subject matter and scientific concepts, while process involves the essential skills students need to acquire (Inan, 2010, 2011; Inan et al., 2014). Science curricula prioritize the development of science process skills as a primary objective, aiming to integrate these skills not only into science courses but across all science-related subjects. Gultepe (2016) emphasizes that science process skills are a key goal in science education, as these skills are not only utilized by scientists but are crucial for fostering scientific literacy in everyone. The scientific process is fundamentally shaped by analytical and critical thinking skills (Ministry of National Education [MONE], 2013a). When examining classifications of science process skills, two main categories emerge: primary and integrated skills. Primary skills, such as observation, deduction, classification, measurement, prediction, numerical use, communication, and spatial-temporal relations, form the foundation for science process skills. Integrated skills, often termed experimental process skills, build upon primary skills by specifying variables, forming hypotheses, collecting data for verification or refutation, recording data, and arriving at judgments. These processes not only answer questions but also pave the way for further inquiries and experiments (Emereole, 2009).

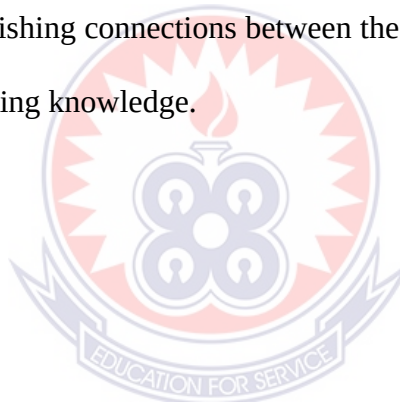
Science process skills serve as the tools that students use to explore their surroundings and construct scientific concepts. Consequently, it is essential for teachers to possess a solid understanding of these skills. Teachers should emphasize curricula that prioritize process over content in problem-solving (Johnson et al., 2014). Integrating science content knowledge and science process skills carefully in teachers' professional development is crucial (Jeanpierre et al., 2005). According to Aybek (2007), schools should ensure that teachers acquire this knowledge, enabling them to educate students who are curious, engaged in discussions, capable of making predictions and priorities, exploring alternatives, and making sense of diverse perspectives. Birman et al. (2000) found that the focus of professional development on content knowledge is directly linked to teachers' increased knowledge and skill.

2.10 The Role of Students' Prior knowledge in teaching and learning

Background knowledge can be described simply as the foundational material that shapes the learning process, serving as mental hooks for assimilating new information. It constitutes the fundamental building block for acquiring both content and skill knowledge. Various authors, such as Marzano (2004) defined prior knowledge as the information individuals already possess about a particular subject. By the time students enter school, they have developed informal theories about how things work, their self-perceptions, and their understanding of others (Bransford et al., 2005).

Cognitive researchers assert that learners actively construct knowledge, and their existing knowledge significantly influences their ability to acquire new information. When new knowledge clashes with prior understanding, effective learning becomes challenging. Recognizing the importance of students' preconceptions, teachers should take them into account when planning instruction. While many instructors emphasize

the content to be taught, they often overlook what students bring to the learning process. Neglecting to consider prior knowledge during teaching can lead to significant consequences. Disregarding students' existing knowledge may result in the teacher's intended message being misunderstood. Understanding students' prior knowledge influences how both teachers and students engage with instructional materials. One of the primary goals of education is to rectify misconceptions and provide accurate information (Strongman & Hall, 2004). Knowing what students bring to the learning environment enables teachers to address and correct any misconceptions effectively. According to Baroody (2017), students' pre-existing ideas lay the foundation for constructing new knowledge. Therefore, learners develop a deeper understanding of new concepts by establishing connections between the new and existing knowledge or restructuring their existing knowledge.



CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter focuses on the research design, population, sample size, research instruments, reliability and validity of the research instruments, data collection procedure and data analysis procedure.

3.1 Design

An Action Research design was used for this project. According to Sidhu (2013), action research is a sort of study that may be carried out on small, readily accessible samples right away to address a pressing issue. Action research allows the participants to create appropriate interventional methods with the goal of resolving issues that have been recognized in the teaching-learning environment, in addition to focusing on the creation of new knowledge. Because it takes a comprehensive and in-depth investigative approach and is specifically created to comprehend the use of hands-on activities in the teaching and learning of science, this design has been chosen for the study.

3.2 Population

According to Willie (2023), the population of a study is the total of all the objects, subjects, or members that conform to a set of a given criteria. Population according to Singleton and Strait (2010) is also defined as a complete set of elements (persons or objects) that possess common characteristics defined by sampling criteria established by the researcher. This study was conducted at Ve Senior High School which is located at Ve in the Volta region. The school has a student population of 1,700 and this population comprises of both females and males. The target population comprised of all form 2 students of Ve Senior High School.

3.2.1 Accessible Population

According to Pernecky (2016), the accessible population is the section of a larger population the researcher can apply his conclusions. The accessible population is derived from the target population and as such can be said to be a subset of the target population. The accessible population comprised all form 2 Business students of Ve Senior High School. There were 220 form 2 Business students during the period of the study.

3.3 Sample and Sampling technique

Johnson and Christensen (2012) defined sample as part of a fully defined population. The purpose of sampling is to obtain a group of subjects that represents the larger population or provides specific information needed (O'Leary, 2011). The researcher used purposive sampling to select fifty (50) students. These were all students in the form 2 Business 2 class of Ve Senior High School. This sampling technique was used because it allows the researcher to select a population with common characteristics and needs which is of interest to the researcher and relevant to the topic under consideration.

3.4 Instruments

The main data collection instruments employed in the study were test items and questionnaire.

3.4.1 Test

The tests were pre-test, which was conducted to identify the difficulties students had in acids, bases and salts. The post-tests were also conducted after the intervention activities. The test items for the pre-test were made up of four theory questions which were application and the questions were set across these process skills; measuring, observation, manipulation and recording. The test items for the post-test were also made

up of four theory questions. The duration for both the pre-test and post-tests were thirty minutes with a total of ten marks. Tests were used because they are effective ways of securing information from students and an ideal method that helped to measure students' performance (Wiggins, 2011). The post-test was purposively employed to measure students' academic performance after the intervention and also to measure their science process skills after the intervention.

3.4.2 Questionnaire

Questionnaire as a research instrument, consisting of a series of questions for the purpose of gathering of information from respondents. The questionnaire was closed ended structured on a 3-point Likert Scale; Agree, Neutral and Disagree and it contained nine items. According to McLeod (2018), questionnaires provide a relatively cheap, quick and efficient way of obtaining large amounts of information from a large sample of people. The questionnaire was used to measure students' perceptions on the use of hands-on instructional approaches in teaching the acids, bases and salts.

3.5 Validity of the Instruments

According to Sudaryono et al. (2019), validity pertains to the accuracy and appropriateness of the interpretations and utilization of assessment outcomes from students. In educational research, ensuring validity is essential for obtaining credible and meaningful data that accurately reflects the constructs being measured. Specifically, content validity refers to the extent to which an assessment instrument adequately and comprehensively covers the intended subject matter or domain of interest (Fraenkel, Wallen, & Hyun, 2019). To establish the content validity of both the tests and questionnaire items used in the study, a rigorous validation process was undertaken.

Firstly, the items were carefully aligned with the identified research problem, research objectives, and the specific constructs under investigation. This ensured that every item directly contributed to measuring students' understanding, attitudes, or perceptions relevant to the focus of the study. Secondly, the instruments were reviewed by a panel of experts, including the Head of the Science Department and experienced science teachers at Ve Senior High School. These experts evaluated whether the items adequately reflected the key concepts and learning objectives outlined in the science curriculum.

Furthermore, the reviewers assessed the instruments for coherence, clarity, and the absence of ambiguous or misleading language. Items were reworded where necessary to enhance comprehension and reduce the likelihood of misinterpretation by students. By doing so, the likelihood that students would interpret the questions as intended by the researcher was increased, thereby supporting the validity of the findings. This review process helped to ensure that the instruments not only measured what they were intended to measure but also did so in a way that was accessible and understandable to the target student population. Therefore, the comprehensive expert review and alignment with curricular goals and research focus strongly supported the content validity of the assessment instruments used in the study.

3.6 Reliability of the Instruments

According to Bell and Holroyd (2009), reliability of a measurement tool refers to its ability to consistently yield similar results when administered under consistent conditions. Yayra (2017) defines reliability as the degree of consistency in assessment outcomes.

To ensure the reliability of the test and questionnaire items used in the research, the test-retest method was employed. This involved administering the test and the questionnaire to other Form 2 classes, and the results demonstrated consistency. Additionally, a Cohen's kappa coefficient value of 0.77 was calculated. Coleman (2022) states that a coefficient value of 0.7 or higher is indicative of reliability. Therefore, the obtained coefficient value suggests that both the test and questionnaire items were reliable.

3.7 Data collection procedure

3.7.1 Pre-Intervention Activities

A test items on acids, bases and salts was given to the students to answer. A duration of 30 minutes was used and all examination rules were adhered to.

3.7.2 Intervention Activities

Week 1: Introduction to Acids, Bases, and Salts

Objective: Introduce students to the concepts of acids, bases, and salts through hands-on activities and demonstrations.

Materials Needed:

- Red cabbage indicator (homemade or store-bought)
- Lemon juice
- Vinegar
- Baking soda
- Ammonia
- Salt
- Water
- Test tubes

- Droppers
- pH paper

Activities:

1. Introduction:

- Begin by discussing the properties of acids, bases, and salts.
- Explain the pH scale and its significance.
- Show examples of common household acids, bases, and salts.

2. Making Red Cabbage Indicator

- Demonstrate how to prepare red cabbage indicator solution.
- Discuss how the indicator changes colour in the presence of acids and bases.

3. Testing Acids and Bases

- Divide students into groups.
- Provide test tubes and various substances such as lemon juice, vinegar, baking soda, ammonia, and water.
- Have students use droppers to place small amounts of each substance into separate test tubes.
- Add a few drops of red cabbage indicator to each test tube and observe the color changes.
- Guide students in recording their observations and discussing the results.

Week 2: Properties and Reactions of Acids and Bases

Objective: Explore the properties and reactions of acids and bases through experiments.

Materials Needed:

- Hydrochloric acid (diluted)
- Sodium hydroxide (diluted)
- Magnesium ribbon
- Zinc granules
- Universal indicator solution
- Safety goggles

Activities:

1. Acids and Metals

- Discuss the reaction of acids with metals.
- Provide students with small pieces of magnesium ribbon and zinc granules.
- Have students place each metal in separate test tubes containing diluted hydrochloric acid.
- Observe the reactions and discuss the results.

2. Bases and Indicators

- Introduce universal indicator solution.
- Demonstrate how universal indicator changes color in the presence of acids and bases.
- Have students perform tests using universal indicator and various bases like sodium hydroxide.

Week 3: Neutralization Reactions and pH Scale

Objective: Understand neutralization reactions and the concept of pH.

Materials Needed:

- Hydrochloric acid
- Sodium hydroxide
- Phenolphthalein indicator
- Graduated cylinders
- Beakers

Activities:

1. Neutralization Reactions

- Discuss neutralization reactions and their importance.
- Perform a demonstration of neutralization reaction using hydrochloric acid and sodium hydroxide.
- Use phenolphthalein indicator to observe the endpoint of the reaction.

2. pH Scale

- Introduce the pH scale and its significance.
- Perform pH testing of various substances using pH paper.
- Have students categorize substances as acidic, basic, or neutral based on their pH.

Week 4: Salts and Their Preparation

Objective: Explore the formation and properties of salts.

Materials Needed:

- Soluble salts (e.g., sodium chloride, potassium nitrate)
- Insoluble salts (e.g., calcium carbonate)
- Dilute acids (e.g., hydrochloric acid, sulfuric acid)
- Dilute bases (e.g., sodium hydroxide)

Activities:

1. Formation of Soluble Salts

- Discuss the formation of soluble salts through the reaction between acids and bases.
- Perform experiments to prepare soluble salts such as sodium chloride and potassium nitrate.

2. Formation of Insoluble Salts

- Discuss the formation of insoluble salts through precipitation reactions.
- Perform experiments to prepare insoluble salts like calcium carbonate.
- Observe and discuss the characteristics of insoluble salts.

3.7.3 Post-Intervention Activities

In the post intervention, the students were given questions as post-tests to examine their improvement and understanding of acids, bases and salts taught as well as process skills gained in the various activities performed through each of the weeks after each intervention. Questionnaire items on students' perceptions on the use of hands-on method of teaching were also given to them to respond after the implementation of the test items.

3.8 Data Analysis Technique

The pre-test data on the difficulties of students on acids, bases and salts was analysed using content analysis. The test data on students' performance was analysed using SPSS Version 27 into frequency distribution tables and percentages while the data on students' science process skills was analysed using SPSS Version 27 into frequency tables and means. The questionnaire data were also collected after a given period of time and it was also analysed frequency table and percentages.

3.9 Ethical Consideration

The researcher met the participants (2 Business 2 students) and discussed the purpose of the research, the expected time for the study and the procedure for the research activities. Permission was also granted by the school the researcher used for the study. All participants were given a guarantee of confidentiality and anonymity in reporting the information provided for the study. Additionally, ethical issues governing human subjects in the research were strictly adhered to. The names of students were not captured in the research. There were no biases towards any religion, race, culture or gender. Additionally, the research subjects were not asked to reveal their identity in any way.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter presents the analysis of the data of the findings. It includes analysis and discussions of pre-intervention results, post-intervention results and questionnaire data.

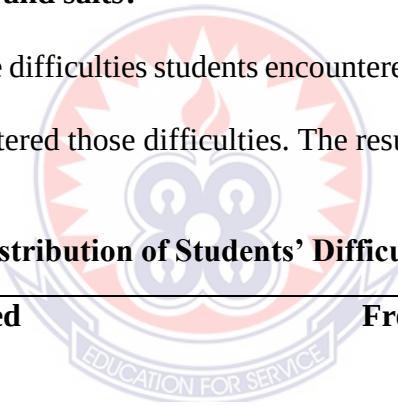
4.1 Presentation of the Results by Research Questions

The results of the study are now presented by research questions as follows;

4.2 Research Question 1: What difficulties do the students encounter during lessons on acids, bases and salts?

This section presents the difficulties students encountered in the pre-test and the number of students who encountered those difficulties. The result is presented in Table 1.

Table 1: Frequency Distribution of Students' Difficulties in Acids, bases and Salts



Difficulty Encountered	Frequency	Percentage (%)
Understanding the different definitions of acids and bases (Arrhenius, Bronsted-Lowry, Lewis)	40	80.0
Grasping the concept of pH and classifying substances based on Ph	35	70.0
Describing the process of neutralization and balancing chemical equations	30	60.0
Explaining how blood functions as a buffer in the human body	45	90.0

From Table 1, one of the primary difficulties encountered by students is understanding the different definitions of acids and bases according to the Arrhenius, Bronsted-Lowry, and Lewis theories. Forty (40) out of 50 students representing 80 %, struggled with this

concept. Many students provided incorrect definitions for the three theories. For instance, one student stated,

"According to Arrhenius, acids donate protons, and bases donate electrons." This is rather an incorrect definition of Arrhenius concepts of acids and base. Another student wrote,

"Bronsted-Lowry acids release hydrogen ions in water". This does not depict the Bronsted-Lowry theory. These responses indicate a fundamental misunderstanding of the distinct characteristics and applications of each theory.

Grasping the concept of pH and classifying substances based on their pH values also posed a significant challenge, with 70 % of students (35 out of 50) struggling in this concept. Many students failed to accurately relate pH values to the acidic, neutral, or basic nature of substances. For example, one student incorrectly stated,

"A pH of 7 means the substance is highly acidic". This showed a misunderstanding of the neutral point on the pH scale. Another student confused basic and acidic substances by writing, *"Substances with a pH above 7 are acids"* which is in contrast of the correct classification. These mistakes revealed a lack of clarity regarding the pH scale and its practical applications in identifying the nature of different substances.

Describing the process of neutralization and balancing chemical equations was another area of difficulty, affecting 60 % of students (30 out of 50). Many students were unable to correctly write balanced chemical equations or explain the neutralization process accurately. One incorrect response stated,

"Neutralization occurs when an acid and a base form water and an acid". This fails to recognize the formation of a salt in the process. Another student attempted to balance

the equation for the reaction between hydrochloric acid (HCl) and sodium hydroxide (NaOH) but wrote,

"HCl + NaOH → NaCl + H₂O₂," introducing an incorrect product (hydrogen peroxide) instead of water. These errors highlight the challenges students encounter in visualizing and accurately representing chemical reactions.

The most significant difficulty was explaining how blood functions as a buffer in the human body, with 90 % of students (45 out of 50) struggling with this concept. Many students showed a lack of understanding of the biological role and mechanisms of buffers. For instance, one student incorrectly wrote,

"Blood acts as a buffer by adding more acid to neutralize bases in the body". This misrepresents the balancing action of buffers. Another student claimed,

"Buffers in blood remove all acids to keep the pH constant". This also fails to recognise the adjustments buffers make to maintain pH within a narrow range. These responses indicate a disconnection between theoretical knowledge and real-life biological processes, particularly in understanding the dynamic equilibrium maintained by buffers in the body.

The content analysis of pre-test responses reveals significant difficulties among students in understanding key concepts related to acids, bases, and salts. The incorrect responses provided for each difficulty illustrate the nature and extent of these difficulties. This therefore implies that students in Ve Senior High school encounter significant difficulties during lessons in acids, bases and salts.

These findings are in line with Gilbert and Treagust (2009) who opined that students often struggle with the abstract nature of these definitions and their applications. Misunderstandings arise when students fail to differentiate between these theories and

their specific contexts (Gilbert & Treagust, 2009). Literature also indicates that students often have a superficial understanding of the pH scale and its implications. According to De Jong and Taber (2007), students commonly misconceive the nature of the pH scale, particularly the logarithmic relationship it represents and its practical implications in classifying substances as acidic, neutral, or basic.

Balancing chemical equations and understanding the process of neutralization is another area where students encounter significant difficulties. Therefore, this particular difficulty is in line with the study by Nakhleh (1992) who suggested that students often find it challenging to understand the conservation of mass and the stoichiometry involved in chemical reactions. It also in line with the findings of Kind and Taber (2005) who found out that students often struggle with the interdisciplinary nature of this concept. The bicarbonate buffer system in blood, which involves the equilibrium between carbonic acid (H_2CO_3) and bicarbonate ions (HCO_3^-), is a complex concept that requires a deep understanding of acid-base chemistry and physiological processes. Misconceptions about how buffers work, such as the belief that they simply neutralize acids or bases, indicate a need for more integrated and context-based teaching approaches (Kind & Taber, 2005).

4.3 Research Question 2: What is the effect of the hands-on teaching and learning approaches on the students' performance in acids, bases and salts?

This section presents data of students' pre-test and post-test scores of students. The results are presented in Table 2 and 3.

Table 2: Frequency Distribution of Pre-Intervention Results of Students

Score	Frequency	Percentage (%)
0–5	18	36
6–10	14	28
11–15	10	20
16–20	5	10
21–25	2	4
26–30	1	2
Total	50	100

Table 2 presents the pre-test scores of 50 students before they were introduced to hands-on activities in the teaching of acids, bases, and salts. The performance levels indicate that a majority of the students scored in the lower ranges, reflecting limited understanding of the concepts prior to the intervention. Specifically, 18 students, representing 36%, scored between 0–5, indicating very poor performance. Additionally, 28% of the students (14 in total) obtained scores between 6–10, further emphasizing the widespread initial difficulty students had with the topic. A moderate proportion of students (20%) scored within the 11–15 range, suggesting partial understanding, but still below average. Only a small fraction of students performed fairly well, with just 10% scoring between 16–20, and 4% obtaining scores within the 21–25 range. Notably, only one student (2%) achieved a score between 26–30, the highest bracket.

Table 3: Frequency Distribution of Post-intervention Results of Students

Score	Frequency	Percentage
0-5	8	16
6-10	6	12
11-15	7	14
16-20	12	34
21-25	10	28
26-30	7	24
Total	50	100

Table 3 shows the post intervention results of students. From the table, eight students representing 16% scored marks between 0 and 5, six students representing 12% scored marks between 6 and 10, seven students representing 14% scored marks between 11 and 15, seventeen students representing 34% scored marks between 16 and 20, fourteen students representing 28% scored marks between 21 and 25%. Lastly, twelve students representing 24% scored marks between 26 and 30.

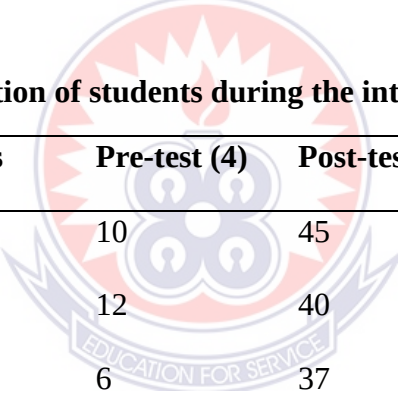
Table 2 shows the students' performance after the intervention. The table shows that twenty-nine students representing 58% passed the test with an average score of 16.1%. This indicated that the intervention improved students' performance on the concept of acids, bases and salts. This is in agreement with Anwer (2019) who reported that hands-on instructional approach has more advantage on teaching and learning science rather than a traditional strategy and it improves creativity and enhances students' achievement in science. According to Kırılmazkaya and Dal (2022), when students engage in practical work, they can test, rethink and reconstruct ideas and thoughts and for these reasons, and they reported that practical work improves students learning and

understanding of science concepts. Such beneficial outcomes may be due to students feeling ownership over the concept they learn as they find the knowledge for themselves during practical work (Ekwueme et al., 2015). According to Ekwueme et al. (2015), there is a positive enhancement in both student performance and engagement in basic science activities. Additionally, teachers express a willingness to incorporate the hands-on approach to effectively communicate scientific concepts to their students.

4.4 Research Question 3: What is the effect of hands-on teaching and learning on the students' science process skills?

This section reveals the science process skills students possess in the chemistry classroom during the intervention activities. The result is presented in Table 4.

Table 4: Skills acquisition of students during the intervention period



Science process skills	Pre-test (4)	Post-test (4)	Total	Mean
Measuring	10	45	55	27.5
Observation	12	40	52	26
Manipulation	6	37	43	21.5
Recording	12	40	52	26

Source: fieldwork data, 2024

The data presented in the Table 4 reflects a significant improvement in the number of students who were proficient in various process skills following the implementation of the hands-on method of teaching. This hands-on method of teaching appeared to have had a profound impact on the students' acquisition of essential science process skills, as indicated by the pre-test and post-test results for measuring, observation, manipulation, and recording skills.

For the skill of measuring, the number of proficient students increased from 10 in the pre-test to 45 in the post-test, making in a total of 55 and an average increase of 27.5 students. This substantial rise demonstrates that the activity method significantly enhanced the students' ability to measure accurately and efficiently. In terms of observation skills, the number of proficient students grew from 12 in the pre-test to 40 in the post-test, totaling 52 with an average increase of 26 students. This improvement suggested that students became considerably more proficient recording details, a critical skill in scientific inquiry. The manipulation skills saw an increase from 6 proficient students in the pre-intervention test to 37 in the post-intervention test, yielding a total of 43 and an average increase of 21.5 students. This indicated a significant enhancement in students' ability to handle and operate experimental equipment, which is important for conducting experiments. Similarly, recording skills improved from 12 proficient students in the pre-test to 40 in the post-test, making a total of 52 and an average increase of 26 students. This demonstrates that students became more capable of accurately documenting experimental procedures and results. The observed improvements across all four skills emphasise the effectiveness of hands-on activities in enhancing students' practical abilities. This is consistent with current educational research, which emphasised the benefits of active learning strategies over traditional lecture-based methods. A study by Freeman et al. (2014) found that active learning significantly improves students' performance in science, technology, engineering, and mathematics (STEM) courses. Their meta-analysis of 225 studies concluded that students in active learning environments are more likely to achieve higher levels of proficiency compared to those in traditional lecture-based settings.

Prince (2004) reviewed the literature on active learning and highlighted its role in promoting greater student engagement, which leads to better retention and

understanding of the material. According to Prince, active learning strategies such as group work, problem-solving, and hands-on activities help students construct knowledge rather than passively receive it. This aligns with the data from the present study, where students showed significant improvements in their skills through active participation in hands-on activities.

This is also in line with Hake (1998) who conducted a study on the comparison of interactive engagement methods with traditional lectures in introductory physics courses. His research showed that students taught using interactive engagement methods exhibited significantly higher learning gains than those taught through traditional lectures. This supports the notion that practical, activity-based teaching methods lead to better learning outcomes, as evidenced by the increased proficiency levels in the current study.

Furthermore, Chi (2009) proposed the ICAP framework (Interactive, Constructive, Active, and Passive) to categorize different types of cognitive engagement during learning activities. Chi's framework suggests that interactive and constructive activities lead to deeper learning compared to active or passive activities. The hands-on method of teaching employed in this study falls under the interactive and constructive categories, where students engage in activities and actively construct their understanding. This likely contributed to the substantial improvements observed in students' science process skills.

4.5 Research Question 4: What are the perceptions of the students of the use of hands-on instructional approaches for science lessons?

This section presents data on students' perceptions of the use of hands-on method of teaching in the science classroom. The results are summarised in Table 5.

Table 5: Frequency Distribution of Students' perception of Hands-on method of teaching in the Science classroom

Item	Agree (%)	Neutral (%)	Disagree (%)
Hands-on instructional approach is time consuming	10(20)	15(30)	25(50)
Hands-on instructional approach makes lesson difficult	6(12)	12(24)	32(64)
Hands-on instructional approach makes lesson boring	8(16)	11(22)	31(62)
Hands-on instructional approach enhances my participation	35(70)	9(18)	6(12)
Hands-on instructional approach enhances my understanding in science	27(54)	17(34)	6(12)
Hands-on instructional approach enhances my attitude towards science	28(56)	15(30)	7(14)
Hands-on instructional approach enhances my retention of science concepts	24(48)	18(36)	8(16)
Hands-on instructional approach increases my interest in science	31(62)	12(24)	7(14)
Hands-on instructional approach improves science process skills	34(68)	12(24)	4(8)

Table 4 indicates students' perception of hands-on activity methods. From the table, ten students representing 20 %, fifteen students representing 30 % and twenty-five students

representing 50 % agree, are neutral and disagree respectively that hands-on instructional approach is time consuming.

Six students representing 12 %, twelve students representing 24 %, thirty- two students representing 64% disagree that hands-on instructional approach makes science lessons difficult. Eight students representing 16% agree, eleven students representing 22% are neutral and thirty-one students representing 62% disagree that hands-on instructional approach makes lesson boring. Thirty-five students representing 70 % agree, nine students representing 18 % are neutral and six students representing 12 % disagree that hands-on instructional approach enhances their participation in science.

Twenty-seven students representing 54 % agree, seventeen students representing 34 % are neutral and six students representing 12 % disagree that hands-on instructional approach enhances their understanding in science. Twenty-eight students representing 48 %, eighteen students representing 36 % and eight students representing 16% agree, are neutral and disagree respectively that hands-on instructional approach enhances their retention. Thirty-one students representing 62 %, twelve students representing 24 % are neutral and seven students representing 14 % agree, are neutral and disagree respectively that hands-on instructional approach increases their performance in science. Lastly, thirty-four students representing 68 %, twelve students representing 24% and four students representing 8% agree, are neutral and disagree respectively that hands-on instructional approach improves their science process skills

From the table most of the students perceive hands-on activity as interesting, facilitate easy understanding of concepts, enhance participation, critical thinking, improving science processing skills and attitudes towards science. These findings are in line with the view that students cantered teaching approach like activity method improves

students' attitudes, performance, scientific processing skill and inspire students to pursue STEM related careers (Gormally et al., 2009; Abdi, 2014; Ergul et al., 2011). According to Gerstner and Bogner (2010), the success of hands-on method is because of the learner-centred nature of this instructional approach. This instructional approach places more emphasis on the active participation of the students in the learning process.



CHAPTER FIVE

SUMMARY, CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS

5.0 Overview

This chapter discussed a number of issues in terms of the following subject headings: summary of findings, conclusion, recommendations and suggestions for further studies.

5.1 Summary of Major Findings

The main findings were summarised below:

- The study revealed that senior high school students at Ve Senior High School had conceptual difficulties in acids, bases and salts. This was revealed in the pre-test analysis.
- It was revealed that students' performance was enhanced after the implementation of hands-on activities. This was revealed in the post-test analysis. This showed how effective hands-on activity was in improving students' performance.
- There was a significant improvement in students' science process skills (measuring, observation, manipulation, recording). This demonstrated the effectiveness of the activity method in developing essential scientific skills.
- Majority of students had a positive perception about the use of hands-on activities in teaching acids, bases and salts.

5.2 Conclusion

Based on the findings the following conclusions were made:

Students' difficulties in the concept of acids, bases and salts were identified. Their performance was not encouraging but after the implementation of hands-on method of teaching, their performance, science process skills and perceptions significantly

improved. It is clear from the findings that intervention measures were effective. It can be concluded that students' academic performance in science was improved through hands-on instructional approach. Students gained a better understanding of science ideas as well as enhanced science process skills acquisition and positive perceptions of the activity method in science lessons. Thus, hands-on method of teaching science appeared to be an effective and innovative approach to enhancing students' learning outcomes during science lessons.

5.3 Recommendations

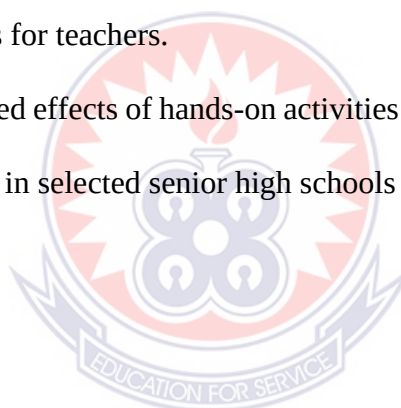
Based on the findings of the study, the following recommendations were made;

- Science teachers should make sure that students' difficulties in science concepts are identified before appropriate interventions implemented.
- Science teachers should use hands-on activity method of teaching in the science classroom to improve the academic performance of students.
- The school authorities should provide enough teaching and learning materials to facilitate hands-on method of teaching science in order to enhance skills acquisition of senior high school students.
- Further training programs are required to plan and develop for both teachers and their students in hands-on method of teaching in order to provide a better perception of students on the use of the hands-on approach in teaching science concepts.

5.4 Suggestions for further Studies

Based on the results of the study, the following suggestions were made for further research.

- This study should be repeated in other Senior High Schools in Volta Region of Ghana to verify the need to use hands-on method in teaching science.
- The effect of hands-on teaching approach on students of different age groups should be conducted to understand the impact of hands-on method on developmental stages of students.
- The study of teachers' perceptions of challenges associated with hands-on approaches to science teaching should also be explored to suggest effective support systems for teachers.
- The differentiated effects of hands-on activities on the performance of male and female students in selected senior high schools should be investigated.



REFERENCES

- Abdi, A. (2014). The effect of inquiry-based learning method on students' academic achievement in science course. *Universal Journal of Educational Research*, 2(1), 37–41.
- Abdi, A. (2014). The effect of inquiry-based learning method on students' academic achievement in science course. *Universal Journal of Educational Research*, 2(1), 37–41.
- Abdulghani, A. M. M. & Al-Naggar, R. A. (2015). Students' perception about learning of pharmacology at a single private institute in Malaysia. *Journal of Taibah University Medical Sciences*, 10(1), 40-44.
- Abdullahi, O. E. (2013). Interrelationship between personal factor and academic achievement in mathematics of Ebira secondary schools students in Kogi state. *Ife PsycholA-An International Journal*, 5(1), 154-155.
- Adeyemi, B. A. (2008). Effect of Cooperative Learning on Secondary School Students Achievement on Social Studies. *Electronic Journal of Research in Educational Psychology* 16(3), 691-708.
- Agboola, O. S., & Ojo, O. E. (2007). Effects of project, inquiry and lecture, demonstration teaching methods on senior secondary students' achievement in separation of mixtures practical test. *Educational Research and Review*, 2(6), 124-132.
- Aidoo, B., Boateng, S. K., & Osei-Poku, P. (2020). Effect of computer simulations on senior high school students' achievement in acid-base reactions. *Journal of Science Education and Technology*, 29(3), 382–395.
<https://doi.org/10.1007/s10956-020-09824-5>
- 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>.
- Anwer, F. (2019). Activity-Based Teaching, Student Motivation and Academic Achievement. *Journal of Education and Educational Development*, 6(1).
- Anwer, F. (2019). Activity-Based Teaching, Student Motivation and Academic Achievement. *Journal of Education and Educational Development*, 6(1).
- Aremu, E. (2010). *Poor academic performance of students in secondary schools*. Retrieved June 10, 2013, from <http://www.google.com.ng/search?>
- Ayas, A., & Demirbaş, A. (2018). Turkish secondary students' understanding of acid–base concepts. *International Journal of Science Education*, 40(1), 32–45.
<https://doi.org/10.1080/09500693.2017.1390479>

- Aybek, B. (2007). Eleştirel düşünmenin öğretiminde öğretmenin rolü [Teacher's role in teaching critical thinking]. *Bilim Eğitim ve Düşünce Dergisi*, 7(2).
<http://www.universite-toplum.org/text.php?id=322>.
- Babb, J. J., & Stockero, S. L. (2020). Impact of Practical Education Network on students in selected Ghanaian junior high school science classrooms. *African Journal of Research in Mathematics, Science and Technology Education*, 1-13.
- Banerjee, R., & Yager, R. E. (2021). Students' understanding of salts and their reactions. *Chemistry Education Research and Practice*, 22(1), 67–78.
<https://doi.org/10.1039/D0RP00238B>
- Barca, A., Peralbo, M., Brenlla, J. C., Seijas, S., Muñoz, M. A., & Santamaría, S. (2013). Enfoques de aprendizaje, rendimiento académico y género en alumnos de educación secundaria (ESO): Un análisis diferencial. *Psicología, educação e cultura*, 2, 25-43.
- Baroody, A. J. (2017). The Use of Concrete Experiences in Early Childhood Mathematics Instruction. *Advances in Child Development and Behaviour*, 53.
<http://dx.doi.org/10.1016/bs.acdb.2017.03.001>.
- Bell, J., & Holroyd, J. (2009). *Review of human reliability assessment methods*. Health and safety laboratory.
- Bellamy, R. K. E. (2016). Designing educational technology: Computer-mediated change. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 123–146). Cambridge, MA: MIT Press.
- Bennett, J., & Kennedy, D. (2001). Practical work at the upper high school level: The evaluation of a new model of assessment. *International Journal of Science Education*, 23, 97–110.
- Biggs, J. B., Kember, D., & Leung, D. Y. P. (2011). The revised two-factor Study Process Questionnaire: R-SPQ-2F. *British Journal of Educational Psychology*, 71, 133-149. Recuperado de http://www.johnbiggs.com.au/pdf/ex_2factor_spq.pdf.
- Birman, B. F., Desimone, L., Porter, A. C., & Garet, M. S. (2000). Designing professional development that works. *Educational Leadership*, 57, 28–33.
- Bloom, B. S. (2014). *Taxonomy of Educational Objectives*. Boston, MA, USA; Allyn and Bacon.
- Bolaji, S. (2007). *Evolving Creativity in Nigeria Education: A Philosophy Paradigm*. Conference Presentation. Philosophy Educatio
- Ibe, E. (2011). Teachers Creativity Behaviours in Science Classroom Interactions: Implications for Entrepreneurial Skills Acquisition among Students. *Journal of Curriculum Studies* 18(1), 169- 175.

- Branch, J. L. (2013). *Extracurricular activities and academic achievement*. PhD. Dissertation, University of Southern Mississippi. Available from: http://aquil.usm.edu/thesis_dissertations/1807 (Accessed on 21st August 2017).
- Bransford, J. D., Brown, A. L., & Cocking, R. R. (2005). *How people learn: Brain, mind, experience, and school*. U.S.A. Washington, D.C. National academy Press. Pp. 12-231.
- Brown, H., & Ciuffetelli, D. C. (Eds.). (2009). *Foundational methods: Understanding teaching and learning*. Toronto: Pearson Education.
- Caballero, C., Abello, R. & Palacio, J. (2007). Relación de burnout y rendimiento académico con la satisfacción frente a los estudios en estudiantes universitarios. *Avances en Psicología Latinoamericana*, 25(2), 98-111. Recuperado de <http://www.scielo.org.co/pdf/apl/v25n2/v25n2a7.pdf>.
- Campbell, J. R., Hombo, C. M., & Mazzeo, J. (2010). *NAEP 1999 trends in academic progress: Three decades of student performance*. Washington, DC: National Center for Education Statistics.
- Cevik, M., Yalcin, N., & Cepni, S. (2019). Investigating high school students' misconceptions about acids and bases. *Journal of Turkish Science Education*, 16(2), 135–151. <https://doi.org/10.12973/tused.10273a>
- Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice*, 8(3), 293–307. <https://doi.org/10.1039/B7RP90006F>
- Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science*, 1(1), 73-105.
- Chikaluma, P. H., David, O., & Nsengimana, V. (2023). Contribution of Inquiry-Based Learning to the Improvement of Biology Teaching and Learning in Malawi Community Day Secondary Schools. *The International Journal of Science, Mathematics and Technology Learning*, 29(2). DOI: 10.18848/2327-7971/CGP/v29i02/29-52.
- Chikuni, B. (2003). *The teachers' handbook: A practical approach to teaching*. Gwanda, Flame Publishers.
- Chiu, M. H., Wu, H. K., & Tsai, C. Y. (2020). Understanding students' difficulties in acid–base titration. *Journal of Research in Science Teaching*, 57(5), 697–718. <https://doi.org/10.1002/tea.21600>
- Clark, J. C. (2003). *Practical activities: What science teaching can learn from primary classrooms?* A paper presented at the Annual Conference of NZARE/AARE, Auckland.

- Cohen, L., Manion, L., & Morrison, K. (2006). *Research Methods in Education*. Routledge/Falmer Taylor & Francis Group.
- Cole, M., & Engeström, Y. (2013). *A cultural-historical approach to distributed cognition*. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 1–46). New York: Cambridge University Press.
- Coleman, P. (2022). Validity and Reliability within Qualitative Research for the Caring Sciences. *International Journal of Caring Sciences*, 14(3) pp. 2041–2045.
- Cooke, T. J., Jensen, J. S., Carleton, K. L., Hall, K. L., Jardine, H. E., Kent, B. W., Redish, E. F., & Shultz, J. W. (2023). Group Active Engagements for Facilitating Principles-Based Learning in Introductory Organismal Biology. *The American Biology Teacher*, 85(6), 317-326. <https://doi.org/10.1525/abt.2023.85.6.317>.
- Dankenda, T. M. P. R. K. T., & Sooriyapathirana, S. D. S. S. (2011). Factors affecting decision making and achievements in educational pursuit of students in selecting careers. *Proceedings of the Peradeniya University Research Sessions, University of Peradeniya, Sri Lanka*, 16, p 12.
- Davis, G. (2010). *Senior secondary school students' and teachers' perception of the difficult organic chemistry topics in the Central Region*. (Unpublished Masters' thesis). Chemistry Department, University of Cape Coast, Cape Coast.
- Dawes, L. (2011). *What stops teaching using new technology?* Routledge.
- De Jong, O., & Taber, K. S. (2007). Teaching and learning the concept of chemical bonding. *Studies in Science Education*, 43(1), 25-82. doi:10.1080/03057260708560273.
- de Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science*, 340(6130), 305-308.
- Demiralp, N., & Ozudogru, H. Y. (2023). An analysis of the learning outcomes of the 2018 geography curriculum for 9th and 10th grades according to Webb's depth of knowledge. *Asian Journal of Education and Training*, 9(4), 142–150. <https://doi.org/10.20448/edu.v9i4.5263>.
- Demircioğlu, H., Ayas, A., & Demircioğlu, G. (2020). Conceptual difficulties and alternative conceptions of acids and bases: A review. *Science Education International*, 31(1), 45–55. <https://doi.org/10.33828/sei.v31.i1.5>
- Eisner, E.W. (2010). Benjamin Bloom. *The Quarterly Review of Comparative Education* 30: 1-5.

- Ekon, E. E. (2013). *Effect of Five-steps Conceptual Change instructional Model on Students' perception of their Psychosocial Learning Environment* (Unpublished doctoral dissertation). Faculty of Education, University of Nigeria, Nsukka.
- Ekwueme, C. O., Ekon, E. E., & Ezenwa-Nebife, D. C. (2015). The Impact of Hands-On-Approach on Student Academic Performance in Basic Science and Mathematics. *Higher Education Studies*, 5(6). doi:10.5539/hes.v5n6p47.
- Ekwueme, C. O., Ekon, E. E., & Ezenwa-Nebife, D. C. (2015). The impact of hands-on-approach on student academic performance in basic science and mathematics. *Higher Education Studies*, 5(6). doi:10.5539/hes.v5n6p47.
- Ekwueme, C. O., Ekon, E. E., & Ezenwa-Nebife, D. C. (2015). The impact of hands-on-approach on student academic performance in basic science and mathematics. *Higher Education Studies*, 5(6). doi:10.5539/hes.v5n6p47.
- Emereole, H. U. (2009). Learners' and teachers' conceptual understanding of science processes: The case of Botswana. *International Journal of Science and Mathematics Education*, 7, 1033-1056.
- Engeström, Y. (2007). *Learning by expanding: An activity-theoretical approach to developmental research*. Retrieved from <http://lchc.ucsd.edu/MCA/Paper/Engestrom/expanding/toc.htm>.
- Engeström, Y. (2009a). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R.-L. Punamaki (Eds.), *Perspectives on activity theory* (pp. 19–38). New York: Cambridge University Press.
- Entwistle, N., & Peterson, E. (2004). Learning styles and approaches to studying. In Ch. Spielberger (Ed.), *Encyclopedia of Applied Psychology* (Vols. 2). Amsterdam: Elsevier.
- Epstein, J. L. & Voorhis, F. V. (2011). More than minutes: Teachers' roles in designing homework. *Educational Psychologist*, 36(3), 181-193.
- Ergul, N., Bayram, H., & Ulusoy, A. (2011). *Promoting scientific process skills and career interest through activity-based learning in STEM education*. Istanbul: University of Istanbul Press.
- Ergul, R., Simsekli, Y., Calis, S., Ozdilek, Z., Gocmencelebi, S., & Sanli, M. (2011). The effects of inquiry-based science teaching on elementary school students' science process skills and science attitudes. *Bulgarian Journal of Science and Education Policy*, 5, 48-68.
- Fehrmann, P. G. (2017). Parental involvement, homework and TV time: Direct and indirect effects on high school achievement. *Journal of Educational Psychology* 375: 373-380. DOI: <https://doi.org/10.1037/0022-0663.78.5.373>.

- Fennema, E., & Sherman, J. (2006, 2008). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *JSAS Catalog of Selected Documents in Psychology*, 6(31).
- Fluty, D. (2017). Single parenting in relation to adolescents' achievement scores. *Research Center for Families and Children*, 6, 4-8.
- Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410-8415. <https://doi.org/10.1073/pnas.1319030111>.
- Gay, G., & Hembrooke, H. (2014). *Activity-centered design: An ecological approach to designing smart tools and usable systems*. Cambridge, MA: MIT Press.
- Gerstner, S., & Bogner, F. (2010). *The efficacy of hands-on activities in fostering learner-centered education in the sciences*. Munich: Springer-Verlag.
- Gerstner, S., & Bogner, F. X. (2010). Cognitive Achievement and Motivation in Hands-on and Teacher-Centred Science Classes: Does an additional hands-on consolidation phase (concept mapping) optimise cognitive learning at work stations? *International Journal of Science Education*. 32 (7). 849-870.
- Gilbert, J. K., & Treagust, D. F. (2009). Understanding Models and Their Use in Science: Conceptions of Middle and High School Students and Experts. *International Journal of Science Education*, 31(6), 725-748. doi:10.1080/09500690802595875
- Gormally, C., Brickman, P., Hallar, B., & Armstrong, N. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for the Scholarship of Teaching and Learning*, 3(2), 1-22.
- Gormally, C., Brickman, P., Hallar, B., & Armstrong, N. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for the Scholarship of Teaching and Learning*, 3(2), 1-22.
- Gozli, D. (2023). Principles of Categorization: A Synthesis. *Seeds of Science*. <https://doi.org/10.53975/6wb9-h8ks>.
- Gray, J. A., & DiLoreto, M. (2016). The Effects of Student Engagement, Student Satisfaction, and Perceived Learning in Online Learning Environments. *NCPEA International Journal of Educational Leadership Preparation*, 11(1).
- Gultepe, N. (2016). High School Science Teachers' Views on Science Process Skills. *International Journal of Environmental & Science Education*, 11(5), 779-800. doi: 10.12973/ijese.2016.348a.

- Gupta, P. K., & Mili, R. (2015). Impact of academic motivation on academic achievement; A study on high school students. *European Journal of Education Studies* 2: 1-8.
- Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64-74.
- Hardman, J. (2007). Making sense of the meaning maker: Tracking the object of activity in a computer-based mathematics lesson using activity theory. *International Journal of Education and Development using Information and Communication Technology*, 3(4), 110–130.
- Hiagh (2013). Associative and propositional processes in evaluation: An integrative review of implicit and explicit attitude change. *Psychological Bulletin*, 132 (692), 731.
- HMI/Office for Standards in Education (2004a). *Science in primary schools*. London: Ofsted.
- HMI/Office for Standards in Education (2004b) (Ofsted). *Science in secondary schools*. London: Ofsted.
- Hofstein, A., & Lunetta, V, N. (2014). The laboratory in science education: Foundation for the 21st century. *Science Education*, 88, 28-54.
- Ibe, E. (2011). Teachers Creativity Behaviours in Science Classroom Interactions: Implications for Entrepreneurial Skills Acquisition among Students. *Journal of Curriculum Studies* 18(1), 169- 175.
- Illeris, K. (2004). *Transformative learning and identity*. London: Routledge Oxford.
- İnan, H. Z. (2011). Teaching science process skills in kindergarten. *Social and Educational Studies (Energy Education Science & Technology Part B)*, 3(1), 47-64.
- İnan, H.Z. (2010). Okul Öncesi Öğretmen Adaylarının Bilimsel Süreç Becerilerine İlişkin Alan Bilgilerinin ve Pedagojik Alan Bilgilerinin İrdelenmesi [Examining Pre-School Education Teacher Candidates' Content Knowledge and Pedagogical Content Knowledge Related Science Process Skills]. *Educational Sciences: Theory and Practice*, 10(4), 2275-2323.
- İnan, H.Z., İnan, T., & Aydemir, T. (2014). *Okul öncesi dönem çocuklarına bilimsel süreç becerilerinin kazandırılması* [Science process skills education in early childhood]. M. Metin (Ed), *Okul öncesi dönemde fen ve teknoloji eğitimi* [Science and technology education in early childhood] (Bölüm 4, 75-95). Pegem A, Ankara.
- James, C. H. (2006). Student success: What research suggests for policy and practice, *The Experiences of Students in Tertiary Education* 3: 2-7.

- James, H. M., & Jessica, H. (2016). Student self assessment: The key to stronger student motivation and higher achievement. *Educational Horizon* 9: 40-45.
- Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effect change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching*, 4(6), 668-690.
- Johnson, R. B., & Christensen, L. B. (2012). *Educational research: Quantitative, qualitative, and mixed approaches* (4th ed.). SAGE.
- Johnson, W. L., Johnson, A. M., & Johnson, J. W. (2014). *Strategies for Improving School Performance*. Conference Presentation: 2014 Curriculum Conference.
- Kalita, S. (2016). Academic achievement of high school students in relation to their emotional stability. *Journal of Process Management* 4:1-4. DOI: <https://doi.org/10.5937/jouproman4-11932>.
- Kaptelinin, V. (2005). The object of activity: Making sense of the sense-maker. *Mind, Culture, and Activity*, 12(1), 4–18.
- Kaya, M., & Kesan, C. (2023). Integrating Higher-Level Thinking Skills into Education: Connecting Knowledge to Real-Life Situations. *Journal of Educational Psychology*, 115(3), 321-335.
- Khan, M., & Iqbal, M. Z. (2011). Effect of inquiry lab teaching method on the development of scientific skills through the teaching of biology in Pakistan. *Language in India: Strength for Today and Bright Hope for Tomorrow*, 11(ISSN 1939-2940), 169-178.
- Kibirige, I., & Tsamago, D. (2022). The influence of language and gender on learners' understanding of acid-base concepts in rural South African schools. *African Journal of Research in Mathematics, Science and Technology Education*, 26(1), 1–12. <https://doi.org/10.1080/18117295.2022.2030534>
- Kind, V., & Taber, K. S. (2005). Teaching and learning the concept of chemical bonding. *Studies in Science Education*, 41(1), 81-112. doi:10.1080/03057260508560265.
- Kırlmazkaya, G., & Dal, S. N. (2022). Effect of hands-on science activities on students' academic achievement and scientific attitude. *International Journal of Education & Literacy Studies*, 10(4). www.ijels.aiac.org.au.
- Kırlmazkaya, G., & Dal, S. N. (2022). Effect of hands-on science activities on students' academic achievement and scientific attitude. *International Journal of Education & Literacy Studies*, 10(4). www.ijels.aiac.org.au.
- Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem based, experimental and inquiry-based teaching. *Educational Psychologist*, 41(2), 75-86.

- Kontra, C., Lyons, D. J., Fischer, S. M., & Beilock, S. L. (2015). Physical experience enhances science learning. *Psychological Science*, 26(6), 737-749.
- Kugamoorthy, S. (2012). *Activity based learning: an effective approach for self-regulated learning practices*. The Open University of Sri Lanka.
- Kwami, F. K. (2024). *The status of integrated science teaching and learning in selected public and private senior high schools in the Ho municipality*. Master of Philosophy (Science Education), Thesis, UEW.
- Lamas, H. (2015). School Performance. *Propósitos y Representaciones*, 3(1), 313-386. doi: [http:// dx.doi.org/10.20511/pyr2015.v3n1.74](http://dx.doi.org/10.20511/pyr2015.v3n1.74).
- Latip, A. D. A., & Supriatna, A. (2023). Strategy of Project Based Learning (PJBL) Based on Science, Technology, Engineering and Mathematics (STEM) in Growing Active and Creative Students. *Jurnal Iqra': Kajian Ilmu PSuydamendidikan*, 8(2), 198-221.
- Lawal, F. K. (2009). Effectiveness of Conceptual Change Strategies in Remediating Misconceptions in Genetic Concept Among Senior Secondary School Students in Kano State. *An unpublished Ph.D Dissertation*. Department of Education, A.B.U. Zaria Nigeria.
- Leont'ev, A. N. (2008). *Activity, consciousness, and personality*. Englewood Cliffs, NJ: PrenticeHall, Inc.
- Li, X., Cheng, Y., & Liu, H. (2013). Cognitive Engagement and Knowledge Construction in Education. *Educational Psychology Journal*, 20(3), 312-327.
- Luecke, S., Schiffman, A., Singh, A., Huang, H., Shannon, B., & Wilder, C. L. (2023). Four guiding principles for effective trainee-led STEM community engagement through high school outreach. *PLoS Computer Biology*, 19(5): e1011072. <https://doi.org/10.1371/journal.pcbi.1011072>.
- Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Teaching and learning in the school science laboratory. An analysis of research, theory, and practice. In, S. K. Abell & N. G. Lederman (Eds), *Handbook of Research on Science Education* (pp. 393– 431).
- Manor, A. K. (2002). *Effects of Constructivist-Based Instructional Models on Acquisition of Science Process Skills among Junior Secondary students* (Unpublished master's thesis). Faculty of Education, University of Nigeria, Nsukka.
- Martí, E. (2013). *Representar el mundo externamente. La construcción infantil de los sistemas externos de representación*. Madrid: Antonio Machado.
- Martínez-Otero, V. (2007). *Los adolescentes ante el estudio. Causas y consecuencias del rendimiento académico*. Madrid: Fundamentos.

- Marzano, R. J. (2004). The developing vision of vocabulary instruction. In J. F. Baumann & E. J. Kameenui (Eds.), *Vocabulary instruction: Research to practice*. New York: Guilford Press. Pp. 100117.
- McBride, N., Farrington, F., Midford, R., Meuleners, L., & Philips, N. (2004). Harm minimization in school drug education: final results of the school wealth and alcohol harm reduction project (SHAHRP). *Addiction*, 99, 278-291.
- McCune, V., & Entwistle, N. (2011). Learning and Individual Differences. *Elsevier*, 21, 303-310.
- McLeod, S. (2018). *Questionnaires*. Simply Psychology. Retrieved from <https://www.simplypsychology.org/questionnaires.html>.
- McLeod, S. A. (2007). *Visual Perception Theory*. Retrieved on 07, 2015, from <http://www.simplypsychology.org/perception-theories.html>.
- McLeod, S. A. (2019). *Constructivism as a theory for teaching and learning*. Simply psychology. Retrieved from <https://www.simplypsychology.org/constructivism.html>.
- Mensah, D., & Ampiah, J. G. (2021). The effect of peer instruction on students' understanding of acid-base reactions in Ghanaian secondary schools. *International Journal of Science Education*, 43(10), 1698–1716. <https://doi.org/10.1080/09500693.2021.1928042>
- Ministry of Education, Youth, and Sports. (2006). *Methods of teaching integrated science [Course: PFC 214]*. Accra: Teacher Education Division. Pp. 16-20, 30
- Ministry of National Education [MONE]. (2013a). *Ortaöğretim fizik dersi öğretim programı, Talim ve Terbiye Kurulu Başkanlığı* [Secondary education physics curriculum, Head Council of Education and Morality]. Ankara, Turkey: Author.
- Ministry of National Education [MONE]. (2013c). *Ortaöğretim biyoloji dersi öğretim programı, Talim ve Terbiye Kurulu Başkanlığı* [Secondary education biology curriculum, Head Council of Education and Morality]. Ankara, Turkey: Author.
- Nakhleh, M. B. (1992). Why some students don't learn chemistry: Chemical misconceptions. *Journal of Chemical Education*, 69(3), 191-196. doi:10.1021/ed069p191.
- Nakhleh, M. B. (2020). Why some students don't learn chemistry: Chemical misconceptions. *Journal of Chemical Education*, 97(3), 619–628. <https://doi.org/10.1021/acs.jchemed.9b00918>
- National Endowment for Science, Technology and the Arts (NESTA) (2005b). *Real science-encouraging experimentation and investigation in school science*

- learning*. London: NESTA. Available at: <http://www.nesta.org.uk/assets/pdf/realsciencereportNESTA.pdf> (accessed on February 18, 2008).
- NCREL (1993). *Chapters' schools: A new breed of public schools*. NCREL Policy Brief, Report 2.
- Nwosu, A. A. (2004). Teachers Awareness of Creativity Related Behaviours in the Science Classroom Implication for National Development. *Journal of Science Teachers Association of Nigeria*, 39(1&2), 22-30.
- Nyachwaya, J. M., & Gillaspie, M. (2016). College students' understanding of chemical reactions. *Chemistry Education Research and Practice*, 17(2), 320–328. <https://doi.org/10.1039/C5RP00209G>
- O'Leary, Z. (2011). *Postgraduate Research Supervision: Transforming Relations*. New York: Peter Lang.
- Obanya, P. (2012). *Transformational Pedagogy in Higher Education*. 26th Convocation Lecture of University of Calabar, Nigeria.
- Okeke, S. O. C. (2014). *School science laboratory organization and management*. Lecture Handout.
- Ornstein, A. (2006). The Frequency of Hand-on Experimentation and Students' Attitudes towards Science: A Statistically Significant Relation. *Journal of Science Education and Technology*, 15(3), 285-297.
- Özmen, H. (2021). High school students' conceptions of acids and bases: A phenomenographic study. *Educational Sciences: Theory & Practice*, 21(2), 78–93. <https://doi.org/10.12738/jestp.2021.2.004>
- Pernecky, G. (2016). Content Knowledge for Teaching. *Journal of Teacher Education*, 59 (5), 389-407.
- Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223-231.
- Roth, W. M., & Lee, Y. J. (2007). “Vygotsky's neglected legacy”: Cultural-historical activity theory. *Review of Educational Research*, 77(2), 186–232.
- Sadi, Ö., & Çakıroğlu, J. (2011). Effects of hands-on activity enriched instruction on students' achievement and attitudes towards science. *Journal of Baltic Science Education*, 10(2), 87-97.
- Sakyi-Hagan, N. A., & Hanson, R. (2019). *Interactive instructional approaches to teaching Integrated Science and their effect on students' performance: A study in a Ghanaian University Context*. University of Education, Winneba.

- Shah, I., & Rahat, T. (2014). Effect of activity-based teaching method in science. *International Journal of Humanities and Management Sciences (IJHMS)*, 2(1). Pp. 1-6.
- Sideri, A., & Skoumios, M. (2021). Science Process Skills in the Greek Primary School Science Textbooks. *Science Education International*, 32(3), 231-236. <https://doi.org/10.33828/sei.v32.i3.6>.
- Sidhu, K. S. (2013). *Methods of research in Education*. Sterling publishers.
- Singleton, R. A., Jr., & Straits, B. C. (2010). *Approaches to social research (5th ed.)*. Oxford University Press.
- Sirin, S. R. (2005). Socioeconomic status and academic achievement. A meta-analytic review of research. *Review of Educational Research* 75: 417-453. DOI: <https://doi.org/10.3102/00346543075003417>.
- Soylu, H. (2004). *Fen öğretiminde yeni yaklaşımlar*. [New approaches to science teaching]. Ankara, Turkey: Nobel Yayınları.
- Steinberg, L., Lamborn, S. D., Dornbusch, S. M., & Darling, N. (2009). Impact of parenting practices on adolescent achievement: Authoritative parenting, school involvement, and encouragement to succeed. *Child Development* 63: 1266-1281. DOI: <https://doi.org/10.2307/1131532>.
- Strongman, N., & Hall, T. (2000). *Background knowledge*. Wake field, MA: National center on assessing the general curriculum. Retrieved September 26, 2005.
- Sudaryono, Rahardja, U., Aini, Q., Graha, Y. I., & Ninda Lutfiani, N. (2019). *Journal of Physics.: Conference Series*, 1364. DOI 10.1088/1742-6596/1364/1/012050.
- Taraban, R., Box, C., Myers, R., Pollard, R., & Bowen, C. W. (2007). Effects of active-learning experiences on achievement, attitudes, and behaviors in high school biology. *Journal of Research in Science Teaching*, 44(7), 960–979.
- The Standard (2005). *Effect of Climate on Learning Nairobi*. Standard group.
- Usman, T. C. (2000). The gap between the intended and the operational forms of the Nigerian integrated science project (NISP). *Curriculum paper presented at the 22nd Annual conference of STAN 23rd-29th august, MUCAST, Makurdi*.
- Uyanık, G. (2018). The effect of experiments with simple equipment on attitudes, academic achievement and permanence towards science course. *OPUS International Journal of Society Researches*, 9(16), 600-624. DOI: 10.26466/opus.462761.
- Uzal, S., Erdem, A., Önen, F., & Gürdal, A. (2010). Teachers' views on science experiments with simple equipment and evaluation of in-service training.

Necatibey Education Faculty Electronic Journal of Science and Mathematics Education, 4(1), 64-84.

van den Hurk, A., Meelissen, M., & van Langen, A. (2019). Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education*, 41(2), 150-164.

Walshaw, M., & Anthony, G. (2008). The teacher's role in classroom discourse: A review of recent research into mathematics classrooms. *Review of Educational Research*, 78(3), 516–551.

Wiggins, G. (2011). Seven keys to effective feedback. *Educational Leadership*, 68(1), 10-16.

Willcox, M. R. (2011). Factores de riesgo y protección para el rendimiento académico: Un estudio descriptivo en estudiantes de Psicología de una universidad privada. *Revista Iberoamericana de Educación*, 55(1), 1-9. Recuperado de <http://www.rieoei.org/deloslectores/3878Wilcox.pdf>.

Willie, M. M. (2023). Distinguishing Between Population and Target Population: A Mini Review. *Surgery Research Journal*, 3(2):1-2.

Yayra, D. (2017). *Rudiments of educational measurement, evaluation and statistics*. (2nd ed). Benjoy ent.



APPENDICES

APPENDIX A

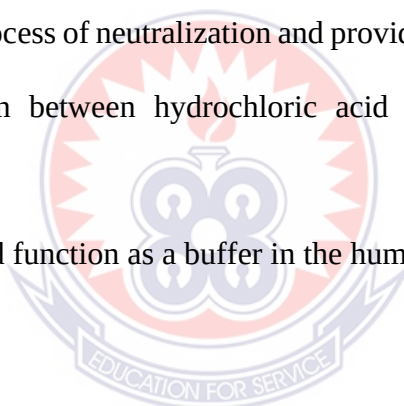
Chemistry Performance Test

(Pre-test)

Duration: 20mins

Answer all questions

1. Define acids and bases according to the Arrhenius, Bronsted-Lowry, and Lewis theories. How do these definitions differ from each other?
2. Explain the concept of pH. How is the pH scale used to classify substances as acidic, basic, or neutral?
3. Describe the process of neutralization and provide a balanced chemical equation for the reaction between hydrochloric acid (HCl) and sodium hydroxide (NaOH).
4. How does blood function as a buffer in the human body?



APPENDIX B

Chemistry Performance Test

Marking Scheme (Pre-test)

1. **a. Arrhenius acids** are substances that produce hydrogen ions (H^+) in aqueous solutions, while bases produce hydroxide ions (OH^-) in aqueous solutions. **1 mark**

Example: $HCl \rightarrow H^+ + Cl^-$; $NaOH \rightarrow Na^+ + OH^-$

- b. Bronsted-Lowry acids** are substances that are proton (H^+) donors, and bases are proton acceptors. **1 mark.**

In the reaction $HCl + NH_3 \rightarrow NH_4^+ + Cl^-$, HCl is the acid (donates a proton) and NH_3 is the base (accepts a proton).

- c. Lewis acids** are electron pair acceptors, and bases are electron pair donors. **1 mark**

Example: In the reaction $BF_3 + NH_3 \rightarrow F_3B-NH_3$, BF_3 is the Lewis acid (accepts a electron pair), and NH_3 is the Lewis base (donates an electron pair).

Differences (1 mark):

- a. **Arrhenius:** Limited to aqueous solutions and focuses on ions.
 - b. **Bronsted-Lowry:** Applies to reactions not involving water and focuses on proton transfer.
 - c. **Lewis:** Broadest definition, applies to all reactions involving electron pair exchange, not limited to proton transfer or water.
2. **pH** is defined as the negative logarithm of the hydrogen ion concentration: $pH = -\log[H^+]$. It is a measure of the hydrogen ion concentration in a solution. **1 mark**

Classification on pH Scale (1 mark):

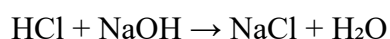
Acidic: $\text{pH} < 7$ (higher concentration of H^+ ions).

Neutral: $\text{pH} = 7$ (equal concentration of H^+ and OH^- ions, e.g., pure water).

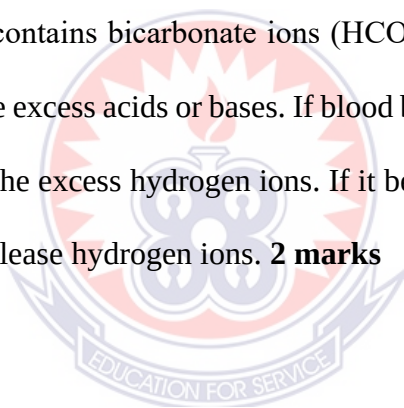
Basic: $\text{pH} > 7$ (lower concentration of H^+ ions, higher concentration of OH^- ions).

3. Neutralization process occur when an acid and a base react to produce water and a salt, thereby neutralizing the acid and base properties. **1 mark**

Balanced Chemical Equation (1 mark):



4. Blood acts as a buffer by maintaining a stable pH through the bicarbonate buffer system. Blood contains bicarbonate ions (HCO_3^-) and carbonic acid (H_2CO_3), which neutralize excess acids or bases. If blood becomes too acidic, bicarbonate ions neutralize the excess hydrogen ions. If it becomes too basic, carbonic acid dissociates to release hydrogen ions. **2 marks**



APPENDIX C

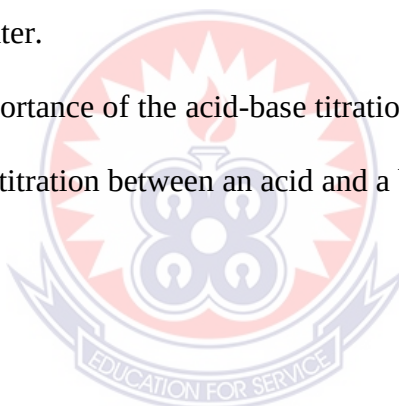
Chemistry Performance Test

(Post-test)

Duration: 20mins

Answer all questions

1. Compare and contrast the properties of acids and bases with respect to their behavior in aqueous solutions.
2. Explain the role of salts in maintaining the pH balance of a solution. Include an example of a salt and its effect on pH.
3. Describe the difference between a strong acid and a weak acid, including their ionization in water.
4. Discuss the importance of the acid-base titration process and provide a general procedure for a titration between an acid and a base.



APPENDIX D

Chemistry Performance Test

Marking Scheme (Post-test)

1. Properties of Acids and Bases in Aqueous Solutions (2 marks):

Acids (1 mark)

- Taste sour, turn blue litmus paper red, react with metals to produce hydrogen gas, and neutralize bases.

Bases (1 mark)

- Taste bitter, feel slippery, turn red litmus paper blue, and neutralize acids.

2. Role of Salts in pH Balance (2 marks):

Salts can influence the pH of a solution depending on the strength of the acid and base from which they are derived. Some salts can hydrolyze in water to form acidic or basic solutions.

Sodium acetate (CH_3COONa) is a salt of a weak acid (acetic acid) and a strong base (sodium hydroxide). It forms a basic solution when dissolved in water because the acetate ion (CH_3COO^-) reacts with water to produce hydroxide ions (OH^-).

3. Difference Between Strong and Weak Acids (3 marks):

Strong acids are substances that completely ionize in water to produce a high concentration of hydrogen ions (H^+). Examples include hydrochloric acid (HCl) and sulfuric acid (H_2SO_4). **1 mark**

Weak acids are substances that partially ionize in water, producing a lower concentration of hydrogen ions. Examples include acetic acid (CH_3COOH) and citric acid. **1 mark**

Comparison (1 mark):

Strong acids have higher ionization and lower pH values in solution, while **weak acids** have lower ionization and higher pH values.

4. Importance and Procedure of Acid-Base Titration (3 marks):

Importance (1.5 marks):

Titration is used to determine the concentration of an unknown acid or base solution by reacting it with a solution of known concentration. It is important for precise chemical analysis and formulation.

General Procedure (1.5 marks):

- **Preparation:** Fill a burette with the titrant (solution of known concentration).
- **Titration:** Slowly add the titrant to the analyte (solution of unknown concentration) while continuously mixing until the endpoint is reached, which is usually indicated by a color change of a pH indicator.
- **Calculation:** Calculate the concentration of the unknown solution using the volume of titrant added and its concentration.

APPENDIX E**STUDENTS' PERCEPTIONS QUESTIONNAIRE ITEMS**

Item	Agree (%)	Neutral (%)	Disagree (%)
Hands-on instructional approach is time consuming			
Hands-on instructional approach makes lesson difficult			
Hands-on instructional approach makes lesson boring			
Hands-on instructional approach enhances my participation			
Hands-on instructional approach enhances my understanding in science			
Hands-on instructional approach enhances my attitude towards science			
Hands-on instructional approach enhances my retention of science concepts			
Hands-on instructional approach increases my interest in science			
Hands-on instructional approach improves science process skills			