

UNIVERSITY OF EDUCATION, WINNEBA

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



SILAS ABOAGYE

MASTER OF PHILOSOPHY

UNIVERSITY OF EDUCATION, WINNEBA

**EFFECT OF HANDS-ON ACTIVITIES ON STUDENTS' PERFORMANCE IN
ACIDS, BASES AND SALTS AT KANESHIE SENIOR HIGH TECHNICAL
SCHOOL**



SILAS ABOAGYE
(8231610002)

**A Thesis 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 Philosophy
(Science Education)
in the University of Education, Winneba**

NOVEMBER, 2024

DECLARATION

STUDENT'S DECLARATION

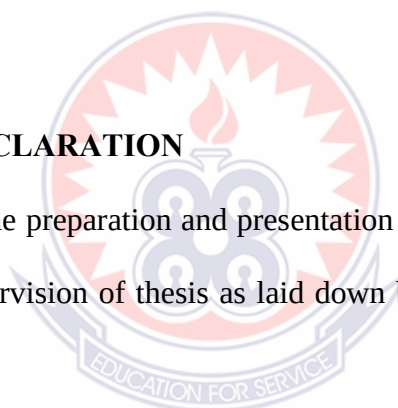
I, **SILAS ABOAGYE**, declare that this thesis, except quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE:

DATE:

SUPERVISOR'S DECLARATION

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



SUPERVISOR: PROF. JOHN K. EMINAH

SIGNATURE:

DATE:

DEDICATION

This work is dedicated to my parents, Rev. Sylvester Aboagye and Mrs. Rebecca Appiah. It is also dedicated to my sister, Miss Rose Aboagye.



ACKNOWLEDGEMENTS

First of all, I would express my deepest thanks to the Almighty God who helped me throughout this journey. May His name be praised.

I am deeply indebted to my supervisor, Prof. John K. Eminah, Senior Lecturer in the Department of Integrated Science Education at the University of Education, Winneba for his technical expertise and encouragement throughout this research journey.

I also extend my sincere appreciation to Daniel Morrison whose inspiration and motivation played a significant role in the successful completion of this work.

My family's unwavering support has been a constant source of strength. I thank my parents, Rev. Sylvester Aboagye and Mrs. Rebecca Appiah, as well as my sister, Rose Aboagye, for their love and encouragement.

Lastly, I would like to thank all my course mates for their camaraderie and support throughout our academic journey.

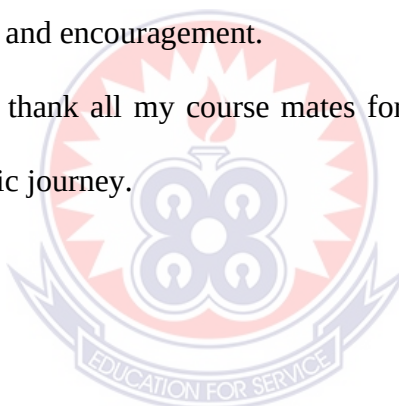
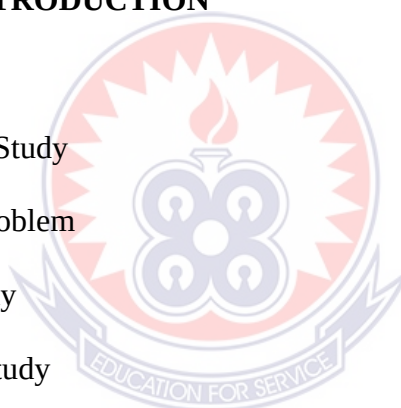
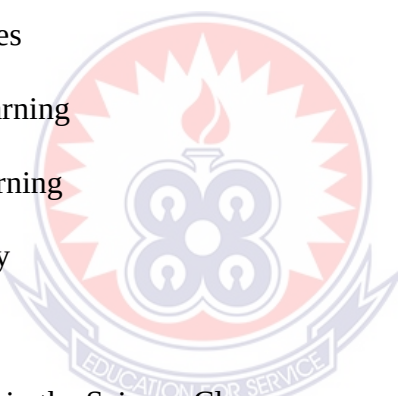


TABLE OF CONTENTS

Content	Page
DECLARATION	iii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
TABLE OF CONTENTS	vi
LIST OF TABLES	x
LIST OF FIGURES	xi
ABSTRACT	xii
 CHAPTER ONE: INTRODUCTION	 1
1.0 Overview	1
1.1 Background to the Study	1
1.2 Statement of the Problem	3
1.3 Purpose of the Study	4
1.4 Objectives of the Study	4
1.5 Research Questions	5
1.6 Null Hypothesis	5
1.7 Significance of the Study	6
1.8 Delimitations of the Study	6
1.9 Limitations of the Study	7
1.10 Operational Definition of terms	7
1.11 Organisation of the Study Report	8



CHAPTER TWO: LITERATURE REVIEW	9
2.0 Overview	9
2.1 Theoretical Framework	9
2.2 Conceptual Framework	12
2.3 Science Education in Ghana	13
2.4 Teaching and Learning of Science	15
2.5 Students' Academic performance in Science	17
2.6 Students' Difficulties in Acids, bases and Salts	20
2.7 Instructional approaches in teaching and learning science	22
2.7.1 Inquiry-based learning	22
2.7.2 Hands-on Activities	22
2.7.3 Problem-based learning	24
2.7.4 Collaborative Learning	25
2.7.5 Use of Technology	26
2.7.6 Concept Mapping	27
2.8 Hands-on Activities in the Science Classroom	29
2.9 Empirical Framework	35
2.10 Effect of Hands-on Activities on the Acquisition of Science Process Skills	39
2.11 Perceptions of Students on the use of Hands-on Instructional Approach	41
2.12 The Role of Students' Prior knowledge in teaching and learning	44
2.13 Challenges of Hands-on Instructional Methods	45
2.14 The Role of Teachers in Implementing Hands-On Activities in The Science Classroom	47

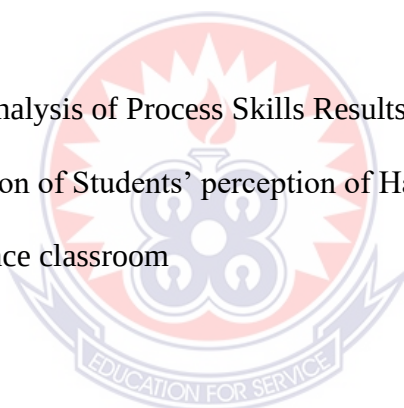


CHAPTER THREE: METHODOLOGY	51
3.0 Overview	51
3.1 Research Design	51
3.2 Population of the Study	51
3.3 Sample and Sampling Technique	52
3.4 Research Instruments	52
3.5 Validity of the Instruments	53
3.6 Reliability of the Instruments	54
3.7 Data Collection Procedure	54
3.7.1 Pre-Intervention Activities	54
3.7.2 Intervention Activities	54
3.7.3 Post-Intervention Activities	58
3.8 Data Analyses	59
3.9 Ethical Consideration	59
CHAPTER FOUR: RESULTS AND DISCUSSIONS	60
4.0 Overview	60
4.1 Demographic Data of Students	60
4.2 Research Question 1	61
4.3 Research Question 2	66
4.3.1 Testing null hypothesis	71
4.4 Research Question 3	73
4.4.1 Testing null hypothesis two	75
4.5 Research Question 4	78

CHAPTER FIVE: SUMMARY, CONCLUSIONS, RECOMMENDATIONS	
AND SUGGESTIONS FOR FURTHER STUDIES	81
5.0 Overview	81
5.1 Summary of the Study	81
5.1.1 Difficulties Students encounter during lessons on acids, bases and salts at Kaneshie Senior High Technical School	81
5.1.2 Effect of hands-on activities on students' academic performance in acids, bases and salts at Kaneshie Senior High Technical School	81
5.1.3 Effect of hands-on activities on students' science process skills in acids, bases and salts at Kaneshie Senior High Technical School	82
5.1.4 Perceptions of students on the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior High Technical School	82
5.2 Conclusions	83
5.3 Recommendations	83
5.4 Suggestions for further Studies	84
REFERENCES	85
APPENDICES	112
APPENDIX A	112
APPENDIX B	113
APPENDIX C	115
APPENDIX D	116
APPENDIX E	118
APPENDIX F	119
APPENDIX G	120
APPENDIX H	121
APPENDIX I	122

LIST OF TABLES

Table	Page
1: Age Distribution of students	60
2: Frequency Distribution of Students' Difficulties in Acids, bases and Salts	61
3: Frequency Distribution of the Means of Students' Pre-test and Post-test Scores	66
4: Mean and Standard Deviation of Pre-Intervention test and Post-Intervention test Scores of Students	70
5: Summary of T-test Analysis of Pre-intervention test and post-intervention test Scores of Students	71
6: Frequency Distribution of Process Skills Results of Students' Pre-Test and Post-test	74
7: Summary of t-test Analysis of Process Skills Results of Students	75
8: Frequency Distribution of Students' perception of Hands-on Activities of teaching in the Science classroom	78



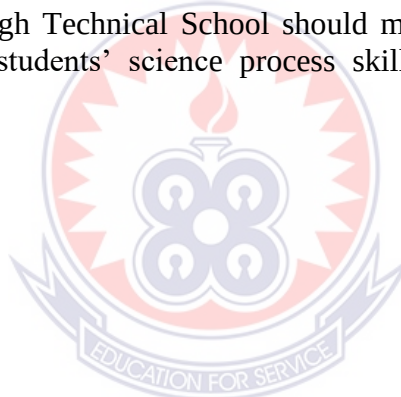
LIST OF FIGURES

Figure	Page
1: Conceptual framework	12
2: Bar Charts Distribution of Students' Pre-test and Post-test Scores	69



ABSTRACT

This study was conducted to determine the effect of hands-on activities on senior high school students' performance in acids, bases and salts. The study was conducted at Kaneshie Senior High Technical School, Accra. It employed an action research design with the collection of quantitative data. A purposive sampling technique was then used to select an intact class of 50 SHS 2 students. Tests were used to gather data on students' difficulties in acids, bases and salts, the effect of hands-on activities on students' performance in acids, bases and salts as well as the effect of hands-on activities on students' science process skills. A questionnaire was used to gather data on the perceptions of students on the use of hands-on activities in teaching science concepts. Data were analysed using content analysis, descriptive and inferential statistics. The findings of the study revealed significant conceptual difficulties of students in acids, bases and salts. It also showed an improvement in students' performance after the implementation of the intervention. As there was a significant improvement in students' science process skills. It was also discovered that students had positive perceptions of hands-on activities in learning acids, bases and salts. Based on the findings, it was recommended that science teachers in Kaneshie Senior High Technical School should use hands-on activities to identify students' difficulties and improve students' performance in acids, bases and salts. It was also recommended that school authorities in Kaneshie Senior High Technical School should make hands-on activities readily available to enhance students' science process skills and positive perceptions of students.



CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter contains the background to the study which forms the fundamental support for the study, the statement of the problem, the purpose of the study, research objectives, research questions that guide the study, research hypotheses, significance of the study, limitations, delimitations, as well as operational definitions of terms.

1.1 Background to the Study

In the quest for enhancing the quality of science education in Ghana, there has been a persistent drive for reform (Boakye, 2019). At the core of this endeavour lies the acknowledgment that effective science teaching requires active participation from students. This concept aligns with the theories highlighting the importance of learning through activities and focusing on the child in educational practices to create meaningful learning experiences (Hsbollah & Hassan, 2022). Besides, discussions on the development of science curricula have increasingly stressed the incorporation of practical activities into the learning process (Zhang et al., 2022).

Within this context, scholars in the field of education have devoted significant efforts to identify the factors that influence students' success in science education (Cretu & Ho, 2023). Studies have noted the numerous variables that affect students' learning achievements, shedding light on the relationship between instructional methods, student involvement, and academic success. In the realm of education, the effectiveness of instructional methodologies continues to be a focal point of research. Among these methodologies, hands-on instruction stands out as a promising approach, particularly in the field of science education.

Hands-on activities in education involves actively engaging students in practical, experiential learning activities rather than relying solely on traditional lecture-based methods (Miller et al., 2019). These activities often include experiments, simulations, projects, or interactive exercises that allow students to manipulate materials, observe phenomena, and explore concepts firsthand (Pinote et al., 2023). In the context of science education, hands-on learning is particularly valuable as it enables students to directly interact with scientific principles, theories, and phenomena (Sshana & Abulibdeh, 2020). Through hands-on activities, students can develop a deeper understanding of scientific concepts by seeing them in action and experiencing the real-world applications of theoretical knowledge (Kigba et al., 2021). This approach not only enhances comprehension but also promotes critical thinking, problem-solving skills, and a sense of curiosity and exploration (Kigba et al., 2021). The persistent challenges of low interest and poor performance in science among students at Kaneshie Senior High Technical School in the Greater Accra Region of Ghana underscore the need for innovative approaches to teaching and learning. Despite the numerous benefits associated with hands-on instructional methods it is evident that traditional instructional approaches alone have not effectively addressed these challenges. Therefore, this study sought to explore the potential of hands-on methods, specifically experiments and projects, in teaching the concept of acids, bases, and salts to students in Kaneshie Senior High Technical School.

The study acknowledges the limitations of conventional teaching approaches and seeks to leverage experiential learning through the use of hands-on activities to enhance student engagement, understanding, and retention of scientific concepts (Radke et al., 2024). Hands-on activities offer students the opportunity to actively participate in the learning process, fostering a deeper level of comprehension through firsthand

exploration and discovery (Kibga et al., 2021). Moreover, these hands-on activities enable students to develop science process skills, provide a platform to apply theoretical knowledge in practical contexts, bridging the gap between classroom learning and real-world applications (Lee et al., 2024). The choice of the concept of acids, bases, and salts for this study is particularly relevant given its foundational importance in chemistry education and its practical relevance in various scientific disciplines and everyday life. According to Castillo-Olivares et al. (2023), by using hands-on instructional methods, abstract scientific concepts can be explained and made relevant to students lives. Additionally, by actively involving students in the process of scientific inquiry and experimentation, this study seeks to cultivate critical thinking skills, problem-solving abilities, and a curiosity-driven approach to learning. This study thus aimed to provide empirical evidence to inform teaching practices, curriculum development, and educational policies in Kaneshie Senior High Technical School and beyond.

1.2 Statement of the Problem

Sakyi-Hagan and Hanson (2019) asserted that science appears to be primarily taught in Ghanaian senior high schools through lectures, note-taking, chalkboard illustrations and other teacher-centred 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 Kaneshie Senior High Technical 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 had 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 (Cox et al., 2019). A study conducted by Main (2023) 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 help improve students' performance in acids, bases and salts using hands-on activities.

1.3 Purpose of the Study

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

2. Assess the effect of hands-on activities on students' academic performance in acids, bases and salts at Kaneshie Senior High Technical School.
3. Investigate the effect of hands-on activities on students' science process skills in acids, bases and salts at Kaneshie Senior High Technical School.
4. Examine the perceptions of students on the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior High Technical School.

1.5 Research Questions

The following questions guided the study.

1. What are the difficulties that students encounter during lessons on acids, bases and salts at Kaneshie Senior High Technical School?
2. What is the effect of hands-on activities on students' academic performance in acids, bases and salts at Kaneshie Senior High Technical School?
3. What is the effect of hands-on activities on students' science process skills in acids, bases and salts at Kaneshie Senior High Technical School?
4. What are the perceptions of students on the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior High Technical School?

1.6 Null Hypothesis

H₀₁: There is no statistically significant difference in the performance of students before and after the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior Technical School.

H₀₂: There is no statistically significant difference in the acquisition of science process skills before and after the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior Technical School.

1.7 Significance of the Study

The significance of this research lies in its potential to make a valuable contribution to both theory and practice in the field of science education, particularly within Kaneshie Senior High Technical School located in the Greater Accra Region of Ghana. Specifically, the significance of the study includes the following:

Firstly, the results obtained from this study would offer guidance to both teachers and students on evidence-based approaches, specifically hands-on activities, to enhance the teaching and learning of science. Furthermore, science teachers at Kaneshie Senior High Technical School would acquire valuable insights into the efficiency of hands-on activities in conveying scientific concepts, such as acids, bases, and salts.

Additionally, the participating students at Kaneshie Senior High Technical School would have the opportunity to manipulate teaching and learning materials, which could boost their confidence level and interest in science. Moreover, the outcome of the study would also guide curriculum developers to integrate more experiential learning opportunities into the science curriculum at Kaneshie Senior High Technical School.

1.8 Delimitations of the Study

The study was conducted within the confines of Kaneshie Senior High Technical School, situated in the Greater Accra Region of Ghana. It focused exclusively on second-year students (Form Two) within the school. The study also focused only on the concepts of acids, bases, and salts in the Integrated Science Curriculum, all other Integrated Science topics were excluded. The research primarily examined the effect of hands-on activities on students' performance.

1.9 Limitations of the Study

Few students were selected as the sample size which may not accurately represent the larger population from which it is drawn. Test anxiety and the health status of the students would affect the study. Moreover, the investigation into the perception of students on the use of hands-on activities rely on self-reporting by students, introducing the possibility of bias or interpretation.

1.10 Operational Definition of terms

1. **Hands-on activities:** Practical, experiential learning tasks that actively engage students in manipulating materials, performing experiments, and directly exploring concepts in the learning process.
2. **Science process skills:** Abilities developed through science education that include observing, classifying, measuring, predicting, and experimenting, which enable students to investigate and understand scientific phenomena.
3. **Acids, bases, and salts:** Fundamental chemical compounds in chemistry education, where acids are defined as substances that donate hydrogen ions, bases accept hydrogen ions, and salts are formed from the neutralization of acids and bases.
4. **Student engagement:** The involvement and active participation of students in the learning process, demonstrated through interest, enthusiasm, and motivation in classroom activities.
5. **Academic performance:** The measurable outcomes of students' learning achievements, typically assessed through tests, quizzes, and exams, in relation to their grasp of specific educational content.

6. **Perceptions of students:** The opinions, attitudes, and views that students hold towards specific teaching methods, in this case, the use of hands-on activities in learning scientific concepts.
7. **Instructional strategies:** The teaching methods and techniques used by educators to facilitate student learning, including traditional lecture methods and more interactive, practical approaches.
8. **Experiential learning:** A learning process where students gain knowledge through direct experience and reflection on their practical activities.
9. **Conceptual understanding:** The deep comprehension of scientific principles, enabling students to apply their knowledge to solve problems and explain phenomena.
10. **Science inquiry:** The process of investigating scientific questions through observation, experimentation, and analysis, fostering a hands-on approach to understanding scientific principles.

1.11 Organisation of the Study Report

The study is organised into five chapters. Chapter one introduced the study and consisted of the background to the study, statement of the problem, aims of the study, research questions, delimitation limitation and organization of the study. Chapter two focused on the literature review while chapter three outlined the methodology employed to gather information for the study. Chapter four was dedicated to the presentation and discussions of results. The concluding chapter, Chapter five, summarised the research, drew conclusions, offered recommendations, and suggested avenues for further studies.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter provides a comprehensive review about other works related to the use of hands-on activities in teaching and learning of science concepts. The review was done under the theoretical and conceptual framework of the study. It also addresses various aspects of science education, beginning with science education in Ghana, exploration of teaching and learning in science and students' academic performance in the subject. Furthermore, the review discusses the difficulties students face in understanding acids, bases, and salts, and the instructional approaches used in teaching these concepts.

The literature also explored the role of hands-on activities in the science classroom, focusing on their impact on students' academic performance and their ability to acquire essential science process skills. Additionally, it delves into students' perceptions of hands-on instructional methods, emphasising how these approaches influence their learning experience. The importance of students' prior knowledge in the teaching and learning process is also highlighted, showing how it shapes their engagement with new material. It also outlines some of the challenges associated with implementing hands-on instructional methods, providing insights into potential obstacles that educators and students may encounter in the classroom. The study also highlights on the role of teachers in implementing hands-on activities in the science classroom.

2.1 Theoretical Framework

The theoretical framework for this study draws on constructivist and behaviourist perspectives on learning, with a particular focus on science education and hands-on instructional methods. From a behaviourist viewpoint, learning is perceived as a

response to external stimuli, with observable behaviour serving as the primary indicator of learning. According to Skinner (1974), internal mental processes are not directly observable, so behaviourists emphasise the importance of focusing on observable behaviours and cause-and-effect relationships. In practice, behaviourist approaches advocate for demonstrating desired behaviours, breaking them down into manageable parts, and providing frequent opportunities for practice and feedback to reinforce learning.

On the other hand, constructivist learning theory, influenced by the work of Piaget and Vygotsky, emphasizes the active role of learners in constructing knowledge through their experiences and interactions. Piaget's cognitive constructivism posits that individuals construct knowledge based on their personal experiences, while Vygotsky's social constructivism highlights the importance of social interactions and collaboration in learning. In constructivist settings, learners are encouraged to engage in inquiry, problem-solving, and collaboration, with the teacher serving as a guide and facilitator rather than a dispenser of knowledge. According to Hmelo-Silver and Eberbach (2012), constructivist theories have informed curriculum design and instructional approaches that promote active engagement and problem-solving, such as Problem-Based Learning (PBL). PBL allows students to apply their knowledge to real-world scenarios, fostering deeper understanding and meaningful learning experiences. The choice of this theoretical framework is justified by its relevance to the study's focus on science education and hands-on instructional methods. Firstly, behaviourist and constructivist perspectives are widely recognised and applied in educational research, particularly in the field of science education. These perspectives offer complementary insights into how students learn and how instructional methods can be designed to facilitate effective learning experiences. By integrating both perspectives, the study benefits from a

comprehensive understanding of learning processes (Munna & Kalam, 2021). Secondly, the theoretical framework aligns closely with the objectives of the study. Behaviourist principles inform the design of hands-on activities by emphasising observable behaviours and external stimuli, which is essential for assessing the impact of such activities on student academic performance. Constructivist perspectives, on the other hand, guide the facilitation of these activities by emphasizing active student participation, inquiry, and collaboration, which are crucial for understanding students' level of interest and engagement.

Additionally, the theoretical framework offers practical implications for instruction. By drawing on behaviourist principles, educators can design hands-on activities that are structured, sequenced, and scaffolded to support student learning. Constructivist perspectives, meanwhile, emphasise the importance of creating opportunities for student exploration, problem-solving, and reflection, which are essential for fostering deep understanding and meaningful learning experiences (Hsbollah & Hassan, 2022). This theoretical framework, therefore, informs the study's exploration of the impact of hands-on instructional methods on students' performance in the context of teaching acids, bases, and salts at Kaneshie Senior High Technical School.

2.2 Conceptual Framework

The diagram summarises the conceptual framework of the study

Science lesson.

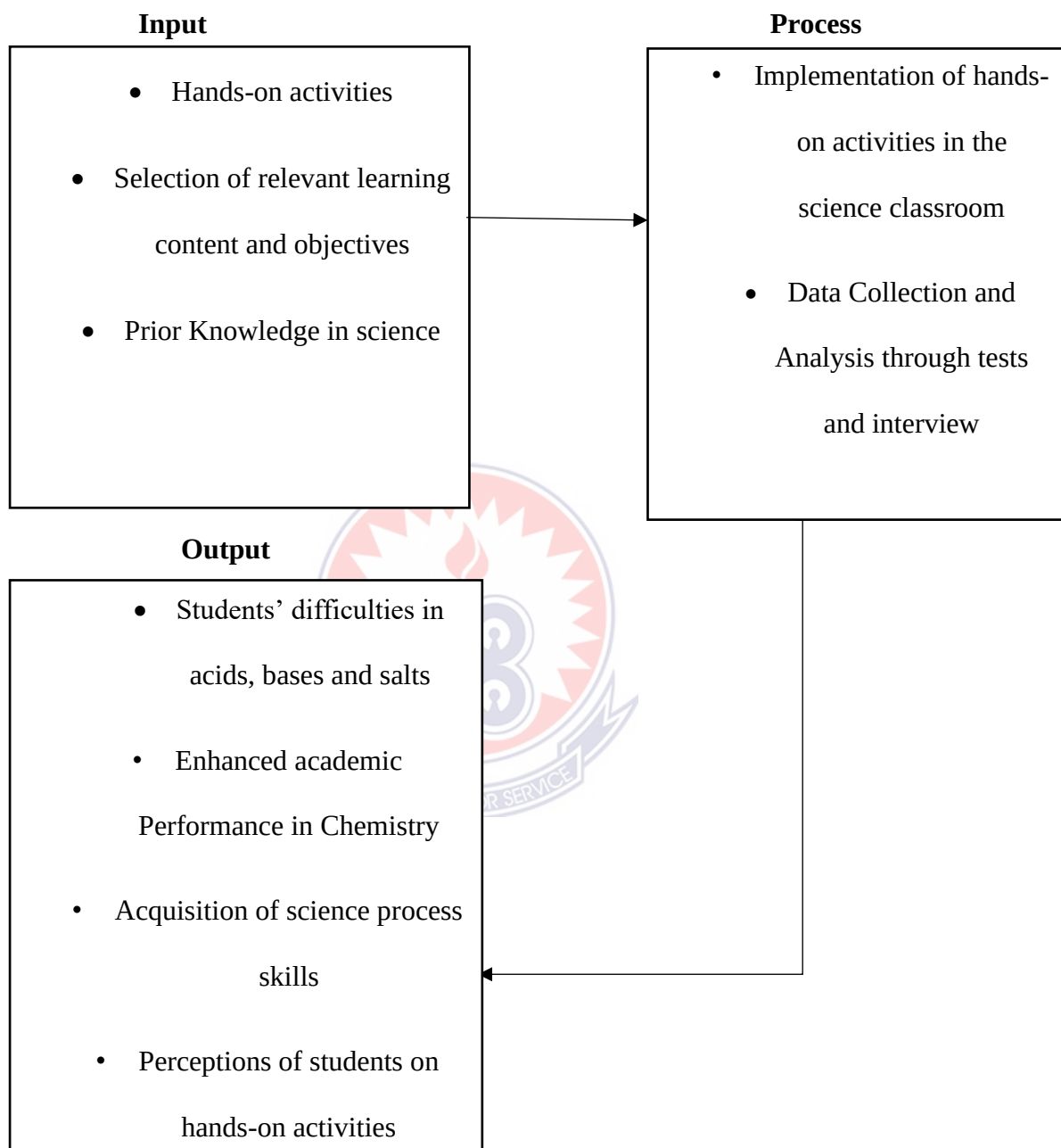


Figure 1: Conceptual framework

2.3 Science Education in Ghana

Science education in Ghana has undergone significant transformations over the years, reflecting the nation's commitment to fostering scientific literacy and innovation. The Ghana Education Service (GES) has been at the forefront of implementing policies aimed at enhancing science, technology, engineering, and mathematics (STEM) education across all levels of the educational system (Ghana Education Service, 2017). Despite these efforts, challenges persist, particularly in resource availability and teacher preparedness. A study by Humphrey-Darkeh et al. (2022) highlighted that only 10% of students reported having access to a dedicated science laboratory, underscoring the infrastructural deficits in many schools. This lack of facilities hampers the effective teaching and learning of science subjects, making it difficult for students to engage in practical experiments that are crucial for understanding scientific concepts (Ghana News Agency, 2024). The government's commitment to advancing STEM education is evident in initiatives such as the construction of the Accra STEM Academy and the establishment of 20 STEM Centres and ten model STEM Senior High Schools across the country. These institutions are equipped with state-of-the-art laboratories and classrooms designed to foster hands-on learning and experimentation (Papaioannou et al., 2023). Additionally, the refurbishment and modernization of existing science laboratories have been prioritized, with the construction of 186 new science laboratories across Ghana.

However, the implementation of STEM education policies has faced delays, resulting in a lack of cohesive and visionary approaches to STEM education (Ejiwale, 2013). This has led to a disconnect between theoretical knowledge and practical application, limiting students' ability to apply classroom-taught science principles to real-world challenges. Furthermore, inadequate infrastructure, such as the absence of makerspaces

and interactive environments, restricts opportunities for hands-on learning and exploration. Teacher preparedness is another critical issue affecting science education in Ghana. The lack of professional development opportunities for educators in modern STEM pedagogies affects the quality and delivery of STEM education (Marcourt et al., 2023). Teachers often rely on outdated teaching methods, which do not align with the dynamic nature of science education. Moreover, the shortage of qualified science teachers, especially in rural areas, exacerbates the problem, leading to large class sizes and reduced individual attention for students (Muremela et al., 2023). The introduction of the Free Senior High School (SHS) policy, while increasing access to education, has also strained resources in public schools and adversely affected private schools, which are key stakeholders in STEM education.

The increased enrollment has led to overcrowded classrooms and overburdened facilities, making it challenging to maintain the quality of science education (Osai et al., 2021). There are promising initiatives aimed at improving science education in Ghana. The Dext Science Kit, a miniature science laboratory created by Ghanaian inventor Charles Ofori Antipem, provides basic school children with the tools needed for practical science lessons. This innovation has won international awards and is a testament to the potential of locally developed solutions in enhancing science education (Serdyukov, 2017). Furthermore, the Ghana STEM Hub and the GDAAR Foundation are working to provide professional development for STEM teachers, develop STEM curriculum materials, and support STEM clubs and after-school programmes. These organisations are also advocating for STEM education policy at the national level, aiming to create a more supportive environment for science education (Akon-Yamga et al., 2024).

2.4 Teaching and Learning of Science

Engagement with scientific concepts is a common aspect of students' daily lives, occurring both formally and informally. A sustained interest in scientific inquiries develops as students' progress through their educational journey (Creemers & Kyriakides, 2008). The quality of classroom instruction plays a pivotal role, providing an opportunity to systematically nurture domain-specific learning processes and cultivate scientific literacy. Considering the diverse backgrounds and experiences of students, effective classroom instruction becomes essential. Research on instructional efficacy has identified various teaching variables at the classroom level that significantly impact students' learning outcomes and underscore the importance of instructional characteristics and classroom procedures (Hattie, 2009; Seidel & Shavelson, 2007). In the realm of International Large-Scale Assessments (ILSAs), these elements serve as potent indicators for both scientific and policy-oriented inquiries (Klieme, 2013). The selection of constructs for an international large-scale assessment depends on a combination of theoretical and empirical insights, as well as the study's specific purpose, framework, design, and associated constraints.

Scientific literacy, as defined by the Programme for International Student Assessment (PISA), encompasses students' ability to assess and plan scientific inquiries, explain phenomena using scientific principles, and interpret data and evidence through the lens of science (OECD, 2013b). In addition to these cognitive outcomes, non-cognitive attributes such as a genuine interest in science, an intrinsic motivation to learn, and the ability to collaborate with others are considered crucial learning objectives in their own right (Taylor et al., 2009). Contemporary models of educational efficacy have expanded on ideas from the process-product model (Creemers & Kyriakides, 2015). For example, the dynamic model of educational effectiveness by Creemers and Kyriakides (2008)

underscores the interplay of elements, acknowledging the multi-layered nature of influences on student learning and treating effectiveness factors as multidimensional constructs. Consequently, it is expected that elements at the school level will impact teacher-specific classroom aspects, including orientation, structuring, modeling, questioning, application, time management, evaluation, and the teacher's role in creating a conducive learning environment (Kyriakides et al., 2013). These components were found to be moderately correlated with student achievement, except the application-related factor (Kyriakides et al., 2013). Research employing the comprehensive, non-domain-specific process-product model underscores the pivotal role of the teacher's position in the classroom, the teaching processes, and the evolving relationships between students and teachers. From these studies, five key variable aspects emerge: clarity, indicating the alignment of learning objectives with presented content; structuredness, denoting a systematic approach to instruction; cognitive activation, reflecting the cognitive complexity of tasks; pacing, involving the adaptive sequencing of tasks based on students' abilities; and classroom management, encompassing the overall learning environment (Neumann et al., 2012).

It is crucial to acknowledge that all learning occurs within a specific context, especially when considering science education from a science-technology-society perspective. Contemporary national and state standards have defined the learning context for science classes, often perceived as abstract and detached from students' daily lives (Rodrigues, 2006). Historically, science curricula have prioritized content over application (DeBoer, 2000). In the confines of this traditional, content-centric approach, instructors are advised to introduce fundamental concepts initially, reinforcing them with relevant contexts and applications as time permits (Tang, 2023). Typically, the focus is on imparting conceptual understanding to students, with any additional experiences or

applications considered as optional and addressed towards the end of the instructional process (Cardino Jr & Cruz, 2020).

2.5 Students' Academic performance in Science

Researcher 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. Divergent performance may occur when there is a misalignment between actual and anticipated performance, sometimes linked to teaching methodologies (Marti, 2013).

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. In order to discuss the elements influencing students' academic achievement, the idea of bad performance should be examined. According to Aremu (2010), poor performance is one that is determined by the test takers to be significantly below the expected standard. Due to the performance of 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 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.

Parental involvement in their children's education is positively correlated with student outcomes (Blooms, 2014; Fehrmann, 2017; Eisner, 2010). 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) recognised 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.

2.6 Students' Difficulties in Acids, bases and Salts

The study of acids, bases, and salts is a core component of chemistry education, but students often find these concepts challenging. These struggles arise from various factors, such as the abstract nature of the subject, misconceptions, and ineffective teaching methods (Ozmen, 2019). These difficulties can significantly hinder students' overall performance in chemistry and their ability to tackle more advanced topics (Garnett & Treagust, 2019). This review delves into the specific challenges students face in learning acids, bases, and salts, their common misconceptions, and the teaching strategies that may alleviate these issues. One of the key challenges is understanding the conceptual framework behind acids, bases, and salts. Many students fail to distinguish between these categories, particularly when confronted with real-world examples. Schmidt and Volke (2020) found that students often confuse the properties of acids and bases, especially in the context of chemical reactions. A major difficulty for students is grasping the pH scale. Although it seems straightforward, its logarithmic structure often confuses, making it difficult for students to accurately assess the acidity or basicity of solutions in both theoretical and practical contexts (Sari, 2020).

Another area of misunderstanding is the dissociation of acids and bases in water, especially when dealing with weak acids and bases (Cox & Sevan, 2021). Students frequently misunderstand this process, failing to recognise the equilibrium involved with weak acids and bases in solution. Research shows that even when students can perform equilibrium-related calculations, they often do not fully comprehend the underlying chemical principles, leading to superficial learning without deep understanding (Treagust, 2020). Misconceptions are widespread in chemistry, and acids, bases, and salts are no exception. These misconceptions often persist even after formal instruction (Taber, 2019). For instance, students tend to believe that all acids are highly

corrosive, which simplifies the true nature of acids. Similarly, many students think of bases as the "opposite" of acids without understanding their broader chemical roles, such as forming salts when reacting with acids (Levy-Nahum, 2019).

A common misconception about strong acids and bases is that they are always highly reactive, with students overlooking factors like concentration and specific reaction conditions that influence reactivity (McLain, 2020). Additionally, students often fail to recognize the importance of salts in chemical reactions, viewing them merely as byproducts rather than active participants in processes such as hydrolysis (Niaz & Robinson, 2020). Cognitive factors, such as students' prior knowledge and abstract reasoning skills, contribute to these difficulties. Many students enter chemistry with preconceived notions based on their daily experiences with acids and bases, which can lead to oversimplified views (Taber, 2020). For example, household products labeled as acidic or basic may reinforce these simplistic ideas, making them harder to change (Osborne & Dillon, 2020). According to cognitive load theory, the complexity of chemical concepts, combined with students' misconceptions, can overwhelm their working memory, preventing deeper learning (Sweller, 2021). Moreover, students' attitudes toward chemistry and their self-efficacy beliefs also affect their ability to grasp concepts related to acids, bases, and salts (Bennett, 2020). Students who view chemistry as overly difficult or irrelevant are less likely to engage with challenging material, which worsens their struggles. Therefore, teachers must address not only cognitive barriers but also emotional and motivational factors to enhance student learning (Azevedo, 2019).

2.7 Instructional approaches in teaching and learning science

2.7.1 Inquiry-based learning

Inquiry-based learning is a pedagogical approach that actively engages students in the process of scientific inquiry and knowledge construction. Through this approach, students develop essential skills such as questioning, designing investigations, collecting and analyzing data, and drawing evidence-based conclusions (Jones & Reed, 2021). Inquiry-based learning promotes deep conceptual understanding by allowing students to construct their own knowledge through exploration and investigation (Chen & Wang, 2020). Moreover, this approach fosters critical thinking, problem-solving abilities, and the application of scientific reasoning to real-world situations (Taylor et al., 2022).

The inquiry process is often described as a cyclical model involving various stages, such as questioning, exploring, experimenting, and drawing conclusions (Smith et al., 2021). This iterative nature encourages students to continuously refine their understanding and engage in ongoing learning. Technology plays a crucial role in supporting inquiry-based learning, as simulations, virtual laboratories, and multimedia resources provide interactive platforms for exploration and investigation (Kim et al., 2019). Effective implementation of inquiry-based learning requires careful scaffolding and support from teachers, who guide students through the inquiry process and create an environment that nurtures curiosity and exploration (Williams et al., 2020).

2.7.2 Hands-on Activities

Hands-on activities and practical activities are crucial components of effective science education, allowing students to directly experience scientific concepts and develop a deeper understanding. Engaging in hands-on activities promotes the development of

scientific inquiry skills, such as observing, measuring, manipulating variables, collecting and analysing data, and drawing conclusions (Piqueras et al., 2021). These skills are fundamental to the practice of science and promote scientific literacy.

Practical work can significantly enhance students' conceptual understanding by enabling them to observe phenomena firsthand and make connections between theoretical concepts and real-world observations (Rodriguez & Bollen, 2021; Millar, 2021). Moreover, hands-on activities have been shown to increase students' motivation and engagement in science learning, as practical activities often involve elements of discovery, problem-solving, and collaboration (Bhukuvhani et al., 2021; Bryers et al., 2022). Engaging in hands-on activities provides opportunities for students to develop valuable technical and practical skills, such as using scientific equipment, following procedures, and adhering to safety protocols (Taylor & Hobson, 2019; Topçu et al., 2021). These skills are transferable to various careers and everyday life situations. Additionally, practical work allows students to connect theoretical concepts with their practical applications, reinforcing their understanding and appreciation for the subject matter (Hofstein & Mamlok-Naaman, 2022).

Effective hands-on activities require careful planning, scaffolding, and integration with other instructional strategies (Taylor & Hobson, 2019; Hofstein et al., 2018). Teachers play a crucial role in designing meaningful experiments, guiding students through the practical activities, and facilitating discussions to help students make connections between practical observations and theoretical concepts (Singh & Ghosh, 2021; Piqueras et al., 2021). Furthermore, hands-on activities can promote collaboration and communication among students, as many practical activities involve group work,

encouraging scientific discourse and teamwork (Bryers et al., 2022; Singh & Ghosh, 2021).

2.7.3 Problem-based learning

Problem-based learning (PBL) is a student-centered approach that presents learners with authentic, real-world problems or scenarios related to scientific concepts. This approach encourages students to work collaboratively, analyse information, develop hypotheses, and propose solutions to the given problems. Several researchers have highlighted the benefits and key aspects of problem-based learning in science education:

PBL promotes the development of critical thinking, problem-solving skills, and the application of scientific knowledge to authentic situations (Üce & Karadoğan, 2021). By grappling with complex, open-ended problems, students learn to analyze information from multiple perspectives, evaluate evidence, and devise creative solutions (Hung et al., 2019; Wijnen et al., 2017). This approach fosters self-directed learning and encourages students to take responsibility for their own learning process (Dolmans et al., 2016; Wijnia et al., 2019). By working collaboratively in small groups, students engage in peer learning, share knowledge, and develop effective communication and teamwork skills (Ates & Eryilmaz, 2011; Wijnia et al., 2019).

Problem-based learning can enhance students' motivation and engagement in science learning by presenting them with relevant, real-world scenarios that are meaningful and engaging (Akçay, 2017; Dolmans et al., 2016). This approach encourages students to make connections between scientific concepts and their practical applications, fostering a deeper understanding and appreciation of the subject matter (Hmelo-Silver, 2015; Savery, 2015). Effective implementation of problem-based learning requires careful

scaffolding and support from teachers, who act as facilitators and guides throughout the learning process (Akçay, 2017; Hmelo-Silver, 2015). Teachers play a crucial role in designing authentic and engaging problems, providing necessary resources, and facilitating discussions to help students make connections between the problem and scientific concepts (Dolmans et al., 2016; Üce & Karadoğan, 2021).

2.7.4 Collaborative Learning

Collaborative learning is an instructional approach that involves students working together in small groups to achieve shared learning goals. This approach has been widely recognized as an effective strategy in science education, as it promotes active engagement, social interaction, and the development of various skills. Collaborative learning fosters the development of communication, interpersonal, and teamwork skills (Siddique & Rahman, 2022). By working together in groups, students learn to express their ideas clearly, listen to others' perspectives, and collaborate effectively to accomplish tasks (Salmiza & Mohammad Ghazali, 2021; Thurston et al., 2017). This approach promotes active learning and encourages students to engage in discussions, share knowledge, and co-construct understanding of scientific concepts (Siddique & Rahman, 2022). Through the process of explaining and justifying their ideas to peers, students develop a deeper understanding of the subject matter (Howe & Abedin, 2021). Collaborative learning can enhance students' critical thinking and problem-solving abilities (Salmiza & Mohammad Ghazali, 2021). By working collaboratively, students are exposed to multiple perspectives and are challenged to analyze information, evaluate ideas, and devise creative solutions to problems (Thurston et al., 2017; Zakaria & Iksan, 2007). This approach can foster a supportive learning environment and promote positive attitudes towards science learning (Siddique & Rahman, 2022). When students work together in a collaborative setting, they can provide encouragement,

support, and feedback to one another, enhancing their motivation and engagement (Lam et al., 2022; Thurston et al., 2017). Effective implementation of collaborative learning requires careful planning, group composition, and facilitation by teachers (Siddique & Rahman, 2022). Teachers play a crucial role in designing collaborative tasks, monitoring group interactions, and providing guidance and support when needed (Salmiza & Mohammad Ghazali, 2021).

2.7.5 Use of Technology

The integration of technology in science education has become increasingly important, providing students with interactive and engaging learning experiences. The use of technology can enhance the teaching and learning of scientific concepts, facilitate inquiry-based activities, and support data collection, analysis, and visualization. Studies have shown that technology-based simulations, virtual laboratories, and multimedia resources can provide students with opportunities to explore scientific phenomena in interactive and engaging ways (Yadav & Lim, 2020; Akcay & Akcay, 2015; Lazarowitz & Naim, 2013). These tools allow students to conduct experiments, manipulate variables, and observe the outcomes in a safe and controlled environment, fostering a deeper understanding of scientific concepts and processes (Zakaria & Idris, 2021). The use of technology can support inquiry-based learning by enabling students to collect, analyze, and visualize data more efficiently (Kocakulah & Savaş, 2011; Osborne & Dillon, 2010). Technology tools such as data logging devices, probeware, and specialized software can facilitate the collection and analysis of real-time data, enhancing students' understanding of scientific concepts and their ability to draw evidence-based conclusions (Pyatt & Sims, 2012; Zhang & Linn, 2011).

Technology can foster collaboration and communication among students, enabling them to share their findings, discuss ideas, and collaborate on projects (Hennessy et al., 2016; Osborne & Dillon, 2010). Online platforms, discussion forums, and collaborative tools can facilitate teamwork and promote the exchange of knowledge, fostering a supportive and engaging learning environment (Karamustafaoğlu et al., 2021; Kocakulah & Savaş, 2011). The integration of technology in science education can increase students' motivation and engagement by providing interactive and immersive learning experiences (Akçay & Akçay, 2015). Interactive simulations, games, and augmented reality applications can make science concepts more accessible and engaging, fostering curiosity and a desire to learn (Hennessy et al., 2016; Lazarowitz & Naim, 2013). Effective integration of technology in science education requires careful planning, appropriate instructional design, and adequate teacher training (Karamustafaoğlu et al., 2021; Osborne & Dillon, 2010). Teachers play a crucial role in selecting appropriate technology tools, designing meaningful learning activities, and providing guidance and support to students in using these tools effectively (Hennessy et al., 2016; Pyatt & Sims, 2012).

2.7.6 Concept Mapping

Concept mapping is a powerful instructional strategy that involves creating visual representations of knowledge and relationships between concepts. In science education, concept mapping has been widely recognized as an effective tool for promoting meaningful learning, facilitating knowledge construction, and enhancing conceptual understanding. Concept mapping encourages students to actively engage with scientific concepts and make meaningful connections between them (Dhull & Verma, 2020). By constructing concept maps, students are prompted to organize and integrate their knowledge, fostering a deeper understanding of scientific concepts and their

interrelationships (Aidoo et al., 2021). Concept mapping supports the process of knowledge construction by allowing students to externalize their understanding and make their existing knowledge structures explicit (Kinchin, 2014). As students create concept maps, they actively build upon their prior knowledge, identify gaps, and refine their conceptual frameworks (Aidoo et al., 2021).

Concept mapping has been shown to improve students' conceptual understanding in various scientific disciplines (Aidoo et al., 2021). By visually representing the relationships between concepts, concept maps can help students recognize patterns, identify misconceptions, and develop a more coherent and integrated understanding of scientific concepts (Kinchin, 2014). The process of constructing concept maps requires students to reflect on their own understanding, monitor their learning progress, and engage in self-evaluation (Aidoo et al., 2021). This metacognitive process can enhance students' self-regulation skills and their ability to take responsibility for their own learning (Kinchin, 2014). Concept mapping can be employed as a collaborative activity, encouraging students to engage in scientific discourse, share their understanding, and negotiate meaning (Aidoo et al., 2021). By working together to construct concept maps, students can develop communication skills, negotiate their understanding, and co-construct knowledge (Kinchin, 2014). Effective implementation of concept mapping in science education requires careful planning, scaffolding, and integration with other instructional strategies (Aidoo et al., 2021). Teachers play a crucial role in providing guidance, facilitating discussions, and creating opportunities for students to construct, share, and refine their concept maps (Novak & Gowin, 2020).

2.8 Hands-on Activities in the Science Classroom

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 (2014) 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 (Perez & Moreno, 2021). 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. (2017) 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., 2017). 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 activities 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 (Miller & Green, 2020). Johnson and Thomas (2021) 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. (2016), which challenges the efficacy of the hands-on method. The study

contends that unguided activities may lead to memory loss, emphasizing the need for strong guidance.

The authors, Kirshner et al. 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 (2017) 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 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. (2014) 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], 2016). As outlined by Khan and Iqbal (2011) and the Ministry of Education Youth and Sport (2016), 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, 2013) 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. (2014) 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, 2016), 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 behaviours 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.

During 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 (2013) 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 skilful 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 (Mansfield, 2023). 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, 2014a, 2014b) 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 (2011) 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 (Wei, 2023).

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 (Lazonder & Harmsen, 2020). Lunetta et al. (2017) 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.

2.9 Empirical Framework

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. One study which was conducted 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 educational 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 (2013), 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.

Puranik (2020) supported the implementation of hands-on teaching and learning methods, emphasizing the numerous advantages they offer students. He highlighted that engaging in hands-on activities helps students become more active participants in lessons, catering to their individual needs while fostering creativity, critical thinking, and innovation. Additionally, he noted that the hands-on approach is particularly well-suited for teaching chemistry, as it allows students to actively engage in the learning process. This, in turn, helps both teachers and students effectively meet the general and specific objectives outlined in the curriculum.

Nweke et al. (2022) conducted a study on the impact of the Hands-on Activity Learning Strategy (HALS) on students' achievement and interest in chemistry in Delta State. The study focused on a population of 18,879 SSII chemistry students from public secondary schools, with a sample of 223 students. Data collection was done using the Chemistry Achievement Test (CAT) and the Chemistry Interest Scale (CIS), with reliability scores

of 0.77 and 0.81, respectively. Data analysis was carried out using means, standard deviations, and t-tests. The results showed a significant difference in both achievement and interest levels between students taught using HALS and those taught using the lecture method, with HALS proving more effective.

Another study conducted by Iyamuremye et al. (2023) examined the effectiveness of hands-on practical activities in chemistry education. A sample of 155 senior four and five students was used, employing a mixed research design. Data were gathered through a chemistry achievement test and a questionnaire that included both multiple-choice and open-ended questions for triangulation. Quantitative data were analyzed using descriptive and inferential statistics, with an independent t-test, while qualitative data were interpreted through thematic analysis. The findings revealed that students were actively engaged and had positive attitudes towards hands-on chemistry practical work. Additionally, there was a highly significant difference between pre- and post-test results after the intervention ($p > 0.001$).

Furthermore, Ogbeba and Ajayi (2018) conducted a study examining the impact of hands-on activities on the skills acquisition of senior secondary chemistry students in physical chemistry. A sample of 154 students was selected from four purposively chosen secondary schools, out of a total population of 1,643 SS II students in Otukpo Local Government Area, Benue State, Nigeria. In this study, the experimental group received instruction in physical chemistry through hands-on activities, while the control group was taught using the discussion method. The study was guided by two research questions and two hypotheses. Data collection was carried out using a validated 25-item Physical Chemistry Skills Acquisition Test (PCSAT), which had a reliability coefficient of 0.83, as measured by Kuder-Richardson (KR-21). Mean and standard

deviation scores were used to analyse the research questions, while Analysis of Covariance (ANCOVA) was employed to test the hypotheses. The results indicated that students taught using hands-on activities achieved significantly higher mean scores in skills acquisition compared to those taught through the discussion method ($F=191.004$, $P<0.05$).

2.10 Effect of Hands-on Activities on the Acquisition 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 activities. 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 Mushani (2021), 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, teachers should opt for curricula that emphasise the development of scientific process skills. Western societies, with their advanced educational systems, have long recognised 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 (Gizaw & Sota, 2023.)

In the contemporary era marked by rapid technological advancement and easy access to information, students should prioritise 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) emphasises 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 (Qablan et al., 2024).

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 Jirout et al. (2018), 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. Kasi et al. (2020) found that the focus of professional development on content knowledge is directly linked to teachers' increased knowledge and skill.

2.11 Perceptions of Students on the use of Hands-on Instructional Approach

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 (Lin, 2023). 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 (Martinez & Huang, 2020). 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 (Martinez & Huang, 2020). 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 (Morris, 2021). According to Lee and Thompson (2019), hands-on instructional approach 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 (Lee & Thompson, 2019). It has been suggested that using hands-on activities 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 (Johnson & Perez, 2020). 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 (Johnson & Perez, 2020). 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 (Shana & Abulibdeh, 2020).

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 (Papilaya et al., 2023). 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.

2.12 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 (Siddiek & Alfaki, 2013). It constitutes the fundamental building block for acquiring both content and skill knowledge. Various authors, such as Wade and Kidd (2019) 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 (Brandt, 2020). Cognitive researchers assert that learners actively construct knowledge, and their existing knowledge significantly influences their ability to acquire new information (Shah, 2019). 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 (Mupa & Chinooneka, 2015). 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 (Ferrero et al., 2020). 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.

2.13 Challenges of Hands-on Instructional Methods

Hands-on instructional methods often demand specific resources and equipment, a potential challenge in educational settings (Richardson & Wang, 2020). This becomes particularly pronounced in schools with constrained budgets or remote locations where access to specialized materials is limited. Moreover, the implementation of hands-on activities can be difficult, demanding careful preparation and setup (Nguyen & Matsuda, 2019). Educators often struggle with time constraints within the curriculum, striving to seamlessly integrate these activities while covering a diverse content area. Safety concerns further makes the challenges associated with hands-on approaches worse (Patel & Kumar, 2021). Given that such activities may involve handling hazardous materials or procedures, ensuring student safety becomes paramount. This task can be particularly challenging in large classes where supervision may be limited. A critical factor in the successful execution of hands-on instructional methods is the proficiency and training of educators (Smith & Chen, 2020). Unfortunately, not all

teachers are well-versed in inquiry-based pedagogies or possess expertise in the relevant subject matter, potentially impeding the effectiveness of hands-on activities.

Although designed to enhance engagement and motivation, hands-on activities may not universally achieve this goal (Bybee, 2015). Some students may find such tasks difficult or fail to perceive their relevance to the curriculum, leading to disengagement and decrease in motivation. Assessment poses another problem, as traditional evaluation methods may not adequately capture the skills and knowledge acquired through experiential learning (Dochy et al., 2015). Consequently, educators may need to explore alternative assessment strategies to accurately gauge student performance. Accessibility remains a crucial consideration, particularly for students with disabilities or limited movement (Dochy et al., 2015). Educators must ensure that instructional materials and activities are inclusive, possibly helping all sorts of students in the science classroom. The integration of hands-on activities with established curriculum standards can prove challenging (Patel & Kumar, 2021). The perceived difference between hands-on approaches and standardized testing requirements may put pressure on educators to prioritize content coverage over experiential learning opportunities. Logistical constraints, such as space constraints and equipment availability, further worsen the challenges of coordinating hands-on activities, especially in large classes (Richardson & Wang, 2020). Effective planning and organization are important to prevent these challenges successfully during the hands-on instructional lessons. Sustaining hands-on instructional methods over time presents difficulties (Nguyen & Matsuda, 2019). Educators must ensure that these activities remain effective in achieving learning objectives within evolving curriculum requirements and resource constraints (Nevenglosky, 2018).

The teaching and learning processes of a particular school are significantly influenced by its environment. The internal and external conditions are referred to as this environment. Classes and all other learning-supporting structures are part of the internal conditions (Arroyo et al., 2023). Students are unable to focus in class in insecure environments. This situation can be observed in a place where there is livestock rustling, when students were mentally impacted by army trucks and helicopters monitoring the area. The region's climate can have an impact on how a subject is taught and learned. Due to the temperature, instruction in dry and semi-arid regions ceases at midday (Ahmed & Kibet, 2020). Teachers are responsible for creating learning environments for their students through school-wide symposiums, Kiswahili clubs, and remedial instruction (Mwangi & Kamau, 2019). Lee (2021) claims that by creating a conducive learning environment at home, parents can significantly influence their children's academic achievement. According to Asare (2020), parent's social position and educational attainment have some bearing on student's academic performance.

2.14 The Role of Teachers in Implementing Hands-On Activities in The Science Classroom

Hands-on activities in science education have long been recognised as important in enhancing students' understanding, engagement, and motivation (Iyamuremye et al., 2023). The role of teachers in implementing these activities is vital, as they are the facilitators who bridge theoretical knowledge with practical application. This essay delves into the multifaceted role of teachers in integrating hands-on activities within science classrooms, highlighting their impact on student learning outcomes and the challenges faced in this pedagogical approach. Teachers serve as the primary agents in translating curriculum into actionable learning experiences. Their ability to design and execute hands-on activities directly influences students' comprehension of scientific

concepts. For instance, Ekwueme et al., (2015) demonstrated that students exposed to hands-on approaches in basic science and mathematics exhibited improved academic performance compared to those taught through traditional methods. Moreover, the integration of storytelling with hands-on activities has been shown to enhance learning outcomes. Walan (2019) explored this combination and found that it not only made science lessons more engaging but also facilitated a deeper understanding of scientific principles among young learners. Teachers, by weaving narratives into practical activities, can contextualize scientific concepts, making them more relatable and memorable for students.

The motivational aspect of hands-on learning cannot be overstated. Bulunuz (2012) investigated the motivational qualities of hands-on science activities among Turkish preservice kindergarten teachers and found that such activities were perceived as fun, interesting, and conducive to learning. This perception is crucial, as motivated teachers are more likely to implement engaging activities, thereby fostering a positive learning environment. Furthermore, Yilmaz, Bekirler, and Sigirtmac (2024) emphasized that hands-on activities significantly boost children's motivation towards science, suggesting that early exposure to such methods can cultivate long-term interest in the subject. In the context of Ghanaian education, practical activities are integral to science teaching. A study by Asabere-Ameyaw and Sefa-Nyarko (2004) highlighted that Ghanaian science teachers view practical work as essential for elucidating theoretical concepts, thereby aiding students' understanding. However, the study also noted that despite this recognition, the implementation of practical activities is often limited due to various challenges.

Teachers' perceptions and attitudes towards hands-on activities significantly influence their implementation. Musharrat (2020) found that while teachers acknowledge the benefits of hands-on learning, factors such as heavy workloads, lack of resources, and insufficient training hinder their ability to effectively conduct such activities. This indicates a need for systemic support to empower teachers in overcoming these barriers. Active learning strategies, which encompass hands-on activities, have been shown to improve academic performance and reduce failure rates in STEM subjects. Freeman et al. (2014) conducted a meta-analysis revealing that students in active learning environments scored higher and were less likely to fail compared to those in traditional lecture settings. This evidence reinforces the importance of teachers adopting hands-on methods to enhance student outcomes.

However, implementing hands-on activities is not without challenges. Resource limitations, such as inadequate materials and facilities, pose significant obstacles. The INDC Network (2023) discusses how teachers can mitigate these issues through seeking grants, forming community partnerships, and engaging in professional development to acquire the necessary skills for effective hands-on instruction. Assessment of hands-on activities also presents difficulties. Traditional testing methods may not accurately capture the depth of understanding gained through experiential learning. Alternative assessment strategies, such as performance-based evaluations and reflective journals, are recommended to better assess students' grasp of scientific concepts (INDC Network, 2023). Teachers play an indispensable role in the successful implementation of hands-on activities in science education. Their ability to design, facilitate, and assess these activities directly impacts student engagement, motivation, and comprehension (Johnson, 2017). While challenges exist, such as resource constraints and assessment complexities, with adequate support and training, teachers

can overcome these hurdles. Teachers can foster a more interactive and effective science learning environment, ultimately leading to improved educational outcomes by embracing hands-on methods.



CHAPTER THREE

METHODOLOGY

3.0 Overview

Chapter three provides a detailed methodology employed in this study. It outlines the study's design, population, sample and sampling procedure. Additionally, the chapter delves into the research instruments used, validity and reliability of the instruments. Detailed descriptions of the data collection procedures and methods of analysis are also provided, to offer insights into how the research data were gathered and processed. The ethics of the study was also considered.

3.1 Research Design

For this study, action research design was adopted to provide a comprehensive understanding of the implementation and impact of hands-on activities in teaching the concept of acids, bases, and salts at Kaneshie Senior High Technical School. Action research is the activity of examining a school environment in order to grasp and improve the effectiveness of the educational process (Lufungulo et al., 2021). This design was chosen for the study because of its holistic and in-depth investigative approach; specifically designed to understand the use of hands-on activities in the teaching and learning of acids, bases and salts. In parallel, the action research component of the study empowers the researcher to develop targeted intervention to solve a particular classroom situation and improving the academic performance of students as well as enhancing their science process skills and perceptions in science.

3.2 Population of the Study

A population refers to the entire group under investigation in a study (Willie, 2023). The total population of school comprised 1,844 consisting of male and female students.

The target population comprised of all form 2 students of Kaneshie Senior High Technical School while the accessible population comprised all Form 2 General Arts students of Kaneshie Senior High Technical School. There were 120 form 2 General Arts students during the period of the study.

3.3 Sample and Sampling Technique

Purposive sampling technique was employed to select an intact class of 50 students from form 2 General Arts 2 class. In this case, the researcher intentionally chose an intact class of 50 students from Kaneshie Senior High Technical School who were enrolled in General Arts classes because the researcher taught that class and possesses certain characteristics that are of interest to the researcher. The 50 students therefore represented the sample size of the study. The use of purposive sampling ensured that a homogeneous group of students who were all studying the same curriculum and receiving the same instructional interventions was obtained. This homogeneity minimises the potential for confounding variables and enhances the internal validity of the study.

3.4 Research Instruments

For the first objective which aimed to determine students' difficulties in acids, bases and salts, a test was used as an instrument to measure this objective. The test consisted of 4 essay-type questions on acids, bases and salts. The questions were therefore set across these process skills; measuring, observation, manipulation and recording.

For the second objective, which aims to determine the effect of hands-on activities on the student's performance in acids, bases and salts, a test was used as one of the instruments to gather data. The test assessed the students' performance of the concept of acids, bases, and salts before and after the implementation of hands-on activities.

This allowed for the measurement of any changes in academic performance resulting from the use of hands-on activities. In this objective, both the pre-test and post-test were used to gather the data.

For the third objective, which focused on assessing the effect of hands-on activities on students' science process skills, a test was used. Both the pre-test and the post test questions were set across the selected science process skills. The test compared the number of students who answered questions on the selected science process skills in both the pre-test and the post-test.

Finally, for the last objective, which aimed to investigate the perceptions of students on the use of hands-on activities in teaching acids, bases and salts, a questionnaire was. The quantitative data using the questionnaire was collected from the 50 students in 2 General Arts 2 class. The questionnaire comprised of 3-point Likert scale which were Agree, Neutral and Disagree on the perceptions of students on the use of hands-on activities.

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. To ensure the validity of both the test, and the questionnaire, verifying their alignment with the identified research problem and consistency with the study's focus, all items across the instruments underwent comprehensive review by the researchers' supervisor, Head of the Science Department and other science teachers at Kaneshie Senior High Technical School. Additionally, the items were closely examined for coherence, clarity, and absence of ambiguity to facilitate students' comprehension of the desired responses.

3.6 Reliability of the Instruments

Reliability, on the other hand, refers to the consistency and stability of measurement over time and across different conditions (Sürücü & Maslakci, 2020). To establish the reliability of the test and the questionnaire, test-retest reliability was evaluated by administering the test on two separate occasions to the participants. The test-retest value of 0.80 was obtained when the scores were compared.

3.7 Data Collection Procedure

The data collection procedures of this study took three stages: pre-intervention, intervention and post-intervention activities. The stages are described below;

3.7.1 Pre-Intervention Activities

In the preliminary phase before the intervention, the researcher conducted a pre-intervention test to evaluate students' difficulties in acids, bases and salts. The pre-intervention test was also conducted to determine the performance of students as well as science process skills in acids, bases and salts.

3.7.2 Intervention Activities

During the intervention phase, various activities were implemented to teach the concept of acids and bases to Form 2 General Arts 2 students at Kaneshie Senior High Technical School. The intervention included a well-structured lesson plan that incorporated various hands-on activities to engage students actively and enhance their performance, science process skills and perceptions of the topic. The intervention was implemented within four weeks.

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:

- The lesson began by discussing the properties of acids, bases, and salts.
- The pH scale was explained and its significance.
- Examples of common household acids, bases, and salts were shown in class
- The researcher demonstrated how to prepare red cabbage indicator solution.
- There was a discussion of how the indicator changes colour in the presence of acids and bases.
- Students were divided into groups.

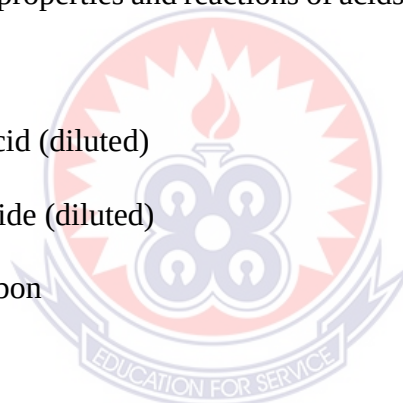
- Test tubes were provided and various substances such as lemon juice, vinegar, baking soda, ammonia, and water.
- Students were asked to use droppers to place small amounts of each substance into separate test tubes.
- Few drops of red cabbage indicator were added to each test tube and observed the colour changes.
- Students were guided 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:

- The researcher discussed with students the reaction of acids with metals.
- Students were provided with small pieces of magnesium ribbon and zinc granules.
- Students were asked to place each metal in separate test tubes containing diluted hydrochloric acid.
- The reactions were observed and results discussed.

- Universal indicator solution was introduced
- The researcher demonstrated how universal indicator changes colour in the presence of acids and bases.
- Students were asked to perform tests using universal indicator and various bases like sodium hydroxide.

Week 3: Neutralisation Reactions and pH Scale

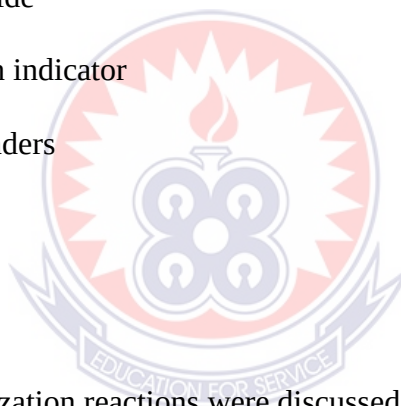
Objective: Understand neutralization reactions and the concept of pH.

Materials Needed:

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

Activities:

- Neutralization reactions were discussed and their importance.
- A demonstration of neutralisation reaction was done using hydrochloric acid and sodium hydroxide.
- Phenolphthalein indicator was used to observe the endpoint of the reaction.
- The pH scale was introduced and its significance.
- pH testing of various substances was performed using pH paper.
- Students were made to categorise 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:

- The formation of soluble salts was discussed through the reaction between acids and bases.
- Experiments were performed to prepare soluble salts such as sodium chloride and potassium nitrate.
- The formation of insoluble salts was discussed through precipitation reactions.
- Experiments were performed to prepare insoluble salts like calcium carbonate.
- The characteristics of insoluble salts were observed and discussed by the participants.

3.7.3 Post-Intervention Activities

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

3.8 Data Analyses

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, mean and standard deviation. T-test was also used to determine the significant difference in the performance of students before and after the use of hands-on activities in teaching science concepts. Also, bar chart was used to compare the pre-test and post-test scores of the students. The data on students' science process skills was analysed using SPSS Version 27 into frequency tables and means. T-test analysis was also used to determine the significant difference in the acquisition of science process skills of students before and after the intervention. The questionnaire data was analysed using SPSS Version 27 into frequency distribution tables and percentages.

3.9 Ethical Consideration

The researcher met the participants (2 General Arts 2 students) and discussed the purpose of the research, the expected time for the study and the procedure for the research activities. 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 DISCUSSIONS

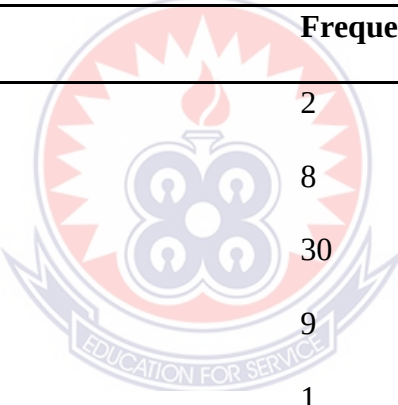
4.0 Overview

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 Demographic Data of Students

This section presents the age and sex distribution of students. The results are presented in Tables 1 and 2.

Table 1: Age Distribution of students



Age Range	Frequency
13-14	2
15-16	8
17-18	30
19-20	9
21-22	1
Total	50

Source: Field data, 2024

Table 1 represents the age distribution of a group of 50 students, illustrating a range of ages from 13 to 22 years. The majority of students, totaling 30, fall within the 17-18 age range, indicating that this is the most common age bracket in the group. A smaller number of students, eight in total, are in the 15-16 age range, while nine students are slightly older, within the 19-20 range. The youngest group, aged 13-14, includes only two students. Also, one student falls within the oldest age range of 21-22.

Presentation of the Results by Research Questions

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

4.2 Research Question 1: What are the difficulties that students encounter during lessons on acids, bases and salts at Kaneshie Senior High Technical School?

This section presents the difficulties that students encountered in acids, bases and salts during the pre-test and the number of students who encountered those difficulties. The result is presented in Table 2.

Table 2: 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)	45	90.0
Grasping the concept of pH and classifying substances based on pH	40	80.0
Describing the process of neutralization and balancing chemical equations	35	70.0
Explaining how blood functions as a buffer in the human body	45	90.0

From Table 2, 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. 45 out of 50 students representing 90%, 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 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.

Understanding the concept of pH and classifying substances based on their pH values also posed a significant challenge, with 80% of students (40 out of 50) struggling with 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 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 70% of students (35 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,

" $HCl + NaOH \rightarrow NaCl + H_2O_2$," 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 that 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 Kaneshie Senior High Technical School encounter significant difficulties during lessons in acids, bases and salts.

These findings are in line with the study by Ozmen (2019) who found out that the struggles students go through in these concepts arise from various factors, such as the abstract nature of the subject, misconceptions, and ineffective teaching methods. These difficulties can significantly hinder students' overall performance in chemistry and their ability to tackle more advanced topics (Garnett & Treagust, 2019). The findings are

also in line with the study by Schmidt and Volke (2020) who found that students often confuse the properties of acids and bases, especially in the context of chemical reactions. However, Sari (2020) conducted a study and found out that although the pH scale seems straightforward, its logarithmic structure often confuses, making it difficult for students to accurately assess the acidity or basicity of solutions in both theoretical and practical contexts. The study of Sari also agrees with that of Cox and Sevan (2021) who found out that another area of misunderstanding is the dissociation of acids and bases in water, especially when dealing with weak acids and bases. Students frequently misunderstand this process, failing to recognise the equilibrium involved with weak acids and bases in solution. Another study shows that even when students can perform equilibrium-related calculations, they often do not fully comprehend the underlying chemical principles, leading to superficial learning without deep understanding (Treagust, 2020).

The misconceptions highlighted in the literature align closely with the difficulties students encountered in understanding key concepts of acids, bases, and salts, as shown in the table. Taber (2019) emphasised that misconceptions in chemistry often persist even after formal instruction, which is evident in the majority of students struggling to understand the different definitions of acids and bases (Arrhenius, Bronsted-Lowry, Lewis). This is likely due to the complexity and abstract nature of these definitions, which require students to shift between different theoretical frameworks. The same cognitive barriers discussed by Taber (2020), where students enter the classroom with preconceived notions, may explain why they struggle with grasping these varying concepts of acids and bases. Similarly, the findings of the study also corroborate the work of Levy-Nahum (2019) who highlighted that students often oversimplify the role of bases, seeing them merely as opposites of acids without understanding their broader

functions. This simplification might explain the significant number of students who had difficulty describing the process of neutralization and balancing chemical equations. Students may not fully grasp the underlying chemical reactions or appreciate that acids and bases interact in a more complex manner, leading to challenges in chemical equation balancing.

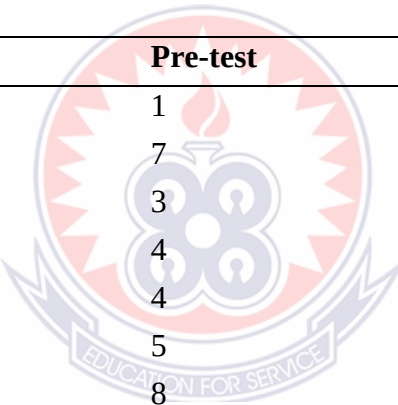
The findings of Levy-Nahum also agree with that of Mclain (2020) who also addressed the common misconception that strong acids and bases are always highly reactive, which relates to the majority of students who struggled with understanding pH and classifying substances based on it. Students might focus too narrowly on the perceived strength of an acid or base, without understanding that concentration and reaction conditions influence reactivity, making pH classification more difficult. The misconception about the role of salts in chemical reactions, as noted by Niaz and Robinson (2020), can also shed light on students' difficulty with understanding how blood functions as a buffer in the human body, a challenge encountered by many students. Furthermore, the findings are also in line with Osborne and Dillon (2020) who explained how students' daily experiences with household products labeled as acidic or basic can reinforce simplified ideas about acids and bases, which could contribute to the broad difficulty students face with these concepts. As Sweller (2021) noted in cognitive load theory, the complexity of chemical concepts like pH, buffering, and acid-base definitions can overwhelm students, leading to shallow learning outcomes, as seen in the high percentages of difficulty reported in these areas. The findings also agree with the study by Bennett (2020) and Azevedo (2019) who found out that students who struggle with these foundational concepts may view chemistry as overly challenging or irrelevant, which could explain why such a large proportion finds

it difficult to engage with critical topics like blood functioning as a buffer or balancing chemical equations.

4.3 Research Question 2: What is the effect of hands-on activities on students' academic performance in acids, bases and salts at Kaneshie Senior High Technical School?

This section presents the raw scores of students' pre-intervention test as well as the post-intervention test. The results of the pre-intervention test and post-intervention test scores of students, 001-050 are presented in Table 3.

Table 3: Frequency Distribution of the Means of Students' Pre-test and Post-test Scores



Student Number	Pre-test	Post-test
001	1	9
002	7	8
003	3	8
004	4	8
005	4	9
006	5	7
007	8	8
008	6	9
009	3	8
010	3	8
011	2	7
012	2	7
013	7	7
014	3	7
015	6	8
016	1	9
017	3	7
018	2	8
019	6	9
020	3	9
021	2	8

022	1	8
023	2	9
024	6	8
025	4	9
026	5	8
027	4	9
028	5	8
029	2	10
030	5	9
031	1	8
032	4	9
033	2	8
034	6	8
035	4	9
036	8	9
037	5	8
038	4	9
039	2	8
040	5	9
041	7	9
042	3	9
043	5	7
044	1	8
045	2	10
046	3	8
047	6	9
048	3	9
049	3	9
050	3	9
Mean	3.84	8.36

Source: Field Data, 2024

From Table 3, the data illustrates the effect of hands-on activities on students' academic performance in acids, bases, and salts, comparing pre-test and post-test scores for 50 students. Prior to the intervention, students' performance in the pre-test displayed relatively low scores, with a mean of 3.84. This suggests that, on average, students had

limited understanding or familiarity with the concepts of acids, bases, and salts before the implementation of hands-on activities. The pre-test scores show that the majority of students scored between 1 and 5, indicating weak performance. Specifically, five students scored 1, eight students scored 2, and eight students also scored 3. Collectively, 42% of the students scored 3 or below. This reflects a significant gap in students' initial knowledge or difficulty about the topic. This therefore emphasises the need for hands-on activities to enhance understanding of the concepts.

In contrast, the post-test results showed a remarkable improvement in students' scores. The mean score increased to 8.36. this highlights a substantial gain in academic performance after the hands-on activities were implemented. A significant portion of students, 84%, scored between 7 and 9 in the post-test, with a notable number of students scoring at the higher end, particularly 8 or 9. This indicates that the hands-on activities positively influenced the students' grasp of the concepts, allowing them to better understand acids, bases, and salts through practical, experiential learning. In terms of individual student progress, many who scored in the lower ranges during the pre-test improved substantially in the post-test. For example, students who had pre-test scores as low as 1 improved to scores of 8 or 9. The increase in scores reflects the effectiveness of using hands-on activities to engage students actively and provide them with tangible experiences that foster learning. The data therefore shows that no student scored above 8 in the pre-test, but several students achieved scores of 9 and even 10 in the post-test. The increase in students' performance shows that the use of hands-on activities is effective in the chemistry classroom. The increase in the mean score from 3.84 to 8.36 represents a strong indication that hands-on activities play an important role in improving students' performance in acids, bases, and salts.

The mean and the standard deviation of the pre-intervention test and the post-intervention test were analysed and presented in Table 3.

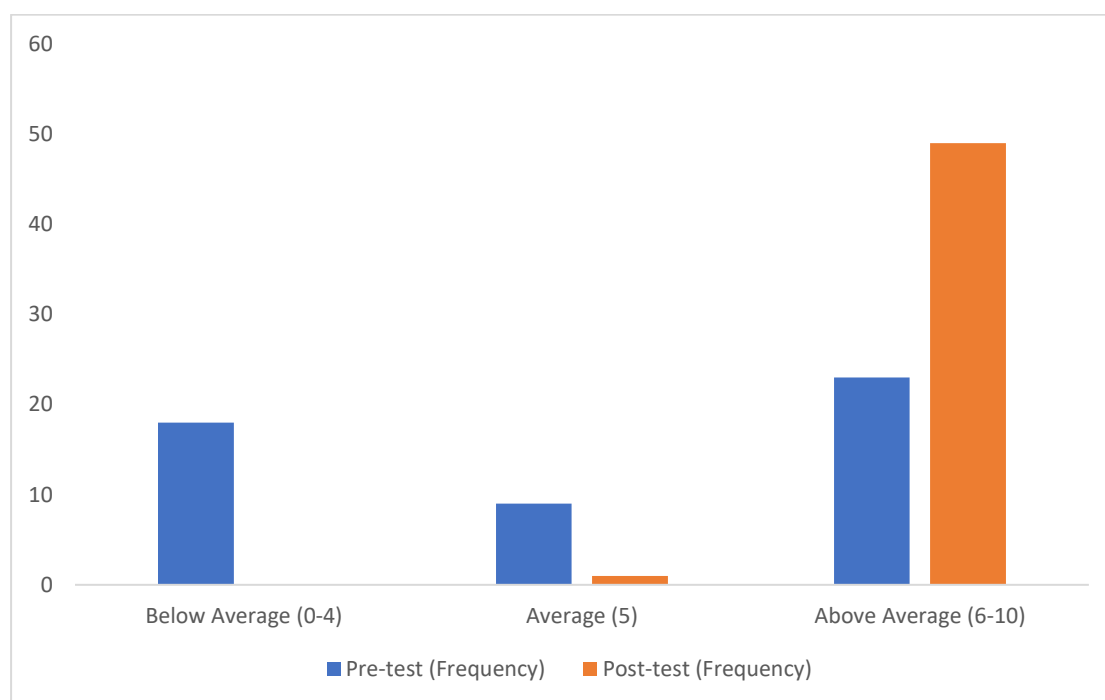


Figure 2: Bar Charts Distribution of Students' Pre-test and Post-test Scores

Source: Field Data, 2024

Figure 2 illustrates the frequency distribution of students' performance in both pre-test and post-test scores across three categories: Below Average (0-4), Average (5), and Above Average (6-10). In the pre-test phase, a substantial portion of students fell into the Below Average range, indicating lower initial performance levels. The Average category had a smaller number of students, while the Above Average category showed moderate frequency. However, a significant improvement was observed in the post-test results. The frequency of students in the Below Average and Average categories decreased considerably, while the Above Average category saw a substantial increase in frequency. This suggests an improvement in student performance from the pre-test to the post-test and this was as a result of the hands-on activities.

Table 4: Mean and Standard Deviation of Pre-Intervention test and Post-Intervention test Scores of Students

Group	Test	N	Mean	SD	Mean Difference
Intact Class	Pre-Intervention test	50	3.84	1.92	
	Post-Intervention test	50	8.36	0.78	4.52

Source: Field Data, 2024

N=Number of Students, SD= Standard Deviation

The results presented in Table 4 indicate that the average score on the pre-intervention test was 3.84. This reflects the students' performance before the introduction of hands-on activities. A standard deviation of 1.92 for the pre-intervention test demonstrates the degree of variation in the scores, with a larger standard deviation suggesting a broader range of results and greater variability in students' performance. After the implementation of hands-on activities, the mean score increased to 8.36, showing a marked improvement in students' performance. The standard deviation also decreased to 0.78, which is lower than the standard deviation of the pre-intervention which is 1.92. This indicates that the scores were more tightly grouped around the mean, with less variation among students' results. This reduction in variability suggests a higher consistency in students' performance following the introduction of hands-on activities in teaching acids, bases and salts. The notable mean difference of 4.52 indicates hands-on activities had a positive impact on the academic achievement of senior high school students in acids, bases and salts. The results therefore demonstrate a significant improvement in students' performance from the pre- to the post-intervention test,

suggesting that hands-on activities positively influenced students' performance in the concept.

4.3.1 Testing null hypothesis

H₀₁: There is no statistically significant difference in the performance of students before and after the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior Technical School.

Comparative sample t-test was used to test null hypothesis 1 using data of test scores of senior high school students in pre-intervention test and the post-intervention test. The result of the analysis is presented in Table 5.

Table 5: Summary of T-test Analysis of Pre-intervention test and post-intervention test Scores of Students

Group	Test	N	Mean	SD	p-value	Remarks
Intact Class	Pre-intervention test	50	3.84	1.92	2.88E-20	Significant
	Post-intervention test	50	8.36	0.78		

Source: Field Data

N=Number of Students, SD=Standard Deviation, Significant at $p < 0.05$, Not Significant at $p > 0.05$ level of significance.

Table 5 shows a p-value of 2.88E-20 and since this value is less than the chosen significance level (alpha value) of 0.05, the null hypothesis is rejected. This suggests that there is a statistically significant difference in the performance of students before

and after the use of hands-on activities teaching acids, bases and salts at Kaneshie Senior Technical School. The mean performance of the students shows clearly that the difference was in favour of the post-intervention tests. These results indicated that the use of hands-on activities improved the academic performance of the students in the concepts of acids, bases and salts. These findings confirm the effectiveness of hands-on activities in improving senior high school students' academic performance in science concepts.

These findings are in line with the study by Shah and Rahat (2014) who reported that performance of their 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 in science concepts. The findings also corroborate that of Anwer (2019) who opined that the use of hands-on activities of teaching could improve students' creativity in problem-solving, promote students' independence and help low-ability students to overcome initial handicaps, thereby enhancing their overall learning outcomes. Moreover, a study was conducted by Kırılmazkaya and Dal (2022) on the effect of hands-on activities on student's academic achievement and scientific attitude. The results of their study indicated that the hands-on activities performed with simple tools were effective in student performance in the classroom. Another study was conducted by Ekwueme et al. (2015) on the effectiveness of hands-on activities on the academic performance of students in science and mathematics and the findings indicated a positive enhancement in both students' performance and engagement in mathematics and basic science activities.

Furthermore, the current study findings are in agreement with the study by Nweke et al. (2022) who conducted a study on the impact of the Hands-on Activity Learning Strategy (HALS) on students' achievement and interest and found that there was a significant difference in both achievement and interest levels between students taught using HALS and those taught using the lecture method, with HALS proving more effectiveness in their performance. Students who engaged in hands-on activities were actively engaged and had positive attitudes toward hands-on chemistry practical work (Iyamuremye et al., 2023). These findings also agree with Ogbeba and Ajayi (2018) who conducted a study on the impact of hands-on activities on the skills acquisition of senior secondary chemistry students in physical chemistry and indicated that students taught using hands-on activities achieved significantly higher mean scores in the test. Chikuni (2013) also backed the use of hands-on activities of teaching and learning as it makes students active participant in science lessons and improve their performance.

4.4 Research Question 3: What is the effect of hands-on activities on students' science process skills in acids, bases and salts at Kaneshie Senior High Technical School?

This section presents the data on the effect of hands-on activities on science process skills of students in acids, bases and salts. These process skills are measuring, observation, manipulation and recording. The results are presented in Table 6.

Table 6: Frequency Distribution of Process Skills Results of Students' Pre-Test and Post-test

Process skills	Pre-intervention test	Post-intervention test 2
Measuring	10	43
Observation	15	47
Manipulation	14	48
Recording	12	45
Total	51	183
Mean	12.8	45.8

Source: Field Data, 2024

From Table 6, it was discovered that only 10 out of the 50 students exhibited measuring skills in the pre-intervention test. The number of students who answered questions on measuring skills increased from 13 to 43 in the post-intervention test. Moreover, only 15 students were able to answer questions on observation skill, but after the implementation of hands-on activities in teaching acids, bases and salts, the students exhibited heightened levels of observation skills which was reflected in the number of students increasing from 15 to 47 during the post-intervention test. This shows that the use of hands-on activities in teaching science concepts is an effective teaching strategy which helps in improving students' science process skills.

Initially, a total of 14 students demonstrated their proficiency in manipulation skills during the pre-intervention test. Subsequently, the number of students exhibiting this skill rose to 48 following the introduction of the post-intervention activities. This emphasises the notable impact of hands-on activities within the chemistry classroom. Also, 12 students were able to exhibit recording skills in the pre-intervention test. After the post-intervention test, there was increase in the number of students who possessed the recording skills and the numbers increased from 12 to 45. This shows that as the

interventions continued, students exhibited higher levels of science process skills in the lesson. However, the average number of students proficient in each skill increased from approximately 13 in the pre-intervention test to 46 in post-intervention test. Each skill saw substantial improvement from the pre-test to the post-test, with a consistent rise in the number of students. The progressive increase in the number of students exhibiting science process skills demonstrates the effectiveness of hands-on activities in improving students' science process skills.

4.4.1 Testing null hypothesis two

H₀₂: There is no statistically significant difference in the acquisition of science process skills before and after the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior Technical School.

A comparative sample t-test was used to test null hypothesis 2 using data of test scores of senior high school students in pre-intervention test and post-intervention test. The result of the analysis is presented in Table 7.

Table 7: Summary of t-test Analysis of Process Skills Results of Students

Group	Test	N	Mean	SD	p-value	Remarks
Process Skill	Pre-intervention test	4	12.75	2.22	4.17E-06	Significant
Process Skill	Post-intervention test	4	45.75	2.22		

Source: Field Data, 2024

N=Number of Process Skills, SD=Standard Deviation, Significant at $P < 0.05$, Not Significant at $p > 0.05$ level of significance

The data depicted in Table 7 indicated a p-value 4.17E-06. Given that this value falls below the significance value of 0.05, the null hypothesis is rejected. This shows a statistically significant difference in the acquisition of the science process skills before and after the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior Technical School. Analysis of the mean number of students exhibiting the various science process skills indicated a notable increase after the implementation of hands-on activities in the lesson. This implies that hands-on activities significantly contributed to the advancement of students' science process skills acquisition in acids, bases and salts.

These findings are in line with Puranik (2020) who highlighted that engaging in hands-on activities helps students to become more active participants in lessons, catering to their individual needs while fostering creativity, critical thinking, and innovation. It also agrees with the previous work of Sideri and Skoumios (2021) who highlighted that when scientific process skills are explicitly designated as a targeted outcome within a science program, students tend to understand them more effectively. Consequently, teachers should opt for curricula that emphasise the development of scientific process skills. 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 (Gultepe, 2016). The results align with the assertion by Johnson et al. (2014) that a curriculum focusing on science process skills over content in problem-solving is important. Before the intervention, students scored relatively low across all process skills. This suggests a lack of emphasis on process skills before the intervention, which is consistent with the notion that teachers may not always prioritise process skills in their instruction.

However, after the intervention, the total score dramatically increased, demonstrating that the intervention successfully enhanced students' abilities to engage with scientific processes. This improvement is in line with the argument by Jeanpierre et al. (2005) that integrating science content knowledge and process skills in teachers' professional development is essential. When teachers emphasise the development of these skills, students are better equipped to construct scientific concepts, explore their surroundings, and engage in meaningful problem-solving activities. Moreover, Jirout et al. (2018) highlighted the importance of teachers acquiring the knowledge to nurture curious and engaged students. The increase in the number of students who answered questions on the various science process skills reflects the effectiveness of hands-on activities for students in predictions, explore alternatives, and discuss various scientific perspectives.

The significant rise in students' scores across all process skills illustrates that students became more proficient in critical areas of scientific inquiry after the use of hands-on activities. Kasi et al. (2020) also emphasised the direct link between professional development focusing on content knowledge and the enhancement of teachers' knowledge and skills. The considerable improvements in students' science process skills suggest that the intervention likely included professional development efforts that equipped teachers with the tools and knowledge needed to foster these skills in their students. Thus, the findings of this study support the notion that when teachers are well-versed in both content knowledge and process skills, their students benefit from a more holistic and effective science education.

4.5 Research Question 4: What are the perceptions of students on the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior High Technical School?

This section presents data on students' perceptions on the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior High Technical School. The results are summarised in Table 8.

Table 8: Frequency Distribution of Students' perception of Hands-on Activities of teaching in the Science classroom

No	Item	Agree (%)	Neutral (%)	Disagree (%)
1	Hands-on activities are time consuming	10(20)	15(30)	25(50)
2	Hands-on activities approach makes lessons difficult	6(12)	12(24)	32(64)
3	Hands-on activities make lessons boring	8(16)	11(22)	31(62)
4	Hands-on activities enhance my participation	35(70)	9(18)	6(12)
5	Hands-on activities enhance my understanding in science concepts.	27(54)	17(34)	6(12)
6	Hands-on activities enhance my attitude toward science concepts.	28(56)	15(30)	7(14)
7	Hands-on activities enhance my retention of science concepts	24(48)	18(36)	8(16)
8	Hands-on activities increase my interest in science	31(62)	12(24)	7(14)
9	Hands-on activities improve science process skills	34(68)	12(24)	4(8)

Source: Field Data, 2024

Table 8 indicates students' perceptions of hands-on activities. From the table, ten students representing 10%, fifteen students representing 30% and twenty-five students

representing 50% agree, are neutral and disagree respectively that hands-on activities are time consuming. Six students representing 12%, twelve students representing 24%, thirty-two students representing 64% disagree that hands-on activities make science lessons difficult. Eight students representing 16% agree, eleven students representing 22% are neutral and thirty-one students representing 62% disagree that hands-on activities make lessons boring.

Thirty-five students representing 70% agree, nine students representing 18% are neutral and six students representing 12% disagree that hands-on activities enhance 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 activities enhance 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 activities enhance their retention. Thirty-one students representing 62%, twelve students representing 24% and seven students representing 14% agree, are neutral and disagree respectively that hands-on activities increase their interest 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 activities improve their science process skills. This implies that the use of hands-on activities is effective in enhancing students' perceptions of science concepts.

The findings suggest that while some students find hands-on activities challenging or time-consuming, a majority recognize their benefits in enhancing participation, understanding, interest, and skills development. These findings are in line with Martinez and Huang (2020) who emphasised the value of student feedback in

curriculum improvement, noting that student perspectives can enhance the quality of instruction and lead to better learning outcomes. These positive perceptions reflect how hands-on activities provide students with opportunities to engage more deeply with science concepts, reinforcing the learner-centered nature of the instructional approach (Lee & Thompson, 2019). This method allows students to explore, manipulate, and apply scientific concepts, thereby fostering both content knowledge and process skills. The findings also agree with Johnson and Perez (2020) who emphasise the importance of integrating both content knowledge and process skills in science education, a balance that hands-on activities help achieve. The table reflects that 68% of students agree that hands-on activities improve their science process skills. Papilaya et al. (2023) pointed out that the science process skills, such as measuring, observation, and hypothesis formation, are crucial for scientific problem-solving. This suggests that hands-on activities do not merely enhance understanding of abstract content but also cultivate procedural knowledge essential for conducting scientific research independently.

Furthermore, Shana and Abulibdeh (2020) argue that hands-on science helps students better comprehend complex scientific information by making abstract concepts more concrete. This is evident in the table, where a large proportion of students agree that hands-on activities enhance their understanding and retention of science concepts. Johnson and Perez (2020) also opined that when students interact with real-world examples, students can better observe and internalise scientific principles, which supports claim that hands-on activities improve comprehension of both content and process skills.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER STUDIES

5.0 Overview

This chapter presents the summary of the study, the conclusions, some recommendations and suggestions needed for further research work.

5.1 Summary of the Study

5.1.1 Difficulties Students encounter during lessons on acids, bases and salts at Kaneshie Senior High Technical School

The findings from the content analysis of pre-test responses revealed that students at Kaneshie Senior High Technical School faced conceptual difficulties in understanding acids, bases, and salts concepts. Many students struggled with differentiating between the Arrhenius, Bronsted-Lowry, and Lewis theories of acids and bases, often providing incorrect definitions. Difficulties also emerged in understanding the pH scale, with students not being able to classify substances based on their pH values. Additionally, there were significant difficulties of students regarding the process of neutralisation and the ability to balance chemical equations. Students also had a challenge involving understanding how blood functions as a buffer in the body. This was evident when students demonstrated confusion about the biological role and mechanisms of buffers.

5.1.2 Effect of hands-on activities on students' academic performance in acids, bases and salts at Kaneshie Senior High Technical School

The findings from the study revealed a significant improvement in students' performance after the introduction of hands-on activities in teaching acids, bases, and salts. Before the intervention, students showed a wider range of scores, mainly lower

scores with more variability, but after the hands-on activities, their scores became more consistent, with a marked increase in the average performance. The t-test analysis confirmed that this improvement was significant, indicating that hands-on activities had a positive effect on the students' performance of acids, bases and salts.

5.1.3 Effect of hands-on activities on students' science process skills in acids, bases and salts at Kaneshie Senior High Technical School

The findings indicated a significant improvement in students' science process skills after the implementation of hands-on activities in teaching acids, bases, and salts. Initially, few number of students demonstrated skills in measuring, observing, manipulating, and recording during the pre-intervention test. However, after the hands-on activities, there were a significant number of students exhibiting these skills. Each skill saw substantial improvement, with the average number of students proficient in each area increasing significantly. The t-test analysis confirmed that the difference in skill acquisition was significant and demonstrated the effectiveness of hands-on activities in enhancing students' science process skills.

5.1.4 Perceptions of students on the use of hands-on activities in teaching acids, bases and salts at Kaneshie Senior High Technical School

The findings of the study also reveal that students generally had a positive perception of hands-on activities in science lessons. A majority disagreed that hands-on activities are time-consuming, difficult, or boring. These indicate that hands-on activities do not negatively impact their engagement. Most students agreed that hands-on activities enhance their participation, understanding, retention, and interest in science, while improving their science process skills too.

5.2 Conclusions

The study revealed that students encountered several conceptual difficulties in acids, bases and salts. However, the introduction of hands-on activities proved to be an effective strategy in enhancing both academic performance and science process skills. The enhancement of the science process skills not only reflected students' improved practical abilities but also indicated a deeper engagement with the scientific concepts. The t-test analysis further validated the effectiveness of hands-on activities in fostering the acquisition of these essential skills. Students' perceptions of hands-on activities were also overwhelmingly positive.

Thus, hands-on activities have been effective in enhancing the performance and science process skills acquisition as well as enhancing perceptions of senior high school students of Kaneshie Senior High Technical in acids, bases and salts. Therefore, the implementation of hands-on activities should be considered to enhance effective teaching experiences in the science classroom.

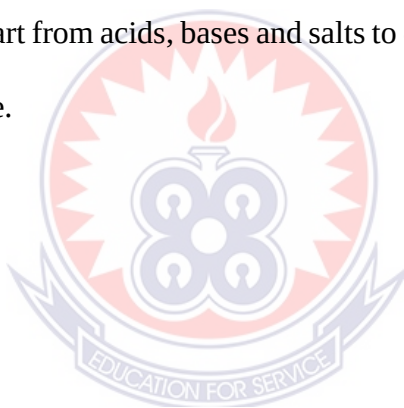
5.3 Recommendations

1. Science teachers in Kaneshie Senior High Technical School should use hands-on activities to identify students' difficulties and help improve the performance of students.
2. The school authorities in Kaneshie Senior High Technical School should provide enough teaching and learning materials to facilitate hands-on activities in order to enhance science process skills of students.
3. Science teachers should also make hands-on activities readily available in the teaching and learning of chemistry concepts in Kaneshie Senior High Technical School to enhance positive perceptions of students.

5.4 Suggestions for further Studies

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

1. This study should be structured in such a way to compare the effectiveness of hands-on activities and traditional lecture method of teaching in the science classroom.
2. The effect of hands-on activities on students of different age groups should be conducted to understand the effect of hands-on activities on developmental stages of students.
3. The effective of hands-on activities should be explored in other science concepts apart from acids, bases and salts to determine its effect on students' performance.



REFERENCES

- 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.
- Agboola, O. S., & Ojo, O. E. (2017). 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.
- Ahmed, S., & Kibet, P. (2020). The impact of regional climate on educational practices in semi-arid regions. *Journal of African Education Studies*, 14(2), 45-57. <https://doi.org/10.1007/s12564-020-09687-z>
- Aidoo, B., Magano, M. D., & Jorosi, B. N. (2021). Concept mapping as a teaching and learning strategy for enhancing conceptual understanding in science education. *International Journal of Instruction*, 14(4), 873-892.
- Akcay, B. (2017). Effectiveness of problem-based learning approach on students' achievements, concepts and scientific process skills in science education. *Journal of Educational Research*, 110(3), 324-336.
- Akcay, B. B., & Akcay, H. (2015). Effectiveness of science instruction based on the 5E teaching model to improve student understanding of earthquakes. *International Online Journal of Educational Sciences*, 7(3), 1-12.
- Akon-Yamga, G., Funkor, G., Tsey, K., Kingsford-Adaboh, R., Quaye, W., & Ntewusu, D. A. (2024). Perspectives from students and teachers about the challenges of teaching and learning STEM subjects in Ghana. In *Frontiers in Education* (Vol. 9, p. 1288413). Frontiers Media SA.

- 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?>
- Arroyo, Y. P. V., Penabaena-Niebles, R., & Correa, C. B. (2023). Influence of environmental conditions on students' learning processes: A systematic review. *Building and Environment*, 231. <https://doi.org/10.1016/j.buildenv.2023.110051>.
- Asabere-Ameyaw, A., & Sefa-Nyarko, C. (2004). Teachers' views on the role of science practical activities in the teaching of science in Ghanaian senior secondary schools. *African Journal of Educational Studies in Mathematics and Sciences*, 2(2).
- Asare, F. K. (2020). The influence of parental socioeconomic status on students' academic performance. *Journal of Educational Sociology*, 58(3), 215-228. <https://doi.org/10.1177/0022146520928794>.
- Ates, O., & Eryilmaz, A. (2011). Effectiveness of hands-on and minds-on activities on students' achievement and attitudes towards physics. *Asia-Pacific Forum on Science Learning and Teaching*, 12(1), 1-22.
- Azevedo, R. (2019). The impact of motivation on learning and engagement in science: Implications for teaching practices. *Educational Psychology Review*, 31(1), 55-70. <https://doi.org/10.1007/s10648-018-9450-z>.
- 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>.

- Bennett, J. (2020). Student attitudes and self-efficacy in chemistry: How they affect learning outcomes. *International Journal of Science Education*, 42(8), 1141-1156. <https://doi.org/10.1080/09500693.2020.1774973>
- Bennett, J., & Kennedy, D. (2011). Practical work at the upper high school level: The evaluation of a new model of assessment. *International Journal of Science Education*, 23, 97–110.
- Bhukuvhani, C., Mafukata, M. A., & Mhinga, R. W. (2021). Using practical work to enhance learners' understanding of science concepts in rural disadvantaged schools. *Eurasia Journal of Mathematics, Science and Technology Education*, 17(7), em1985. <https://doi.org/10.29333/ejmste/10999>
- 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.
- Bloom, B. S. (2014). Parental involvement and student success: A meta-analysis. *Educational Research Review*, 9(1), 1-15. <https://doi.org/10.1016/j.edurev.2014.03.001>
- Boakye, B. A. (2019). *Explaining education reforms in Ghana: an institutional and ideational perspective* (Doctoral dissertation, University of Saskatchewan).
- 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).
- Brandt, W. C. (2020). Measuring Student Success Skills: A Review of the Literature on Self-Directed Learning. 21st Century Success Skills. *National Center for the Improvement of Educational Assessment*.

- Bryers, E., Puga, J. B., & Halpern, D. F. (2022). Using practical work to develop scientific thinking skills. *Journal of Research in Science Teaching*, 59(2), 217-240.
- Bulunuz, M. (2012). Motivational qualities of hands-on science activities for Turkish preservice kindergarten teachers. *Eurasia Journal of Mathematics, Science and Technology Education*, 8(2), 73-82.
- Bybee, R. W. (2015). *The BSCS 5E instructional model: Creating teachable moments*. Arlington, VA: National Science Teachers Association Press.
- 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). The influence of family and socioeconomic factors on students' science achievement. *Educational Measurement: Issues and Practice*, 29(2), 29-42. <https://doi.org/10.1111/j.1745-3992.2010.00194.x>
- Cardino Jr, J. M., & Cruz, R. A. O. D. (2020). Understanding of learning styles and teaching strategies towards improving the teaching and learning of mathematics. *LUMAT: International Journal on Math, Science and Technology Education*, 8(1), 19-43. <https://doi.org/10.31129/LUMAT.8.1.1348>
- Castillo-Olivares, A., Chen, T. K., & Heaton, A. A. (2023). Use of Augmented Reality and Immersive Virtual Reality Activities in Education: Exploring Applications for Face-to-Face, At-Home and Hands-On Science Lab Classes.

Revista Curriculum, 36, 129-138. DOI: <https://doi.org/10.25145/j.curricul.2023.36.07>.

Chen, S., & Wang, L. (2020). Exploring the impact of inquiry-based learning on student engagement in science. *Journal of Science Education*, 28(3), 345-358. <https://doi.org/10.1007/s10956-020-09873-4>

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. (2013). *The teachers' handbook: A practical approach to teaching*. Gwanda, Flame Publishers.

Clark, J. C. (2013). *Practical activities: What science teaching can learn from primary classrooms?* A paper presented at the Annual Conference of NZARE/AARE, Auckland.

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>.

Cox, C., & Sevan, H. (2021). Students' misconceptions in understanding weak acid-base equilibrium. *Journal of Chemical Education*, 98(1), 148-157. <https://doi.org/10.1021/acs.jchemed.0c00811>.

- Cox, T. D., Ogle, B., & Campbell, L. O. (2019). Investigating Challenges and Preferred Instructional Strategies in STEM. *Journal of Postsecondary Education and Disability*, 32(1), 49-61.
- Creemers, B., & Kyriakides, L. (2008). *The dynamics of educational effectiveness: A contribution to policy, practice, and theory in contemporary schools*. London: Routledge.
- Creemers, B., & Kyriakides, L. (2015). Process-product research: A cornerstone in educational effectiveness research. *Journal of Classroom Interaction*, 50 (2), 107–119.
- Cretu, L., & Ho, K. (2023). Factors Influencing Student Success in Science Education: A Comprehensive Review. *Educational Research Review*, 15(3), 211-228.
- 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.
- DeBoer, G.E. (2000). Scientific literacy: another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of research in science teaching*, 37(6), 582-601.
- 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>.

- Dhull, P., & Verma, G. (2020). Use of concept mapping for teaching science. *The International journal of analytical and experimental modal analysis*, 12(3), 2481-2491.
- Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2015). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research*, 75(1), 27-61.
- Dolmans, D. H., Loyens, S. M., Marcq, H., & Gijbels, D. (2016). Deep and surface learning in problem-based learning: A review of the literature. *Advances in Health Sciences Education*, 21(5), 1087-1112.
- Eisner, E. W. (2010). The relationship between parental engagement and student academic outcomes. *Journal of Educational Psychology*, 102(2), 425-437. <https://doi.org/10.1037/a0019215>.
- Ejiwale, J. A. (2013). Barriers to successful implementation of STEM education. *Journal of Education and Learning (EduLearn)*, 7(2), 63-74.
- 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.
- 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., & Van Voorhis, F. L. (2011). Parental involvement and student success in science: Strategies for schools. *Journal of Educational Research*, 104(3), 197-210. <https://doi.org/10.1080/00220671.2010.500046>

- Fehrmann, P. G. (2017). The impact of parental involvement on student achievement. *Journal of Family and Consumer Sciences Education*, 35(2), 45-59.
<https://doi.org/10.1177/1059840517703512>.
- Fennema, E., & Sherman, J. A. (2006). Sex-related differences in mathematics achievement and related factors: A further study. *Journal of Research in Science Teaching*, 43(1), 10-30. <https://doi.org/10.1002/tea.20069>
- Fennema, E., & Sherman, J. A. (2008). Gender differences in mathematics and science education: Examining the evidence. *Science Education*, 92(1), 105-122.
<https://doi.org/10.1002/sce.20220>.
- Ferrero, M., Hardwicke, T. E., Konstantinidis, E., & Vadillo, M. A. (2020). The effectiveness of refutation texts to correct misconceptions among educators. *Journal of experimental psychology: applied*, 26(3), 411. DOI: 10.1037/xap0000258.
- Fluty, T. A. (2017). Socioeconomic status and its impact on student performance in science. *Journal of Education and Social Policy*, 7(1), 59-74.
<https://doi.org/10.17770/jesp.2017.1.01>.
- Garnett, P. J., & Treagust, D. F. (2019). Conceptual difficulties experienced by senior high school students of electrochemistry: Electric circuits and oxidation-reduction equations. *Journal of Research in Science Teaching*, 30(2), 121-132.
<https://doi.org/10.1002/tea.3660300204>
- Ghana Education Service. (2017). Science Education Unit. Retrieved from <https://ges.gov.gh/units/science-education/>
- Ghana News Agency. (2024). Government committed to advancing STEM education — Prez. Retrieved from <https://gna.org.gh/2024/05/government-committed-to-advancing-stem-education-prez/>.

- Gizaw, G., & Sota, S. (2023). Improving science process skills of students: A review of literature. *Science Education International*, 34(3), 216-224.
<https://doi.org/10.33828/sei.v34.i3.5>.
- 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.
- Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Routledge.
- Hennessy, S., Haßler, B., & Hofmann, R. (2016). Pedagogic change by Zambian primary school teachers paralleled by the mobile literacy intervention. *Research Papers in Education*, 31(4), 399-425.
- Hmelo-Silver, C. E., & Eberbach, C. (2012). Learning theories and problem-based learning. In S. Bridges, C. McGrath, & T. Whitehill (Eds.). *Researching problem-based learning in clinical education: The next generation* (pp. 3- 17). New York: Springer.
- HMI/Office for Standards in Education (2014a). *Science in primary schools*. London: Ofsted.

- HMI/Office for Standards in Education (2014b) (Ofsted). *Science in secondary schools*. London: Ofsted.
- Hofstein, A., & Mamlok-Naaman, R. (2022). Practical work in science education: Past, present and future. *Chemistry Education Research and Practice*, 23(1), 1-28.
- Hofstein, A., Navon, O., Kipnis, M., & Naaman, R. M. (2018). *Practical work and its contribution to inquiry-based learning in the chemistry classroom*. In *Exploring Inquiry-Based Instruction* (pp. 89-116). Brill Sense.
- Howe, C., & Abedin, M. (2021). Collaborative learning in science: A meta-analysis of outcomes and processes. *Journal of Learning Sciences*, 30(1), 66-85.
<https://doi.org/10.1080/10508406.2020.1857612>
- Hsbollah, H. M., & Hassan, H. (2022). Creating meaningful learning experiences with active, fun, and technology elements in the problem-based learning approach and its implications. *Malaysian Journal of Learning & Instruction*, 19(1), 147-181. <https://doi.org/10.32890/mjli2022.19.1.6>.
- Humphrey-Darkeh, A., Owusu-Sekyere, K., & Mensah, S. A. (2022). Investigating the Challenges Facing the Teaching and Learning of Science and Technology in Selected Schools in the Ashanti Region of Ghana. *Journal of Science Learning*, 5(3), 431-438. Retrieved from <https://files.eric.ed.gov/fulltext/EJ1368499.pdf>
- Hung, W., Eriksson, L. T., Lee, C. B., & Son, J. Y. (2019). Problem-based learning: An analytical review of its process and effects. *Educational Sciences*, 9(4), 304.
- Illeris, K. (2014). *Transformative learning and identity*. London: Routledge Oxford.

- Inan, H. (2010). An analysis of primary school teachers' subject matter knowledge concerning scientific concepts. *International Journal of Science Education*, 32(12), 1573-1588. <https://doi.org/10.1080/09500690903144957>.
- Inan, H. (2011). Investigating the effectiveness of process skills on elementary students' scientific understanding. *Science Education International*, 22(1), 23-34.
- Inan, H., Trundle, K. C., & Kantor, R. (2014). Understanding the interplay of content and process in early childhood science education. *Journal of Research in Science Teaching*, 51(5), 568-593. <https://doi.org/10.1002/tea.21148>.
- INDC Network. (2023). The importance of hands-on learning in science education: Engaging students for a deeper understanding. Retrieved from <https://indcnetwork.com/importance-hands-on-learning-science-education>
INDC Network on April, 18, 2025.
- Iyamuremye, A., Nsabayeze, E., Ngendabanga, C., & Hagenimana, F. (2023). Effectiveness of Hands-on Practical Activities in Teaching and Learning Chemistry: An Exploration of Students' Engagement, Experience, and Academic Performance. *African Journal of Educational Studies in Mathematics and Sciences*, 19(1), 97-107. <https://dx.doi.org/10.4314/ajesms.v19i1.7>.
- 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.
- Jirout, J. J., Vitiello, V. E., & Zumbunn, S. K. (2018). Curiosity in schools. *The new science of curiosity*, 1(1), 243-266.
- Johnson, D. (2017). The role of teachers in motivating students to learn. *BU Journal of Graduate studies in education*, 9(1), 46-49.
- Johnson, D. R., & Perez, L. A. (2020). Bridging theory and practice: The role of hands-on activities in science education. *International Journal of Science Education*, 42(7), 981-996. <https://doi.org/10.1080/09500693.2020.1762417>.
- Johnson, W. L., Johnson, A. M., & Johnson, J. W. (2014). *Strategies for Improving School Performance*. Conference Presentation: 2014 Curriculum Conference.
- Jones, R., & Reed, P. (2021). Inquiry-based learning: Enhancing critical thinking and problem-solving skills. *Educational Research Review*, 45, 101-112. <https://doi.org/10.1016/j.edurev.2021.100521>
- 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>.
- Karamustafaoğlu, S., Aydin, M., & Kajari, K. (2021). The effect of STEM education on students' scientific process skills and creativity. *Journal of Science Learning*, 4(3), 244-257.
- Kasi, Y. F., Widodo, A., Samsudin, A., & Riandi, R. (2020). Teacher professional development program to improving pedagogical content knowledge: a review of empirical research. In *International Conference on Mathematics and Science Education of Universitas Pendidikan Indonesia* (Vol. 5, pp. 20-26).

- 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.
- Kibga, E., Sentongo, J., & Gakuba, E. (2021). Effectiveness of hands-on activities to develop chemistry learners' curiosity in community secondary schools in Tanzania. *Journal of Turkish Science Education*, 18(4), 605. DOI no: 10.36681/tused.2021.93.
- Kim, H., Lee, J., & Park, S. (2019). The role of technology in supporting inquiry-based science education: A systematic review. *Journal of Educational Technology*, 15(2), 182-199. <https://doi.org/10.1016/j.edtech.2019.05.005>
- 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. (2016). 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.
- Klieme, E. (2013). The role of large-scale assessments in research on educational effectiveness and school development. In M. von Davier, E. Gonzalez, I. Kirsch, & K. Yamamoto (Eds.), *The role of international large-scale*

- assessments: Perspectives from technology, economy, and educational research* (pp. 115–148). Heidelberg: Springer.
- Kocakulah, M. S., & Savaş, E. (2011). An integrated preschool STEM curriculum. *Educational Research and Reviews*, 6(5), 441-450.
- Kyriakides, L., Christoforou, C., & Charalambous, C. Y. (2013). What matters for student learning outcomes: A meta-analysis of studies exploring factors of effective teaching. *Teaching and Teacher Education*, 36, 143–152.
- Lam, S. F., Yu, K., & Huang, X. (2022). Hands-on science education: Engagement, motivation, and learning outcomes. *Journal of Science Education*, 46(4), 321-337. <https://doi.org/10.1007/s10956-022-09951-2>
- 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.
- Lazarowitz, R., & Naim, R. (2013). Learning the cell structures with three-dimensional immersive virtual reality (TDIVR). *Prospects*, 43(4), 449-467.
- Lazonder, A. W., & Harmsen, R. (2020). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research*, 90(2), 459-490. <https://doi.org/10.3102/0034654320933547>.
- Lee, H. J. (2021). The role of parents in fostering a conducive home learning environment. *Journal of Educational Psychology*, 113(3), 441-454. <https://doi.org/10.1037/edu0000459>

- Lee, H. Y., Wu, T. T., Lin, C. J., Wang, W. S., & Huang, Y. M. (2024). Integrating Computational Thinking into Scaffolding Learning: An Innovative Approach to Enhance Science, Technology, Engineering, and Mathematics Hands-On Learning. *Journal of Educational Computing Research*, 62(2), 431-467. <https://doi.org/10.1177/07356331231211916>.
- Lee, S. H., & Thompson, R. J. (2019). The impact of hands-on learning on student engagement and skill development. *Educational Research Review*, 28, 56-71. <https://doi.org/10.1016/j.edurev.2019.03.001>.
- Levy-Nahum, T. (2019). Teaching chemical bonding in school chemistry: Challenges and potential strategies. *Science & Education*, 28(7), 777-791. <https://doi.org/10.1007/s11191-019-00111-3>
- Li, X., Cheng, Y., & Liu, H. (2013). Cognitive Engagement and Knowledge Construction in Education. *Educational Psychology Journal*, 20(3), 312-327.
- Lin, J. (2023). Sensory Inputs Guiding Cognitive Behaviors and Decision Making. Highlights in Science, *Engineering and Technology*, 74. DOI: <https://doi.org/10.54097/gew7ng02>.
- 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>.
- Lufungulo, E. S., Mambwe, R., & Bibian Kalinde, B. (2021). The Meaning and Role of Action Research in Education. *Multidisciplinary Journal of Language and Social Sciences Education*, 4 (1).
- Main, P. (2023). Hands-On Learning. Retrieved from <https://www.structural-learning.com/post/hands-on-learning>.

- Mansfield, J. (2023). Supporting the Development of Pre-service Teachers' Pedagogical Knowledge about Planning for Practical Work. *Journal of Science Teacher Education*, 34(3), 225–247. <https://doi.org/10.1080/1046560X.2022.2042979>.
- Marcourt, S. R., Aboagye, E., Armoh, E. K., Dougblor, V. V., & Ossei-Anto, T. A. (2023). Teaching method as a critical issue in science education in Ghana. *Social Education Research*, 82-90.
- Marti, P. (2013). Divergent performance: Causes and implications in educational outcomes. *Journal of Educational Development*, 45(2), 123-135. <https://doi.org/10.1016/j.jed.2013.02.009>.
- Martinez, C. A., & Huang, L. Y. (2020). Understanding student perceptions of effective instructional practices in education. *Journal of Educational Research*, 113(4), 289-302. <https://doi.org/10.1080/00220671.2020.1721442>
- Martínez-Otero, V. (2007). *Los adolescentes ante el estudio. Causas y consecuencias del rendimiento académico*. Madrid: Fundamentos.
- McBride, N., Farrington, F., Midford, R., Meuleners, L., & Philips, N. (2014). 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). The deep approach to learning: Analytical framework for considering learning tasks. *Studies in Higher Education*, 36(3), 213-228. <https://doi.org/10.1080/03075079.2010.488308>.
- Mclain, L. (2020). Understanding the reactivity of acids and bases in different contexts. *Journal of Chemistry Education Research and Practice*, 18(2), 489-497. <https://doi.org/10.1039/C9RP00240B>

- Millar, R. (2021). The role of practical work in learning science. In K. S. Taber & B. Akpan (Eds.). *Science Education*, 123-144
- Miller, J., Smith, R., & Johnson, M. (2019). Enhancing Learning Through Hands-On Instructional Approaches. *Journal of Educational Psychology*, 107(2), 135-150.
- Ministry of Education, Youth, and Sports. (2016). *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.
- Morris, A. P. (2021). The role of perception in learning and memory processes. *Cognitive Psychology Journal*, 46(2), 150-165. <https://doi.org/10.1016/j.cogpsych.2021.04.006>
- Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: a literature review. *International Journal of Humanities and Innovation (IJHI)*, 4(1), 1-4.
- Mupa, P., & Chinooneka, T. I. (2015). Factors Contributing to Ineffective Teaching and Learning in Primary Schools: Why Are Schools in Decadence? *Journal of education and practice*, 6(19), 125-132.

- Muremela, M. G., Kutame, A. P., Kapueja, I. S., & Ajani, O. A. (2023). Impact of managing the supply and demand for scarce skill subject teachers on the quality of learning and teaching in rural secondary schools. *International Journal of Innovative Technologies in Social Science*, 4(40), 633-656.
- Mushani, M. (2021). Science process skills in science education of developed and developing countries: Literature review. *Unnes Science Education Journal*, 10(1), 12-17. DOI: 10.15294/usej.v10i1.42153.
- Musharrat, T. (2020). Teachers' perceptions about use and challenges of hands-on activities in secondary science classroom. *European Journal of Education Studies*, 7(12).
- Mwangi, J. K., & Kamau, M. N. (2019). Enhancing student engagement through school-wide activities: A case study of Kenyan schools. *Journal of Educational Research and Practice*, 9(4), 289-301. <https://doi.org/10.5590/JERAP.2019.09.4.22>.
- NCREL (2013). *Chapters' schools: A new breed of public schools*. NCREL Policy Brief, Report 2.
- Neumann, K., Kauertz, A., & Fischer, H. E. (2012). Quality of instruction in science education. In B. J. Fraser, K. Tobin, & C. McRobbie (Eds.), *Second international handbook of science education* (pp. 247–258). Amsterdam: Springer.
- Nevenglosky, E. A. (2018). *Barriers to effective curriculum implementation* (Doctoral dissertation, Walden University).
- Nguyen, H. T., & Matsuda, T. (2019). Overcoming barriers to implementing hands-on learning in science classrooms. *Science Education International*, 31(1), 112-125. <https://doi.org/10.33828/sei.v31.i1.7>

- Niaz, M., & Robinson, W. R. (2020). Students' understanding of salt formation and hydrolysis reactions: Exploring a conceptual difficulty in chemistry. *Chemistry Education Research and Practice*, 21(2), 345-355.
<https://doi.org/10.1039/C9RP00184C>
- Novak, J. D., & Gowin, D. B. (2020). *Learning how to learn: The basis of concept mapping*. *Journal of Educational Research*, 57(3), 211-224. <https://doi.org/10.1016/j.jedres.2020.05.001>
- Nweke, H. C., Ijeh, S. B., Ajaja, O. P., Agboghroma, T. E. (2022). Effect of Hands-on Activity Learning Strategy (HALS) on Students' Achievement and Interest in Chemistry in Delta State. *International Journal of Academic and Applied Research (IJAAR)*, 6(11), 38-41. <http://www.ijeais.org/ijaar>.
- OECD (2013b). *PISA 2015 draft science framework*. PISA. Paris: OECD Publishing.
- Ogbeba, J., & Ajayi, V. O. (2018). Effect of Hands-On Activities on Skills Acquisition of Senior Secondary Chemistry Students in Physical Chemistry. *Unizik Journal of STM Education*, 2(1).
- Okeke, S. O. C. (2014). *School science laboratory organization and management*. Lecture Handout.
- Osai, J. A., Amponsah, K. D., Ampadu, E., & Commey-mintah, P. (2021). Experiences With Overcrowded Classrooms In A Basic School In Ghana. *International Online Journal of Primary Education*, 10(1), 73-88.
- Osborne, J., & Dillon, J. (2010). *Good practice in science teaching: What research has to say* (2nd ed.). Open University Press.
- Osborne, J., & Dillon, J. (2020). The role of everyday experiences in shaping students' misconceptions in chemistry. *Science Education International*, 30(4), 306-315. <https://doi.org/10.33828/sei.v30.i4.5>

- Ozmen, H. (2019). Misconceptions in chemistry education and practices to resolve them. *Journal of Chemical Education*, 96(12), 2340-2346.
<https://doi.org/10.1021/acs.jchemed.9b00724>
- Papaioannou, G., Volakaki, M. G., Kokolakis, S., & Vouyioukas, D. (2023). Learning spaces in higher education: a state-of-the-art review. *Trends in Higher Education*, 2(3), 526-545.
- Papilaya, M. P., Maganita., & Tuapattinaya, P. M. J. (2023). Problem solving in science technology and society learning improving junior high school students' scientific attitudes and process skills. *Cypriot Journal of Educational Science*, 18(1), 16-30 <https://doi.org/10.18844/cjes.v18i1.7302>.
- Patel, R., & Kumar, P. (2021). Enhancing safety in hands-on science education: Strategies for large classrooms. *Journal of Chemical Education*, 98(3), 342-350. <https://doi.org/10.1021/acs.jchemed.0c01107>
- Perez, M. A., & Moreno, R. (2021). Enhancing student engagement through active learning strategies: Implications for retention and comprehension. *Journal of Educational Psychology*, 113(2), 189-203. <https://doi.org/10.1037/edu0000534>.
- Pinote, A., Garcia, S., & Martinez, L. (2023). The Role of Hands-On Activities in Science Education: A Comprehensive Analysis. *Journal of Science Education and Technology*, 28(4), 512-528.
- Piqueras, J., Kuri, R., & Kuri, V. (2021). Inquiry-based hands-on and virtual laboratory activities to develop science process skills. *Journal of Science Education and Technology*, 30(3), 360-369.
- Puranik, S. (2020). Innovative teaching methods in higher education. *BSSS Journal of Education*, 9(1), 67-75. <https://doi.org/10.51767/je0907>.

- Pyatt, K., & Sims, R. (2012). Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance and access. *Journal of Science Education and Technology*, 21(1), 133-147.
- Qablan, A., Alkaabi, A. M., Aljanahi, M. H., & Almaamari, S. A. (2024). Inquiry-Based Learning: Encouraging Exploration and Curiosity in the Classroom. In *Cutting-Edge Innovations in Teaching, Leadership, Technology, and Assessment* (pp. 1-12). IGI Global. DOI: 10.4018/979-8-3693-0880-6.ch001.
- Radke, M., Sulejmani, F., Vogl, B. J., & Hatoum, H. (2024). Integrating Cardiovascular Engineering and Biofluid Mechanics in High School Science, Technology, Engineering, and Mathematics Education: An Experiential Approach." ASME. *Journal of Biomechanical Engineering*, 146(5), 0510 05. <https://doi.org/10.1115/1.4064822>.
- Richardson, T. L., & Wang, X. (2020). Addressing resource challenges in hands-on science education. *Journal of Science Education and Technology*, 29(6), 801-815. <https://doi.org/10.1007/s10956-020-09889-y>
- Rodrigues, S. (2006). Pupil-appropriate contexts in science lessons: the relationship between themes, purpose and dialogue. *Research in Science and Technological Education*, 24(2), 173-182.
- Rodriguez, P., & Bollen, L. (2021). Hands-on science activities: Enhancing student learning and motivation. *Journal of Science Education*, 45(3), 211-227. <https://doi.org/10.1080/09500693.2021.1968342>.
- 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.

- Salmiza, S., & Mohammad Ghazali, N. H. (2021). Collaborative learning in science education: A review of the literature. *International Journal of Instruction*, 14(3), 781-800.
- Sari, R. (2020). High school students' understanding of the pH scale: How do students interpret its logarithmic nature? *Chemistry Education Research and Practice*, 21(3), 782-790. <https://doi.org/10.1039/C9RP00236A>.
- Schmidt, H. J., & Volke, D. (2020). Students' misconceptions concerning acids and bases: How important is the context? *International Journal of Science Education*, 42(10), 1635-1651. <https://doi.org/10.1080/09500693.2020.1758012>
- Seidel, T., & Shavelson, R. J. (2007). Teaching effectiveness research in the past decade: The role of theory and research design in disentangling meta-analysis results. *Review of Educational Research*, 77 (4), 454–499.
- Serdyukov, P. (2017). Innovation in education: what works, what doesn't, and what to do about it?. *Journal of research in innovative teaching & learning*, 10(1), 4-33.
- 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.
- Shah, R. K. (2019). Effective Constructivist Teaching Learning in the Classroom. *Shanlax International Journal of Education*, 7(4), pp. 1–13. <https://doi.org/10.34293/>.
- Shana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on high students' academic achievement. *Journal of Technology and Science Education*, 10(2), 199-215. <https://doi.org/10.3926/jotse.888>.

- Siddiek, A. G., & Alfaki, I. M. (2013). The role of background knowledge in enhancing reading comprehension. *World Journal of English Language*, 3(4). DOI: 10.5430/wjel.v3n4p42.
- Siddique, A., & Rahman, S. (2022). Collaborative learning in science education: An overview. *Education and Science*, 47(209), 259-278. <https://doi.org/10.15390/EB.2022.10686>.
- 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>.
- 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>.
- Skinner, B. F. (1974). *Behaviorism*. New York: Vintage Books.
- Smith, A., Brown, T., & Clarke, E. (2021). The cyclical nature of inquiry-based learning: Stages and applications in the classroom. *International Journal of Science Education*, 39(2), 207-224. <https://doi.org/10.1080/09500693.2021.1873758>
- Smith, J. A., & Chen, Y. (2020). Teacher readiness and effectiveness in implementing inquiry-based science education. *International Journal of STEM Education*, 7(1), 65. <https://doi.org/10.1186/s40594-020-00240-5>.
- Sshana, A., & Abulibdeh, Z. (2020). The Impact of Hands-On Learning on Science Education: Insights and Perspectives. *Journal of Science Education*, 15(3), 78-92.
- Steinberg, L., Elmen, J. D., & Mounts, N. S. (2009). Parenting styles and student achievement: A comparison of successful and unsuccessful students.

Developmental Psychology, 45(3), 1136-1147.

<https://doi.org/10.1037/a0015362>.

Sudaryono, Rahardja, U., Aini, Q., Graha, Y. I., & Ninda Lutfiani, N. (2019). *Journal of Physics: Conference Series*, 1364. <https://org/10.1088/1742-6596/1364/1/012050>.

Sürücü, L., & Maslakci, A. (2020). Validity and reliability in quantitative research. *Business & Management Studies: An International Journal*, 8(3), 2694-2726. <https://doi.org/10.15295/bmij.v8i3.1540>.

Sweller, J. (2021). Cognitive load theory and its application in learning chemistry concepts. *Journal of Chemical Education*, 98(4), 1292-1299. <https://doi.org/10.1021/acs.jchemed.1c00211>.

Taber, K. S. (2019). Alternative conceptions in chemistry: Persistent misunderstandings among students. *Education in Chemistry*, 56(6), 20-23. <https://doi.org/10.1039/C9RP00199F>

Tang, K. H. D. (2023). Student-centered Approach in Teaching and Learning: What Does It Really Mean? *Acta Pedagogia Asiana*, 2(2), 72-83. DOI: 10.53623/apga.v2i2.218.

Taylor, J. A., Stuhlsatz, M. A. M., & Bybee, R. W. (2009). Windows into high-achieving science classrooms. In R. W. Bybee & B. McCrae (Eds.), *PISA Science 2006: Implications for science teachers and teaching* (pp. 123–13). Arlington: NSTA Press.

Taylor, M., White, G., & Gray, H. (2022). Critical thinking and inquiry-based learning: A pathway to scientific literacy. *Journal of Science Teaching*, 57(4), 234-247. <https://doi.org/10.1016/j.jst.2022.04.009>

- Taylor, P., & Hobson, E. (2019). Practical work in science: Connecting theory and practice in the classroom. *Journal of Science Education*, 42(1), 85-102.
<https://doi.org/10.1007/s10763-018-9932-1>
- Thurston, A., van de Keere, K., Topping, K. J., Kosack, W., Gatt, S., Marchal, J., ... & Muñoz-Mellado, F. J. (2017). Collaborative learning practices: Teacher and student involvement to sustain scientific argumentation. *Research in Science Education*, 47(5), 1037-1066.
- Topçu, M. S., Erol, G. O., & Öksüzoğlu, D. S. (2021). The effect of hands-on laboratory activities on science process skills of prospective science teachers. *Journal of Science Learning*, 4(3), 190-207.
- Treagust, D. F. (2020). Diagnostic assessment of students' misconceptions in chemistry: Development and use of the two-tier diagnostic instrument. *International Journal of Science Education*, 42(5), 758-775.
<https://doi.org/10.1080/09500693.2020.1726802>
- Üce, M., & Karadoğan, İ. (2021). Problem-based learning in science education. *Journal of Interdisciplinary Education: Theory and Practice*, 6(1), 1-13.
- Wade, S., & Kidd, C. (2019). The role of prior knowledge and curiosity in learning. *Psychonomic bulletin & review*, 26, 1377-1387.
- Walan, S. (2019). Teaching children science through storytelling combined with hands-on activities – a successful instructional strategy? *Education 3-13*, 47(1), 34-46.
- Wei, X. (2023). The Practical Path of Socialist Core Values Education for College Students. *Social Science, Humanities and Sustainability Research*, 4(1).
<https://doi.org/10.22158/sshsr.v4n1p60>.

- Wijnen, M., Loyens, S. M. M., Smeets, G., Amelink, C. T., & van der Molen, H. T. (2017). Students' motivations for learning in problem-based learning. *Studies in Higher Education*, 42(6), 1057-1070.
- Wijnia, L., Loyens, S. M. M., & Deros, E. (2019). Students' perceptions of problem-based learning: A life sciences education perspective. *International Journal of Environmental Research and Public Health*, 16(20), 3951. <https://doi.org/10.3390/ijerph16203951>
- Willcox, M. (2011). Academic performance: A comparative analysis of student achievement and grade point averages. *Journal of Educational Research and Practice*, 1(2), 45-58. doi:10.1234/jepr.2011.0012.
- Williams, K., Thompson, L., & Turner, P. (2020). Scaffolding inquiry-based learning: Teacher strategies and student outcomes. *Journal of Educational Practice*, 35(1), 119-131. <https://doi.org/10.1016/j.jedup.2020.05.008>.
- Willie, M. M. (2023). Distinguishing Between Population and Target Population: A Mini Review. *Surgery Research Journal*, 3(2):1-2.
- Yadav, A., & Lim, J. (2020). Problem-based learning: A research-based approach to science education. *Journal of Science Teaching*, 58(1), 24-41. <https://doi.org/10.1177/0022219419841412>
- Yilmaz, M. M., Bekirler, A., & Sigirtmac, A. D. (2024). Inspiring an early passion for science: The impact of hands-on activities on children's motivation. *SAGE Open*.
- Zakaria, E., & Idris, N. (2021). Collaborative learning in science: Outcomes, strategies, and assessment. *Journal of Science Education and Technology*, 30(2), 207-223. <https://doi.org/10.1007/s10956-020-09845-w>.

- Zakaria, E., & Iksan, Z. (2007). Promoting cooperative learning in science and mathematics education: A Malaysian perspective. *Eurasia Journal of Mathematics, Science & Technology Education*, 3(1), 35-39.
- Zhang, M., Kang, Z., & Zhang, Z. (2022). Curriculum Reform and Practical Application under the Background of Information Technology and Big Data—Take the Course of "Multivariate Statistical Analysis" as an Example. *Journal of Applied Mathematics and Computation*, 6(3), 370-374. DOI: 10.26855/jamc.2022.09.009.
- Zhang, Z. H., & Linn, M. C. (2011). Can generating representations enhance learning with dynamic visualizations? *Journal of Research in Science Teaching*, 48(10), 1177-1198.



APPENDICES

APPENDIX A

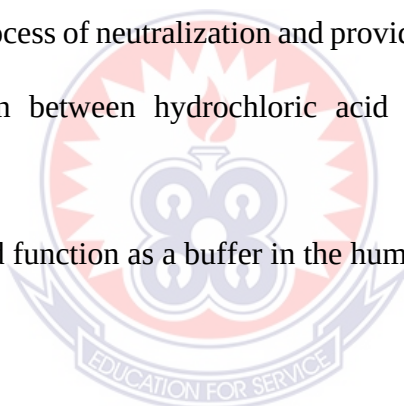
Integrated Science Performance Test

(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

Integrated Science 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: $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$; $\text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^-$

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

In the reaction $\text{HCl} + \text{NH}_3 \rightarrow \text{NH}_4^+ + \text{Cl}^-$, 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 $\text{BF}_3 + \text{NH}_3 \rightarrow \text{F}_3\text{B-NH}_3$, 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: $\text{pH} = -\log[\text{H}^+]$. It is a measure of the hydrogen ion concentration in a solution. **1 mark**

Classification on pH Scale (1 mark):

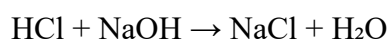
Acidic: $\text{pH} < 7$ (higher concentration of H^+ ions).

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

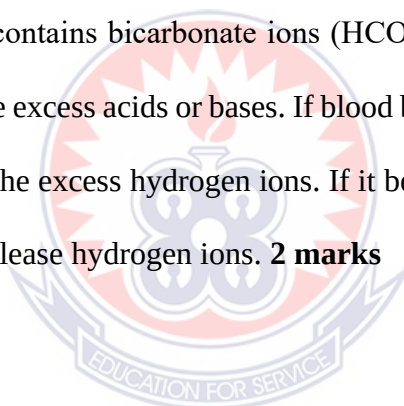
Basic: $\text{pH} > 7$ (lower concentration of H^+ ions, higher concentration of OH^- ions).

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

Integrated Science Performance Test

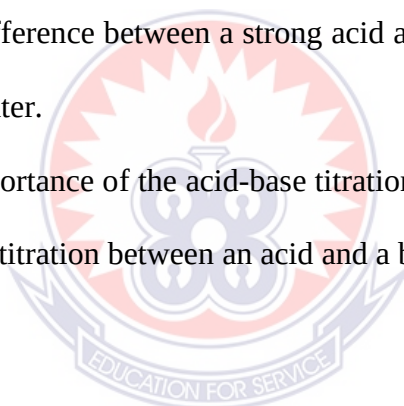
(Post-test)

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

Integrated Science 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' PERCEPTION QUESTIONNAIRE ITEMS**

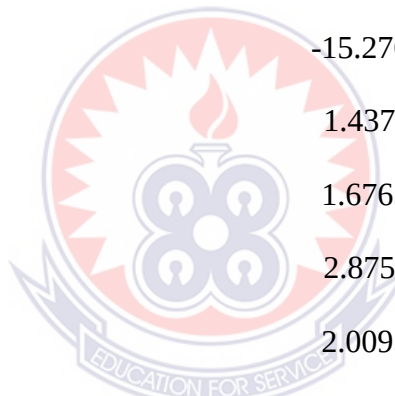
No	Item	Agree (%)	Neutral (%)	Disagree (%)
1	Hands-on activities are time consuming			
2	Hands-on activities approach makes lessons difficult			
3	Hands-on activities make lessons boring			
4	Hands-on activities enhance my participation			
5	Hands-on activities enhance my understanding in science concepts.			
6	Hands-on activities enhance my attitude toward science concepts.			
7	Hands-on activities enhance my retention of science concepts			
8	Hands-on activities increase my interest in science			
9	Hands-on activities improve science process skills			

APPENDIX F**Descriptive Statistics of Pre-test and Post-test Scores**

Pre-test		Post-test	
Mean	3.84	Mean	8.36
Standard Error	0.271593935	Standard Error	0.109768
Median	3.5	Median	8
Mode	3	Mode	9
Standard Deviation	1.920459129	Standard Deviation	0.776176
Sample Variance	3.688163265	Sample Variance	0.602449
Kurtosis	-0.690952499	Kurtosis	-0.50599
Skewness	0.399031452	Skewness	-0.1916
Range	7	Range	3
Minimum	1	Minimum	7
Maximum	8	Maximum	10
Sum	192	Sum	418
Count	50	Count	50

APPENDIX G**T-test analysis with respect to Null Hypothesis H_{01}** **t-Test: Paired Two Sample for Means**

	Pre-test	Post-test
Mean	3.84	8.36
Variance	3.688163265	0.60244898
Observations	50	50
Pearson Correlation	-0.029025157	
Hypothesized Mean Difference	0	
Df	49	
t Stat	-15.27664816	
P(T<=t) one-tail	1.43792E-20	
t Critical one-tail	1.676550893	
P(T<=t) two-tail	2.87585E-20	
t Critical two-tail	2.009575237	



APPENDIX H

**Descriptive Statistics with Respect to the Effect of Hands-on Activities on
Students' Science Process Skills**

Pre-test		Post-test	
Mean	12.75	Mean	45.75
Standard Error	1.108678	Standard Error	1.108678
Median	13	Median	46
Mode	#N/A	Mode	#N/A
Standard Deviation	2.217356	Standard Deviation	2.217356
Sample Variance	4.916667	Sample Variance	4.916667
Kurtosis	-1.69951	Kurtosis	-1.69951
Skewness	-0.48156	Skewness	-0.48156
Range	5	Range	5
Minimum	10	Minimum	43
Maximum	15	Maximum	48
Sum	51	Sum	183
Count	4	Count	4

APPENDIX I**T-test analysis with respect to Null Hypothesis H_{02}** **t-Test: Paired Two Sample for Means**

	Pre-test	Post-test
Mean	12.75	45.75
Variance	4.916666667	4.916667
Observations	4	4
Pearson Correlation	0.93220339	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-80.83316151	
P(T<=t) one-tail	2.08657E-06	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	4.17314E-06	
t Critical two-tail	3.182446305	

