UNIVERSITY OF EDUCATION, WINNEBA

THE EFFECT OF PRACTICAL WORK ON SCIENCE PROCESS SKILLS AND CRITICAL THINKING DEVELOPMENT ON SENIOR HIGH CHEMISTRY STUDENTS.

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

NOVEMBER, 2023

DECLARATION

STUDENT'S DECLARATION

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

SIGNATURE:…………………………….

DATE:…………………………………….

SUPERVISOR'S DECLARATION

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

PROF. RUBY HANSON (PRINCIPAL SUPERVISOR)

SIGNATURE:…………………………

DATE:………………………………

DEDICATION

This project work is dedicated to my daughter,

Gifty Baaba Dan-Nyame Hinson.

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As the author, however, I accept the sole responsibility for any errors or omissions pertaining to this work.

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ABBREVIATIONS

SPS:	Science Process Skills
CT:	Critical Thinking Skills
SHS:	Senior High School
SHTS	Senior High Technical School
POC:	Participant Observation Checklist,
ABCTT:	Acid-Base Critical Thinking Test
IGD:	Intact Group Discussions
WAEC:	West Africa Examinations Council
CTI:	Critical Thinking Indicator
PW:	Practical Work
MoE	Ministry of Education

ABSTRACT

This study determined the effect of conduct of chemistry practical work on the development of basic science process skills (measuring, observing, calculating, recording, predicting, classifying and inferring) and critical thinking among third year elective chemistry students. Two senior high schools in the Sekondi-Takoradi Metropolis of the western region of Ghana were selected for the study. The study was necessitated by the continuous poor performance of SHS chemistry students in the test of chemistry practical conducted by the West Africa Examinations Council over the years. The intrinsic case study design with multiple data source was employed in this study. The stratified purposive sampling adopting simple frequency counts was used in selecting 160 third year chemistry students. Two classes each consisting of Home Economics and General Science making a total of four strata was sampled from the two senior high schools. The participants for the study were maintained in their schools while the teachers conducted practical work for them. A Participant Observation Checklist and a Questionnaire on Science Process Skills were used to collect data on science process skill development in both schools. An Acid-Base Critical Thinking Test was administered to determine how the third year senior high student's elective chemistry students employed their critical thinking in solving scientific problems. Intact Group Discussions was conducted after the study in both schools. The use of multiple instruments enabled the researcher to triangulate the results obtained from the study. The findings revealed that the third year elective chemistry students were not engaged in practical work during their first and second years. Practical work conducted in the two senior high schools did not aid the development of the students' science process skills. The student's inability to develop science process skills has affected the development of their critical thinking skills. Practical work conducted in the two schools has been focused primarily on helping the students pass the test of practical work conducted by WAEC to the neglect of development of science process skills. The situation has led to memorization of scientific concepts/facts without understanding. The researcher recommends that chemistry teachers employ modern innovative pedagogies in developing science process skills by conducting engaging practical work from first year through to third year.

CHAPTER ONE

INTRODUCTION

1.0 Overview

The chapter considers the background to the study, statement of the problem, objectives of the study, research questions and purpose of the study, significance of the study as well as limitations and delimitations for the study.

1.1 Background

Science is a great enterprise on which nations depend in order to advance technologically (Gilpin, 2015). It is the bedrock of civilisation and the yardstick by which development is measured globally (Richta, 2018). Science has improved the economy of many nations and it is the benchmark for achieving national development (Mormina, 2019).Science forms the key foundation for technological growth and plays an important role in improving the lives of mankind through medicine, agriculture, communication, transportation, engineering and economy (Olutola, 2016). Science is receiving much emphasis in education because of its significance and relevance to life and society in the 21st Century (Nwangbo & Chukelu, 2011). The rapid technological development associated with globalization, and the quest to develop smart ways of life has come with attendant human problems that need urgent attention. Solving the problems of the 21st century era demand individuals with critical and analytical thinking dispositions, who are able to unravel the myth surrounding the solution to the problems (Rodzalan, & Saat, 2015). Surmounting the problems of society requires individuals who can reason logically and think proficiently from a scientific view point, backed by data collection and respect for evidence to arrive at the solutions (Murawski, 2014). Individuals who can reason this way are best described as critical thinkers. Critical thinkers are very proficient at solving problems (Facione, 2015). For this reason, corporate organizations all over the world, are hiring individuals who can think critically and logically, to develop solutions to problems that confront humanity (Akramova, 2017).Following the important role played by science in development, countries all over the world are changing and reforming their science education curricula with the intension to develop innovative pedagogies (Mansour, 2013).These pedagogies seek to equip the human capita with critical thinking dispositions and problem solving skills (Eilks & Hofstein, 2017). Most countries have placed premium on hands on activities in science to help in developing individuals with the right attitudes needed for development (Sjøberg & Jenkins, 2022).

In Ghana, the teaching of Chemistry, a branch of science, in the Senior High schools, seek to develop scientific literacy, science process skills, critical/analytical thinking, logic reasoning and problem solving skills (MOE, 2010). The Senior High curriculum seeks to give scientific impetus to chemistry students to plan and investigate scientific problems. These scientific problems must relate to society so that the knowledge acquired can be used to solve the problems of man (Kapanadze & Eilks, 2014). The teaching of Chemistry also aims to equip students with basic scientific knowledge of concepts and skills which form the key prerequisites for future academic and professional work (MOE, 2010). Sjøberg & Jenkins (2022) again contend that the development of critical/analytical thinking, logic reasoning and scientific concepts/theories cannot be complete without practical work in chemistry. In view of its importance, the chemistry curriculum in senior high schools in Ghana specify that, practical experimental investigative hands-on activities be employed in teaching the theories in science (Furtak & Penuel, 2019). Practical work must seek to enable Senior High students develop a better understanding of concepts as opposed to just being told from textbooks. This is because practical work translates most abstract ideas into simple and concrete forms (Taale, Hanson & Antwi, 2018). Practical work also allows students to develop their own understanding of scientific concepts. Abunga, Okere & Wachanga, (2014), contend that engaging students in practical activities afford them the opportunity to develop skills that can be used to solve problems in everyday life. According to Brobbey, Baah, and Ampon-Wireko (2020), the teaching of chemistry practical work in the Senior High Schools in Ghana is intended to equip students with critical thinking, collaboration, innovation as well as deductive and inductive inquiry skills. These skills form the key agents on which knowledge develops. The practical component of the chemistry curriculum also emphasizes the development of chemical knowledge, through practical problems designed by teachers. It is expected that practical problems are delivered through scientific processes with the students at the center of the teaching and learning to discover facts and concepts on their own (MOE, 2010). During practical work students are involved in manipulating and or observing real objects and materials and phenomenon with the key aim of increasing understanding of scientific concepts (Sjøberg & Jenkins, 2022). Practical work offer pieces of experience and skills to students when they are engaged with materials either alone or in groups under the guidance of the teacher (Akramova, 2017). Jack (2018) posits that practical work should not just be putting apparatus together when seen, but demands planning, designing problems, creating new approaches and procedures and also arranging familiar things in a new way. This implies that science teachers, as change agents, should design their practical work by planning scientific problems in line with the intended concepts or theories. Science teachers are expected to align equipment and instrument for manipulation through activities to help students develop understanding of scientific concepts. Designing practical work this way, offer students the opportunity to develop hands-on, minds-on and hearts-on in science which increases their interest (Taale et al, 2018). Singh (2020) posits that practical work when properly planned and executed within time and space, by providing students with adequate materials, and guided through effective students' engagement, develops students' scientific skills and attitudes. The use of student's scientific skills and attitudes during practical work sharpens their science process skills (SPS) and critical thinking (CT) development (Sunyono, 2018). SPS and CT development increases students' interest, confidence, creativity and ability to develop solutions to daily scientific problems confronting them (Vieira & Vieira, 2016).The knowledge of creativity exhibited by science students in practical work helps in manipulating practical equipment with dexterity and accuracy so as to attain the desired SPS (Facione, 2015).

SPS is a cognitive and psychomotor skill used in problem solving. SPS are activities, which students carry during scientific investigations (practical work) to enable the acquisition of scientific knowledge and skills. The work of scientist involves manipulating instruments with skills and accuracy backed by scientific knowledge capable of explaining data obtained from a scientific view point. SPS are used during the processes of science to generate knowledge, test theories, and validate/falsify facts (Kelley & Knowles, 2016). Chemistry students as practicing "young scientists" need to develop SPS to guide them in designing and conducting scientific investigations, formulating and testing hypothesis, drawing relevant conclusions and communicating findings obtained during practical work. Developing SPS is very important since its guides the processes the scientist use in the conduct of their activities (Lederman, Lederman & Antink, 2013). The importance of SPS in practical work cannot be underestimated. The senior high school chemistry curriculum highlights the development of SPS through practical experimental work. The SPS highlighted by the curriculum includes; planning, designing experiments, observation, manipulation, classification, drawing, measurement, interpretation, recording, and reporting (MOE, 2010). These skills when properly integrated by students with the right practical approache using the appropriate scientific apparatus develop SPS. These skills in practical work is essential for building a firm scientific foundation by developing critical/analytical thinking dispositions as well as scientific attitudes needed to generate scientific knowledge. Critical thinking is necessary when analyzing, assessing, evaluating, comparing, and contrasting abstract concepts in science in the real sense (Holt & Pache, 2012). Critical thinking in science as an attitude must also be developed. Critical thinkers are able to think logically by analyzing, and evaluating problems using evidence, concepts, methodology and criteria as basis for making decisions employed in solving problems (Carriger, 2015). One of the ultimate goals of education in the 21st Century is to generate critical thinkers (Alkharusi, Sulaimani & Neisler, 2019). For this reason, education around the world today seeks to develop critical thinkers by offering classroom environment that stimulates thinking with practical activities which provide opportunities for students to reason logically (Vieira, 2016).

When students are offered the opportunity to design and construct their own investigations by observing phenomenon and giving reasons, they are able to draw their own conclusions. Chemistry students' practical interest and motivation increases if they are able to engage in critical/analytical thinking and logic reasoning by drawing on their understanding of scientific concepts (Brobbey, Baah, & Ampon-Wireko, 2020). This practice prevents students from memorizing scientific facts in textbooks without understanding.

1.2 Statement of the Problem

In Ghana, the senior high school chemistry curriculum emphasizes the conduct of practical work to guide science process skills and critical thinking development. The curriculum assigns two out of the six periods per work for practical work where teachers are expected to engage students in practical activities (MoE, 2010). This is done to develop the students scientific competences (critical/analytical thinking, logic reasoning and problem solving) required for 21st century living (MoE, 2010). The chemistry curriculum also demands that, chemistry teachers begin each practical lesson with a practical problem by offering the students the opportunity to investigate issues and draw conclusions. It is important to note that, chemistry practical work seeks to consolidate theoretical concepts and help students to develop critical/ analytical thinking, reasoning, inquiry, problem solving and scientific attitudes. Students who are deeply involved in opportunities for logic reasoning develop critical thinking and are very proficient at solving problems (Facione, 2015). The chemistry curriculum recommends the development of analytical thinking and practical problem solving techniques to emanate from effective practical engagement with students. This curriculum postulate should be developed by offering opportunities that stimulate students' critical thinking and reasoning (MoE, 2010). It is seemingly important to note, that, because of the desire to increase high order level thinking, reasoning and logic, the profile dimension, specifies 30% weighting allocated to practical and experimental activities in the senior high schools. Profile dimension is the underlining behaviour for teaching and learning and assessment. This, the experts of the chemistry curriculum believe will accord chemistry students the opportunity to be involved in practical work that will develop their manipulative skills and thought (Kelley & Knowles, 2016). However, the challenges inherent in the conduct of practical work in senior high schools coupled with the urgency to complete the chemistry curriculum of the Ministry of Education, has motivated most chemistry teachers to teach the subject as bundles of abstractions using thories (Azuuga, Baawuo, & Apene, 2021). Most chemistry teachers teach chemical concepts without adequate practical exposure intended to offer students the opportunity to reason logically (Mohammed, Amponsah, Ampadu & Kumassah, 2020). The chemistry students are not involved in developing creativity and critically thinking during practical work. Research suggests that most senior high Schools in Ghana do not engage their chemistry students in effective practical work (Ghartey-Ampiah, 2004; Azure, 2015; Agyemang, 2016). This is evident in the continuous low performance of students in tests of practical conducted by West Africa Examinations Council over the years (Chief Examiners Report, 2015, 2016, 2017, and 2018). A study conducted by Koomson, (2020), revealed that most science students are not adequately exposed to practical work and this affects their reasoning patterns and their ability to answer practical questions with high order thinking. In a another study, Yeboah, Abonyi & Luguterah, (2019) concluded that most science teachers teach more theories in abstract than involving students in actual practical work. This, they commented, does not contribute to students' process skills development and reasoning. Most chemistry teachers tend to confuse the teaching of test of practical work with the conduct of actual practical work which is expected to develop student's practical skills. It is for this reason that the researcher conducted this study "the effect of practical work on science process skills and critical thinking development'' to ascertain how students science process skills development affect their critical thinking skills.

1.3 Purpose of the Study

The purpose of this study was to determine the effect of practical work on third year senior high school chemistry students' science process skills and critical thinking development, by considering regularity of conduct and effective engagement of students.

1.4 Objectives of the Study

The objectives that guided this study were:

I. To determine the effect of chemistry practical work (titremetry) on student's science process skills development.

II. To determine the regularity of conduct of practical work develops students' science process skills.

III. To determine whether science process skill development of chemistry students influence their critical thinking ability.

1.5 Research Questions

The following questions guided the study;

I. What is the effect of practical work on senior high students' level of science process skill development?

II. What effect has regularity of conduct of practical work facilitate science process skills development of SHS Chemistry Students?

III. To what extent does science process skill development influence the student's critical thinking?

1.6 Significance of the Study

The study is intended to enrich chemistry students with the practical approaches needed for effective conduct of practical work by providing them with opportunities to be involved in logic reasoning, critical and analytical thinking and the development of problem solving skills.

The study is also intended to be used in sensitizing Senior high school students on the importance of developing scientific skills and attitudes necessary for conducting effective practical work so as to enhance their manipulative and innovative skills.

1.7 Limitations of the Study

The observance of COVID 19 protocols in the laboratory during practical work, limited the number of students who were to collaborate in performing practical work at a section. This invariably affected the level of cooperation and collaboration needed for discussion of observations made during the practical sections. Few students' opted out of the study because they did not have basic protective equipment (PPEs).

Because of time constraints, the teachers could not effectively engage students in post practical discussions. This affected the students from accessing how they could apply theoretical knowledge in solving practical problems.

1.8 Delimitations of the Study

The study is limited to only two grade C schools offering chemistry major in the Sekondi-Takoradi metropolis of the western region of Ghana. The intension is to determine the ideal situation pertaining to the conduct of practical work in less endowed schools.

The study is limited to only basic science process skills such as observing, measuring, calculating, manipulating and inferring.

The study was conducted in only selected public senior high schools offering elective chemistry in the Sekondi-Takoradi metropolis.

1.9 Definition of Terms

Practical Work: An experimental, investigative laboratory activity engaged by students using apparatus.

Science Process Skills: A set of skills used in scientific activities to develop critical thinking and problem solving skills.

Scientific Literacy: Knowledge and understanding of scientific concepts and processes required for personal decision making.

Critical Thinking: An intellectual discipline process of skillfully and actively analyzing facts to make judgment.

Analytical Thinking: The ability to seek information, analyse alternatives and make conclusions or form opinions.

Logic Reasoning: The ability to use rational and systematic series of steps to draw conclusions for a phenomenon.

Scientific Attitudes: The desire to seek accurate knowledge. E.g. open mindedness, objectivity and fair testing

CHAPTER TWO

LITERATUREREVIEW

2.0 Overview

This chapter reviews literature related to the study. The key variables in the study including practical work, science process skills and critical thinking are reviewed. The chapter begins with historical perspective of practical work, definition of practical work, importance of practical work and how practical work develops science process skills. The chapter continues by exploring literature on types of process skills and cognitive development, critical thinking development as well as the tools employed in measuring critical thinking. The chapter finally ends with the theoretical and conceptual review backing the study.

The current spate of technological advancement has resulted in knowledge explosion in the 21stcentury and turned the world into a global village (Malik, 2018). The unprecedented development of the world has come with attendant human problems requiring deep seated thoughts to uncover the misery surrounding the problems of the world (Rodzalan, & Saat, 2015). The current demand to solve the problems of society requires the human capita be equipped with 21st century scientific skills essential in dealing with these emerging issues (Reeve, 2016). Further to this, education around the world is assuming a global trend to developing individuals with critical, innovative and problem solving orientations capable of unraveling the problems of the21st century world (Murawski, 2014). It is for this reason that nations the world over, have reformed and organized their science curricula to incorporate the development of 21st century scientific skills with the intent to produce critical thinkers and problem solvers within the citizenry (Alkharusi, Sulaimani & Neisler, 2019).

2.1 The Current Perspective of Practical Work in Science

The current scientific, technological and economic demands of the world require that the frontiers of education reform its curricula and pedagogy to make teaching and learning more meaningful(Lim, Cope & Kalantzis, 2022).Practical work must be student centered, problem oriented and hands on in order to meet these changing demands (Hogan, & Stewart, 2014).

In recent times, science teachers all over the world have shifted the focus of teaching and learning of science from teacher centered approaches to practical hands on investigative approaches (Scheurs & Dumbraveanu, 2014). This new development is intended to offer science students the opportunity to develop their critical thinking, creativity and innovation.Practical work is also intended to develop scientific knowledge, attitudes and values as well the skills needed for solving the problems of society (Fitriani, Zubaidah, Susilo & Al Muhdhar, 2020).

The development of 21st century skills require that teachers effectively plan and engage science students in the conduct of hands on practical work, by creating practical problems and offering students' avenues to be involved in solving those problems (MoE, 2010). Solving practical problems require students' to be innovative in analysing issues, and using their imaginations to scientifically assign reasons which conforms to logic (Fitriani et al, 2020). Engaging students in creative and analytical reasoning through practical orientation develops students' critical thinking dispositions which are the key prerequisites for decision making and problem solving in life (Facione, 2015). Practical work provides opportunities for students to develop their natural intuition to reasoning when confronted with real life problems (Glen, Suciu, & Baughn, 2014). This suggests that practical work as an avenue for teaching the sciences must be given the needed impetus by teachers, if it is intended to make the desired impact of helping equip chemistry students with practical dispositions.

From the literature reviewed above, it can be deduced that the current perspective of practical work in science is to equip science students with scientific attitudes and values borne out of exposure to science investigations. Practical activities in the 21st century develop through having access to materials and equipment and chemicals as well as careful panning by science teachers. Science students are to be guided through practical activities to develop cutting edge scientific ideas and concepts relevant for developing critical thinking and solving the problems of society (Fitriani, et al, 2020).

However in Ghana, the conduct of practical work in most senior high schools leaves much to be desired. Most senior high students complain that the practical component of the senior high chemistry curriculum is not well dealt with by teachers. Senior high students are not developing their science process skills and critical thinking abilities due to ineffective practical work conducted. The situation is further exacerbated by the lack of chemical and equipment as well as low commitment of chemistry teachers. Science teacher motivation, irregular conduct of practical work and inadequate apparatus has prevented the conduct of effective practical work in most senior high schools in Ghana (Koomson, 2020).

2.1.1 Historical perspective of practical work in science

The development of practical work in science predates the Nineteenth Century. Practical work was introduced in schools in Britain years before the eighteenth Century, The aim for introducing practical work then was not only for doing experiments or confirming a theory, but in finding out new things that had not been known previously. Isozaki (2017) posits, practical work refers to any activity related to teaching and learning of science (carried out individually or in small groups) in a school laboratory or field. Practical work which involves observation, experimentation or investigation requiring manipulation of objects/materials have existed since the eighteenth century. However, the focus of practical work for teaching and learning science has undergone so many changes over the centuries (Jenkins, 1998). Jenkins (1998) again contends that the use of science teaching laboratory designed and equipped for teaching science is essentially a nineteenth-century phenomenon.

During the eighteenth century, science teaching in the United States was not well defined with practical work even though science activities were used. The main objectives for teaching science then was; (1) To learn by observing the natural world; (2) To learn through comparison and induction; (3) To use one's imagination to stimulate creativity; (4) To learn through self-elimination; and (5) To implement useful information (Smith & Hall, 1910). The conceptualization of scientific training in the United States was not based on objective lessons and demonstrations that involved deep seated scientific skills. However, learning science was geared towards developing logic and analysis, so they did not emphasize the role of sophisticated laboratory work.

The Americans studied science to develop the human resource with an understanding of their world and to gain insights that will harness creativity. Their view of practical work and laboratory investigations during the eighteenth century was not different from that of the United Kingdom.

In the United Kingdom, many teachers had developed worksheets called the Card System for teaching and learning science (Woolnough & Allsop, 1985). The card system also known as the cookbook approach required students to carry out procedures mechanically, without deep reflection or engagement. The cookbook approach may have caused Britain to lose sight of the intended purpose of practical work. This is because the cookbook approach was designed to lead students directly to correct answers without student's involvement in drawing conclusions from the experiments. The teaching and learning of science in the eighteenth century Britain was also not so much focused on practical laboratory work although teacher demonstrations were done to help students understand some basic scientific concepts. Students looked on as teachers explained most scientific concepts and theories with procedural cookbook approach (Woolnough & Allsop, 1985).

In Japan, the teaching and learning of science during the eighteen century was molded on Henry E. Armstrong's heuristic method (Hodson, 1993). The Heuristic method of teaching involved placing students as far as possible in the altitude of a discoverer without teacher guidance or assistance in directing the students to the outcome of the engagement. Hodson (1993), argues that Armstrong's approach emphasized doing science in order to understand it. Boy's schools in Tokyo prefecture in Japan revised their science education curricula to include facilities in the classroom for demonstrations. However, standardized experiments in laboratory notebooks led students to follow recipes in order to verify theories, their goal being to illustrate scientific concepts under the teachers' instruction. It must be noted that during the early days, science teaching was not practical oriented and goal directed but was aligned to helping students understand theories and concepts handed down by the proponents of the earlier scientific community. Teacher demonstrations which were strongly procedural were used to develop science concepts. Research on the impact of the procedural cookbook approach to science teaching is very rear. The beginning of the 20th Century revolutionized the teaching and learning of science in the world (Slavin, 2002). This revolution became more prominent after the Russians launched their first space satellite in 1957, the Sputnik. Governments all over the world changed their science education curricula to include more emphasis on practical and goal oriented science (McKinley, 2005). Many countries invested heavily in science education with increase in the supply of facilities and equipment suitable for teaching practical science in schools. Subsequent to the Russian sputnik launch, a new American and English curricula spread to different parts of the world. Some initiatives were embarked on in Europe leading to large-scale curriculum reform movements in the 1960's in England and Wales. This initiative was financed by the Nuffield Foundation, and later by the Schools Council. The mandate for this curricula reform was to concentrate on laboratory practical work which was goal directed by engaging students in investigative activities and, thereby gaining vicarious experiences of scientific discovery.

In Africa, prior to the 1950's, the textbook was the curriculum for science and hence what passed as the teaching of science was nothing more than information-giving by teachers and memorization of the information by students (Ghartey - Ampiah, 2004). Brilliant students were classified as students who were able to recall by memorizing science facts taught. The theoretical approach to teaching science was further encouraged by the emphasis it received in public examinations such as the West

Africa Examinations Council (WAEC) which tested student's practical knowledge using theory.

In Ghana, the teaching of science was more rooted in theory than practical. The textbook concept of cookbook teaching was imported from the United States and the United Kingdom in the 1960's. However, the cookbook concept changed with the advent of WAEC. WAEC introduced examination in practical work with the aim of providing opportunities for students to solve practical problems. This was to be achieved in class by teachers introducing students to enquiry processes to develop decision-making skills. However, during the 2010 curriculum reform by the Ministry of education, the teaching of science in Ghana was also transformed when the curriculum designers emphasized the teaching and learning of science in Senior High Schools through practical work. The curriculum mandated teachers to engage science students in practical activities with the intent to develop innovation and critical thinking dispositions among them (MoE, 2010). The essence of the practical approach to teaching science was to develop critical thinkers and proficient problem solvers who will be capable of solving the nation's problem (Facione, 2015). The practical approaches to science teaching were also intended to develop practical and manipulative skills of students by introducing them to the processes and procedures for the conduct of investigations in science. This was a way of introducing students into the world of work of the scientist, develop interest and also foster collaboration among the students.

The historical development of practical work in science have been one of recipes without a focus, to the cookbook approach towards the teaching of scientific concepts. This has given way to the heuristic approach where teachers were consigned to the background to allow students to discover things on their own without teacher succor or direction. Currently, the teaching of scientific concepts embroils engagement of students in practical work by offering opportunity to be involved in analytical and logic thinking. This has resulted in the development of critical thinking of students required for problem solving needed in the 21st century. Recent development in science teaching suggests, to enable students derive maximum benefit from practical work, it has to be designed with the student in mind instead of the student left alone (Heuristic Method). The students' prior conceptions and experiences as well as exposure to scientific information serves as guide towards the conduct of the practical and must be (Scheurs & Dumbraveanu, 2014). Students must be offered the opportunity to engage in hands on practical work that has the advantage of developing critical thinking and problem solving skills. Teachers must not be relegated to the fore, but must be involved in co-creating scientific knowledge through effective use of apparatus and skills. This will equip the students with scientific competencies and dispositions required for solving their individual and societal problems (Antink, 2013).

2.2 The Concept of Practical Work in Science

In today's world where technology has been improving rapidly, understanding the nature of science and attaining knowledge has become relatively easier (Nwangbo & Chukelu, 2011). Producing scientific knowledge, suggesting and interpreting problems, developing scientific attitudes as well as creative thinking skills have become the primary aim for teaching chemistry (Ghartey-Ampiah, Tufuor, & Gadzekpo, 2004).The teaching and learning of chemistry cannot be complete without the practical component (MoE, 2010). Practical work seeks to equip students with motivation, interests, attitudes and development of skills that help in student's achievement (Vieira & Vieira, 2016). Good quality practical work helps develop student's understanding of scientific processes and concepts (Asmah, Baah & Eghan, 2021). Practical work seeks to complement the understanding of theories, principles, facts and concepts which form the basic tenets on which science education thrives (Antwi, 2017). Practical work is used as the medium employed in teaching the products and the processes of science and the thinking required to make meaning from the findings obtained (Shana & Abulibdeh, 2020). Practical work is defined by Millar (2004) as any type of science teaching and learning activity in which students, working either individually or in small groups are involved in manipulating and or observing real objects. According to Millar, (2004), the manipulation of materials are intended to study phenomenon with the aim of increasing understanding of the real world. From Millar's definition, it can be deduced that practical work can be conducted either in groups where the materials are not enough or individually, when the materials are in abundance. The act of working together helps develop collaborative and corporative skills needed for solving societal problems (Bridges, Davidson, Odegard, Maki & Tomkowiak, 2011). Practical work involves operation of instruments and equipment aimed at developing students understanding of the natural world. The operation of instruments and equipment in science demands that students develop basic skills required for handling and interpreting data obtained during practical work. Millar (2004) in his definition of practical work again posits that students understanding, motivation and interest increases when they are offered the opportunity to be involved in manipulating scientific equipment and apparatus. The act of engaging students in scientific activities with the view to developing the skill of using scientific tools and equipment introduces them to the world of work of the scientist (Jokiranta, 2014). Practical work must appeal as a way of allowing students to learn with understanding while at the same time, engaging in a process of constructing knowledge by doing (Akben, 2015). The knowledge of science thrives when students' scientific processes are employed through practical work in guiding the development of understanding the products of science unaided or with little guidance (Zeidan & Jayosi, 2015). Thus said, it can be deduced that scientific knowledge does not develop by the mere fact that teachers use practical work. Teachers are expected to plan the material to use as well as define effective engagement strategies that will enable students to manipulate scientific apparatus using scientific basis to construct their own knowledge. Teachers must facilitate student's engagement in their learning process with opportunities for exploring, discussing and analysing so as to solve assigned problems (Twahirwa & Twizeyimana, 2020). Teachers are expected to be creative and insightful in this regard. A broadened definition of Practical work was stated by Millar (2008), when he concerted that practical work involves engaging learners in experiences, skills and enjoyment of science while enabling them to think and act in a scientific manner. Millar's claim is in tandem with Woodley (2009) when he posits that, the essence of practical work in teaching science is to enable students to form links between the domains of real objects and observable things and the domains of ideas. Woodley (2009) remarked that drawing these links could be very challenging. Science teachers needs to be innovative and versatile at any point to make these links implicit (Bridges et al, 2011). Science teachers are expected to be abreast with current pedagogies to practical work so that they can devout much time and efforts to reflect on linking scientific concepts with the natural world (Jokiranta, 2014). Students can make sense of the links when they are involved in assigning reasons to observed phenomenon by drawing on their experiences and logic analogized from scientific concepts and theories learnt from science lessons (Pan, 2016).

Undoubtedly, the focus of practical work in the teaching of science has changed in recent times from the use of tangible laboratory equipment that require skillful handling to virtual laboratory suites (Baladoh, Elgamal & Abas, 2017). The use of softwares such as Chem-lab and Electronic-laboratory (E-lab) have become very efficient for teaching practical work especially during the lock downs when our world was ravished with COVID-19 (Rohim, 2020). However, there is very limited literature on the efficacy of use of these softwares at developing science process skills and critical thinking. Most teachers who have used these softwares complain of its efficacy at helping students to understand concepts in science (Rohim, 2020). However, the use of Chem-labs and Electronic-laboratory (E-labs) are limited to the student's knowledge and competency in information technology skills. To ensure effective utilization of practical work in the teaching and learning of science, it is important that practical work is designed to enable students make connections between the real world that is known and the unknown world (Pan, 2016). This can be achieved when teachers do effective planning of practical sections by allowing students access to laboratory equipment, apparatus and chemicals. Engaging students in meaningful practical sections by providing opportunity for them to explain their observations in consonance with scientific propositions develop problem solving skills (Akben, 2015).In this regard, it is important that teachers perform their role tactfully during practical lessons so that students develop love and interest in science enabling them to opt for carriers in science. Practical work can stimulate and engage students' learning at different levels, challenging them mentally and physically in ways that other science pedagogies and experiences do not (Shana& Abulibdeh, 2020).

2.3 The Importance of Science Practical Work

Many researchers have emphasized the importance of practical work in teaching science. Millar (2008); Woodley (2009) have asserted that effective practical work can develop science students' skills in understanding the processes and procedures of scientific investigations. They were of the opinion that science practical work develops students' science concepts, theories, laboratory skills and scientific knowledge. Their assertion is supported by Hodson (1996) who believes that learning about science has to be linked with doing science. This implies that it is not enough to introduce scientific concepts and theories to students without allowing them to embark on scientific procedures that guide their development. Alkan (2016) again posits that practical work develops problem solving skills by improving conceptual understanding of students. Students learn better and are able to retain majority of material learnt, when they are allowed to practice by manipulating equipment and apparatus in order to find things for themselves. Practical work in science seeks to afford students the opportunity to practice the scientific method by collecting data through observation, formulating hypothesis, testing them and developing meaningful conclusions (Pan, 2016). Learning science this way, enables students to form their own conceptions of the world without being told. According to Okam and Zakari (2017), Practical work promotes students' positive attitudes and enhances motivation for effective learning. However, the task of finding meaning to data and observations made in line with scientific reasoning could be very daunting for students. Encouraging students to learn science in the face of such difficulty helps develop students' self-assurance and the belief that they can prevail in the face of challenges. In lieu of such difficulties, teachers must strive to motivate students during practical work such that students develop a feeling of satisfaction and sense of accomplishment when a problem is solved or an explanation given. Alkan (2016) once again posits that, practical work encourages and increases students interest in science and promote it as an engaging subject. From Alkan's view, practical work in science develops student's confidence when they are allowed to practice as "would be scientist" by allowing them to either design their own practical solution or guiding them to follow laid down procedures. Students get introduced into the practices of the scientist by developing the skills and attitudes required for effective practice. These skills includes recognition for evidence through observation and data collection and confirming or falsifying scientific piece of information using data. The skills required by scientist are the process skills (observing, recording, measuring, inferring and drawing conclusions) whereas the attitudes required for effective practice includes, objectivity, open-mindedness, creativity, critical thinking and innovation. Thus said, it can be inferred, practical work develops both science process skills as well as scientific attitudes(Van-Driel, 2021).The argument made by Alkan (2016) is in tandem with Sotiriou, Bybee, and Bogner (2017) when they asserted that practical work improves students understanding, develops students skill of solving problems, and guide students to understand the nature of science. These fetes in science can be achieved and consolidated by students when they are offered the chance to replicate the actions of scientist in the classroom. The scientific skills required for solving problems in science are the process skills. Process skill develops when students are effectively engaged in practical work by offering those hands-on and minds-on opportunities (Taale et al, 2018). Practical work should be designed to offer opportunities to students to apply their hands to task by managing apparatus with skill in obtaining information. The information obtained should be analysed, evaluated and interpreted in line with scientific concepts by critically examining the facts and making sense in relation with scientific practices. The use of apparatus with skill in generating students own information provide students with first-hand experience which can easily be remembered and related to applicable areas in solving societal problems (Sotiriou, Bybee, & Bogner, 2017). Practical work offer opportunities to students to be involved in high order thinking. Students who are involved in high order thinking are effective in analysing and are very proficient at solving problems (Facione, 2015). Practical work must be effectively utilized in schools to achieve student's proficiency. Teachers should always link the theoretical basis of practical activities conducted in science classrooms to observations made by students in order that students will appreciate the processes involved in the development of scientific knowledge. This can be done by allowing students to design their own practical work which seek to uncover the knowledge base of scientist. Applying the relevant scientific process skills backed by high order thinking involved in analysing scientific facts guides students to uncover and understand scientific truths in life (Jokiranta, 2014). Appreciable use of science processes skills to uncover scientific knowledge motivates students to appreciate how knowledge develops in the real world (Van-Driel, 2021). The practice of teaching science concepts, theories and facts without allowing students the chance to verify or falsify scientific information leads to passivity which induces negative attitudes of students towards learning science (Okam & Zakari, 2017). When this happens, students will see science as knowledge which thrives only on memorization and not on the processes leading to the development of knowledge (Shana & Abulibdeh, 2020). The need to falsify or establish truism of scientific information cannot be complete without students' scientific attitudes. Students can nurture the skill of developing scientific information only when they have developed positive attitudes towards practical work (Hinneh, 2017). This suggests that teachers model positive attitudes during practical work by engaging students in knowledge generating process with the intent to helping them develop an appreciation of scientific attitudes. Teachers need to guide students to develop basic reasons to findings made from practical work by reflecting on the processes and procedures followed through in arriving at the findings. Teachers should respect each student's opinion in an attempt to explain their findings by guiding them to make sense of the observations made from phenomenon (Hinneh, 2017). Students must draw meaning from their own observations made in line with scientific propositions.

From the review above, it can be inferred that teachers play a very crucial role during practical work as far as developing students' science process skills are concerned. Teachers as change agents must stay abreast with current pedagogies used in teaching practical work to inspire students to give off their best. In the face of the numerous challenges confronting the teaching of practical work in chemistry, teachers must strive to achieve heights in practical teaching if the development of the 21st Century citizens would be a reality. Teachers must offer avenues to students' during practical work to develop their own understanding of the world without being told. Teachers must motivate students to bring out the very best in them during practical engagement. Teachers must concentrate their efforts at helping students to do science as opposed to being taught science. When students are offered opportunities to use apparatus and equipment in science with the required skills and enthusiasm, they are able to obtain the desired answers to their questions. The students would be motivated in developing the scientific proficiency expected for problem solving and decision making in life.

2.4 Development of Science Process Skills

Science process skills also known as generic skills are the skills used by scientist to solve problems (Darmaji, Astalini, Kurniawan, Ningsi, Romadona & Dari, 2020). Science process skills involve the use of inquiry backed with manipulating instrument and equipment with reasoning (Malau, Motlan & Lubis, 2020). Science process skills are the tools that students use to investigate the world around them (Ongowo & Indoshi, 2013). Students must have a good understanding of science process skills in order to use them (Kelley & Knowles, 2016). Science process skills when effectively applied aids conceptual understanding through analytical thinking and thus help students in developing problem solving ability (Coleman, 2014). It is very important to note that when knowledge is generated by students through practical work, it stays in their long term memory and help direct independent learning (Irwanto & Rohaeti, 2017). Irwanto and Rohaeti (2017) again contend that science process skills promotes conceptual learning which guides students to move away from rote learning as a consequence of hands-on learning. SPS describes students' thinking ability and requires reasoning. A study conducted in Turkey by Gultepe (2016) on the views of senior high school science (Physics, chemistry and biology) teachers' in the use of science process skills, revealed that science process skills had positive effects on science education in terms of learning, attitude, higher thinking, self-efficacy and practice. More than 50% of all teachers involved in the study held the view that science process skills backed up permanent learning without rote learning and supported higher thinking skills. Gultepe (2016) concluded that science process skills helped improve scientific thinking, creative thinking, analytical thinking, critical thinking and problem solving ability of the students. From the above review, it can be said that practical work tailored and structured with the student in mind would effectively guide students in explaining observed phenomenon. Students must have the chance during practical work to analyse findings and issues that pertains to observations made or information gathered. Teachers need to employ and develop practical sections which emphasize process skill development rather than presenting content (Simon, Erduran & Osborne, 2006). This can best be achieved when students have the chance to design their own practical work to solve daily problems. Teachers must design practical sections which take cognisance of student's ability to gather, analyse and explain data obtained from practical work (Darmaji et al, 2020). This will help develop student's ability to be involved in critical thinking needed for solving problems. However, research suggests that when science process skills are not developed through practical work, it stifles students' high order, analytical, and critical thinking skills (Sunyono, 2018). A study conducted by Irwanto, Rohaeti, Widjajanti and Suyanta (2017) on the use of science process skill in developing critical thinking ability affirmed that most students obtained low score on science process skills. This they suggested did not develop analytical thinking in chemistry because teachers did not engage well with the students during practical work. Their assertion is in tandem with Oloyede and Adeoye (2012), when they concerted that lack of practice in process skills does not develop students' critical thinking. They both concluded that teachers need to enrich the teaching of the science curricula with access to material and equipment backed by guidance in developing student's competences in science. This way, students will develop confidence and interest required for learning science. If the learning of science concepts is integrated with opportunities to develop SPS, learning becomes easier, more effective, worthwhile

and more permanent (Antwi, 2017). To ensure effective engagement of students during practical work, Inan & Inan (2015) contend that opportunities must be given to students for manipulation, teacher support, and enriched activities to help develop students to be more hands-on, minds-on, and hearts-on (Taale et al, 2018). The practice of teaching examination oriented science does not permit students to develop critical thinking because students are not challenged to reason to issues. Students are only involved in memorizing facts just to pass examination. This practice does not develop critical and analytical thinking skills required for problem solving in science. To develop critical thinking, students should be allowed to take full advantage of science practical work with opportunities to explore so as to observe, manipulate, infer, record and communicate their findings (Taale et al, 2018). This is done with the view to enable students assign reasons to basic observations made which draw on high order thinking. However, it is worth noting that, most science teachers do not allow students to develop these methods deemed appropriate during practical work in solving practical problems. Students are made to follow strict practical procedures on task sheets which give little or no room for student's creativity and innovation. Students, in some cases, find it difficult to connect the procedures tabled on the task sheets. Students just carry out the practical work without understanding the processes for developing the science concepts. This attitude by teachers does not allow students to develop the required analytical and critical thinking dispositions intended from practical work. Practical work thus becomes procedural and does not allow students to develop the competences required for critical thinking needed for problem solving in science.

From the review above, it could be deduced that science process skills develop when students are allowed to observe phenomena, make their own conclusions by analysing the observations made in accordance with scientific knowledge. Student's science process skills again develop when they are involved in high order thinking in their attempt to explain observations made during practical work. Students develop their science process skills when they are able to make intelligent guesses based on the observations made by collecting data in substantiating the observations made. Science process skills develop when students are allowed to observe phenomena, make their own conclusions by analysing the observations made in accordance with scientific knowledge. Student's science process skills again develop when they are involved in high order thinking in their attempt to explain observations made during practical work.

2.4.1 How Students Develop Science Process Skills

Science process skills are classified as psychomotor or cognitive skills because they involve both hands and minds in coordinating practical activities to achieve results (Hanson, 2018). Science process skills develop when practical activities are conducted with the intent of helping students in solving practical problems by developing the skills and competencies relevant for working around the problem (Koomson, 2020). For this reason, the senior high chemistry curriculum prescribes that senior high chemistry students must be involved in the demonstration of manipulative skills by using tools, machines and equipment for practical problem solving (MoE, 2010). The senior high curriculum also prescribes the teaching of practical skills to include projects, case studies and field studies where students are involved in practical work in the search of practical solutions to problems (MoE, 2010). This suggests that SPS develop when students are placed at the center of the teaching and learning process (practical activities) to interact with materials and equipment to facilitate the understanding of scientific concepts. Engaging students in practical activity guides the development of scientific skills needed for generating knowledge within the context of the student. Science process skills help students develop their creativity by making them think like scientists (Ozdemir & Dikici, 2017). In titremetry, students are expected to develop the skills needed in handling apparatus, collecting data, making measurement and solving problem assigned. This process when effectively planned and executed has the propensity to develop the following science process skills;

Observing: noting the attributes of objects and situations through the use of the senses. There are three types of observation skills; using various senses to identify similarities and differences, identifying changes, and observing using measurement (Sudibyo, Naini & Sabtiawan, 2019). Generally, the curriculum describes observation as the use of the five senses in collecting information about a phenomena or event (MoE, 2010). The senior high chemistry student that has mastered observing skill should be able to tell the color change, form, texture and the structure of specimens provided and be able to classify them using defined characteristics. During titration, senior high chemistry students observe the fall in level of titrant, record the difference in volume, observe color change at the equivalence point, indicate the color formed at the equivalence point and deduce the stoichiometry concentration of the acid used by calculating the concentration of the unknown base. The exercise above suggests that observing, a process science skill, develops when students collect information and relate to the characteristics of the phenomenon being observed by drawing on facts, patterns, concepts and principles in line with scientific concepts so as to solve personal, social or environmental problems (MoE, 2010). Through hands-on activities(practical work), students use different senses by touching, feeling, moving, observing, listening and smelling and sometimes testing materials in a controlled manner. This help students to progress from concrete thinking levels (psychomotor skills) to more complex thinking levels which promotes higher order thinking (cognitive skills) required for solving problems by reasoning.

Measuring: refers to the accurate use of measuring instruments and equipment for measuring, reading and making observations. Measuring involves the skill of use of accuracy and precision involved in using a quantity in order not to mis-measure. The senior high chemistry curriculum suggests that senior high students must develop appropriate techniques for handling, maintaining and storing laboratory materials and by using appropriate personal protection equipment (MoE, 2010). As a skill, measuring develops when senior high chemistry students are offered the opportunity to use scientific equipment such as burette, pipette, conical flask, retort stand in the laboratory by developing the skills needed in using the equipment accurately. This suggests that measuring, a science process skills, develops through observing phenomenon, manipulating skills and accuracy in recording the measured quantity.

Recording; involves the skill of drawing or making graphical representations boldly, clearly and accurately in relation to findings, observations and the issue at hand (MoE, 2010). The senior high chemistry curriculum again proposes that senior high chemistry students should develop the ability to communicate ideas, plans, procedures, results, and conclusions of investigation orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g. data, tables, laboratory reports, presentations, debates, models) (MoE, 2010). Recording, science process skills develop when students identify appropriate medium by which to record the proceedings or observations made from the practical work conducted. Recording also develops when senior high chemistry students ensure that observations made are accurately documented and can be referred to later as reference. Recording again develops when chemistry students reproduce experiments and verify results (reproducibility) by conducting practical work in the laboratory. Recording of experimental data enable the sharing of findings with others, which can lead to new discoveries and collaborations (sharing) of experimental results or scientific information. Recording data in a structured way helps students to organize their findings and make sense of complex information (Koomson, 2020). The review above suggests that recording, a process skill, develops when chemistry students keep accurate proceedings pertaining to the conduct of titremetry by noting clearly and accurately all the processes involved in the determination of the concentration of the analyte. The senior high chemistry students keep laboratory note books which enable all proceedings including observations made, calculations done, and practical work conducted are accurately kept and referred to at any time (MoE, 2010).

Calculating; in titremetry, students are expected to measure the quantity of base consumed in a neutralization reaction or determine the time required to completely ionize an acid in a chemical reaction. Using numbers to express quantities observed guide students in understanding data by integrating numbers with quantities. The senior high curriculum recommends that students must be guided in using appropriate numeric, symbolic, nomenclature and graphic modes of representation and appropriate units of measurement (e.g. SI units) in expressing quantities of substances used during practical work to enable them relate the unit with quantities (MoE, 2010). Calculating develops when students are able to express in quantitative terms the variables used as observed with their correct units.

Predicting; is the skill of forecasting what will occur in the future. Prediction is closely knit with other process skills such as observing, inferring and classifying (MoE, 2010). Prediction is made about the outcome of future events based on the pattern of evidence and classifying in line with some defined characteristics (Moreno, Alario, Muñoz & Kloos, 2018). Prediction is based on student’s prior knowledge, experiences, observation and investigation. Prediction develops when students are able to question events based on observations by using their experiences. Prediction again develops when students are encouraged in making speculations about hands-on practical activity and stating the reasons why they think in that manner (MoE, 2010). As senior high students become mature thinkers by reasoning, their predictions in enquiry become more justified in line with scientific knowledge and understanding. Prediction becomes a motivating factor when it is gotten right. This suggests that students must be rewarded with prompt feedback to increase the chance of students predicting. Most research suggests that students who are able to offer explanations to phenomenon usually base their predictions firmly on everyday knowledge of their world (Lang, 2021). In effect prediction, a process skill emanates from questioning issues, observing phenomenon, forecasting based on information collected and hypothesizing. Prediction develops when chemistry students make conscious effort to reason to the hypothesis by weighing evidence gathered.

Classifying; involves grouping or ordering objects or events into categories based on shared attribute**s,** properties or criteria (MoE, 2010). Classification, a basic science process skill, provides the foundation for learning more complex integrated skills. During titration, the senior high chemistry students are required to identify liquids and color changes on addition of indicators. The students are also required to identify the color change and use it in predicting both the liquid type as well as the equivalence point of the liquid used. The students then carry out the actual hands-on practical work in verifying the propositions made. This implies that classifying develops when students observe events by noting similarities and differences, questioning the bases for the difference in identifying a common criteria, forecasting the form or characteristic that may be missing and using their scientific knowledge and experience in finding the missing character (Darmaji, Astalini, Kurniawan, & Wirayuda,2022).

Inferring: involves the process of drawing conclusions based on evidence and reasoning (MoE, 2010). It is a logical conclusion based on previous experiences, observations, and scientific knowledge. Inferences can be used to suggest correlations, interpret data, or lead to a hypothesis (Zhang, 2022). Prediction also involves interpretation or explanation of an observation in making inferences, students connect what they observe to their prior knowledge and the new information observed through the senses. Inference develops when alternative hypotheses are devised with alternative possible outcomes. Each of the outcomes will, as nearly as possible, exclude one or more of the hypotheses. Experimental results explained in line with the data gathered or observations made are the only way to get a clean result (Aydin & Esen, 2022). Inference can be used to suggest correlation, interpret data or lead the formulation of hypotheses. Chemistry students are expected to engage in high order deductive and inductive reasoning during practical work in order to develop the skill of drawing inference from the observations made, data collected and explanations made the pursuit of scientific truth.

Conclusion

Science process skills are the skills and procedures used in doing science. Science process skills develops when chemistry students have the opportunity to observe phenomena, question events, use scientific equipment with the required skill and accuracy, and determining quantities of substances used during practical work by assigning appropriate units and reasons. Science process skills develop through hands-on activities during practical work when students engage in high order reasoning in their attempt to justify forecast or predictions. (observing, providing explanations, predicting, forming logic, making inquiry, producing according to a plan). Science process skills develop when students relate facts, principles and concepts by relating to the theory of using scientific process skills and attitudes of the students themselves.

2.5 Types of Science Process Skills

There are two main types of science process skills namely basic/primary science process skills and integrated science process skills (Maison, Darmaji, Astalini, Kurniawan, & Indrawati, 2019). The primary science process skills also known as basic or fundamental process skills includes recording data, classifying, measuring, communicating, observing, using space and time, estimating (predicting) and drawing conclusions. Basic process skills are fundamental for scientific inquiry. Integrated science process skills also referred to as experimental skills are well grounded and more complex and advance (Kalemkus, Bayraktar & Çiftçi, 2021). This is because integrated process skills consist of more than one of the basic skills. Integrated process skills include hypothesizing, determining/controlling variables, interpreting data to prove or rebut, designing/conducting experiments, modeling, and defining operationally. These processes pave the way for more questions to be asked and more experiments to be carried out (Gultepe, 2016). It is important to note that the Senior High School Curriculum in Ghana does not only emphasize the development of basic science process skills but also the integrated process skills (MoE, 2010). Science process skills, according to the Senior High Curriculum should be developed by students working together as a team to solve complex, challenging and thought provoking problems. Students are to work together in developing collaborative and corporative skills during practical work. Developing collaboration among students during practical work becomes a facade in developing scientific attitudes that solving the problems of society demands the collective efforts of all scientists.

From the review above, it can be said that SHS chemistry students can effectively develop their science process skills during practical work by working together with the aim of developing better understanding of scientific problems so that together they can solve. When practical work is designed to allow students to work together, its builds their confidence and interest in issues which are of mutual concern to them. The review also implies that teachers must design practical work with the reason to help students develop their science process skills by offering them opportunity to discuss scientific findings. Students must use every opportunity offered by teachers during practical work to discuss findings, weigh options, examine events and deduce the best possible means that can be used in determining workable solutions. Solving scientific problems involve manipulating scientific apparatus with aim of developing data that can be used to better analyse the problem at stake.

2.6 Science Process Skill and Cognitive Development

Science process skill is a cognitive and psychomotor associative skill used in problem solving. According to Abungua, Okere and Wachanga (2014), engaging students in practical activity affords them the opportunity to interact with science process skills that can be used to solve problems in everyday life. Practical activities offer a rich avenue for students to make meaning from observations and findings deduced from hands - on engagements (Taale et al, 2018).This allows students to draw on creativity and critical thinking to offer explanations backed by data which conforms to the practice of chemistry. Thus practical work in chemistry enables students' to scaffold knowledge construction by relying on practical findings made to creatively and critically offer suggestive reasons to the findings. Practical work guides the development of students' critical and analytical thinking ability. Analytical thinking ability is the ability to analyze, assess, evaluate, compare and contrast abstract concepts (Holt & Pache, 2012). Indicators of analytical thinking include differentiating, organizing and attributing concepts. Analytical thinking ability is harnessed when students are engaged in practical activity which allows them to apply the reason at getting a designed problem solved. As students develop their thinking ability, they develop their senses which in effect help them to develop their SPS. The indicators of science process skills are; observing, designing, drawing, classifying, recording, measuring, predicting, concluding analyzing, applying, summarizing, communicating, evaluating, synthesizing, creating, and solving problems. Engaging students in SPS separately from all the stages of inquiry learning enables students to connect subject content knowledge (Abrahams, 2017).

However, Mwangi (2016) indicated that, currently practical work is ineffectively used in the teaching and learning of science. He hinted that practical work does not contribute very much to learners' conceptual understanding. Most chemistry teachers teach chemistry as bundle of abstractions without engaging students in effective practical hands on activities that give room for students to offer suggestive explanation to phenomenon (Inan & Inan, 2015). This practice does not offer students' the learning experiences needed to develop creativity, critical thinking and process skills. The current approach to teaching practical work where students are exposed to abstract concepts without offering avenues for suggestive explanations breeds passivity in chemistry classrooms. Currently, the teaching of practical work makes the study of chemistry difficult, boring and uninteresting for students(Dawson & Carson, 2013). Chemistrystudents are not actively involved in knowledge construction during practical work (Chairam, Klahan, & Coll, 2015).

To forestall this, teachers in chemistry classrooms have a key responsibility to teach science process skill through a series of scientific learning processes Grumbine

(2010), designed to increase students ability to think critically, solve problems and to develop an appreciation of the knowledge construction process.

2.7 The Concept of Critical Thinking in Science

Critical thinking (CT) is gaining much prominence in the current educational dispensation**.** Dwyer, Hogan and Stewart (2014) contend that critical thinking has much importance because it enables students to think and analyse issues constructively so that they can make informed judgments. Critical thinking has become one of the pillars in modern education (Changwong, Sukkamart & Sisan, 2018). This is because when the human capita is imbued with CT, solving the numerous problems confronting society becomes much easier (Woodhouse & Nieusma, 2018). There is currently no explicit definition for CT (Changwong, Sukkamart & Sisan, 2018). However, most researchers have defined CT based on their academic and professional orientations. Shaw (2014) defines critical thinking as a mental process, strategies, and representations used by people to solve problems, take decisions and learn new concepts. Critical thinking has been defined by Ghanizadeh (2017) as purposeful self-regulatory judgment which results in interpretation, analysis, evaluation and inference. Ghanizadeh (2017) further reiterates that critical thinking also involves contextual considerations on which judgment is made with the intention to undertake meaningful life decisions. Some researchers equate CT with good or desirable thinking (Pithers & Soden 2000: Johnson & Hamby 2015). Other researchers believe that CT is directly linked to existential thinking which relates more as a skill that should be cultivated (Saha & Ahuja, 2017). Again, CT has been defined as the progression of thinking that is intended to lead to a comprehensive, defensible choice, inference or result rather than a category of thinking (Giselsson, 2020). Zhang (2020) contends that critical thinking is a higher-order thinking required for creating innovative abilities engaged in solving the problems of society. In addition, CT skills are required in the process of analysing possible solutions during problem solving and evaluating consistency between alternatives during decision making (Dilekli, 2019). From the perspectives above, there is some complexity and similarity relating to CT. It is very important to note that irrespective of the spectacle with which one looks at it, one major characteristic stands out. Critical thinking involves making value judgment out of empirical evidence by subjecting information to rational analysis in order to making deductions and conclusions (Clor-Proell, Proell & Warfield, 2014). This suggests that CT does not emanate from rote learning or pure memorization of facts. Critical thinking develops by making assertions and weighing options with the view to making the best decision. Both Critical thinking disposition and critical thinking skills are high order skills needed by students for obtaining information, collecting data, evaluating findings and drawing meaningful conclusions (Peter, 2012). To think critically, means to be involved in the mental process of applying concepts, analyzing, synthesizing, evaluating and interpreting results and reflecting on choices made towards decision making (Forawi, 2016). This suggests that Critical Thinking skills or disposition are necessary not only for solving societal problems but also for making meaningful decisions in life (Carriger, 2015). Critical thinking is important in helping students to overcome the incidence of passivity in science classrooms. A lack of CT disposition among students can adversely affect academic achievement (Egege & Kutieleh, 2009). Science teachers and their students become actively involved when they are seen to be assigning reasons to observation or phenomenon by analysing issues using scientific basis. Students make meaning from their own interpretation when they have access to accurate scientific information that make meaning to them. To be conversant with critical thinking, teachers must guide students to subject every piece of information collected or observed to the scientific method. Students should analyse their own information while teachers offer guidance to students reasoning to enable them make sense of the information collected. Thus said, it can also be deduced that CT as a skill should be taught and developed by both science teachers and students to guide their studies. CT thrives on individuals making sense of issues by weighing options and selecting the value which best fits the solution to a problem (Forawi, 2016). Teachers are expected to engage students in critical thinking with the view to developing meaningful learning. Practical activities designed to be carried out by students must have avenues for students to weigh options, analyse the problems, examine facts, select the best option which best fits their experience. However, it is important to note that, CT is not developed adequately in schools by teachers and students these days. This is because students are not given enough experiences which offer a greater challenge in CT. Students are not confronted with opportunities that will enable them to explore variables and options aimed at improving thinking by analysing, evaluating or interpreting alternatives by considering logic in science (Facione, 2011). This situation does not enable students to think and analyse issues on their own. Students are not developing the skills required for CT. An alarming situation that should to be curtailed in order to make teaching and learning of science more meaningful. A study conducted in Malaysia by Prihartiningsih, Zubaidah and Kusairi (2016), revealed that critical and creative thinking dispositions are the least developed among biology and chemistry students in Junior High, Senior High and

University undergraduate students. Prihartiningsih, Zubaidah and Kusairi (2016) again contend that students are not developing their critical thinking skills because teachers do not effectively engage them to observe, predict, analyse and draw conclusions. They reiterated that students are not engaged in high order thinking during practical work in analysing issues. Another study conducted in Lithuania on the value of critical thinking disposition in higher education and the market place revealed that, CT is a key requirement for employment today (Maniusis, 2019). Critical thinking has become a basis for decision making and problem solving among organizations. The study concluded that the development of critical thinking must be a systematic process and all participants in the process (students, lectures, employees and employers) must assume responsibility for its outcome. Science education practitioners must adapt strategies that will offer hands-on opportunities to students and guide them to apply their knowledge to unravel some of the solutions to problems facing societies. To develop CT, students must be guided through pedagogy to intuitively imbibe critical thinking dispositions (Facione, 2013). This can be achieved when students are engaged in the process of analysing, synthesizing, inferring and drawing conclusions based on their own experiences. Research suggests a strong correlation between problem solving and critical thinking. Suarniati et al (2018) in their study on critical thinking development found that students who were involved in problem solving and decision making in class developed the skills of logic thinking which guides them in solving problems. Suarniati et al (2018) again reported that science teachers must involve students in practical problem solving activities which has the advantage of allowing students to conduct investigations by observing phenomenon so that they can conclude on their own using logic. Their findings were in line with Zubaidah, Corebima, Mahanal and Mistianah, (2018) when they concluded that the development of critical thinking skills results in improved quality of thinking needed for reasoning and logic in problem solving. Problem solving enables students to draw on their reasoning and creativity. CT helps students to be autonomous and proficient in problem-solving (Facione, 2015). Students who can reason logically can think critically and are very proficient at solving problems (Facione, 2011). It is imperative on teachers to develop practical pedagogies that seek more from students to apply their thinking in solving problems. Paul and Elder (2008) in their study on the development of CT indicated that teachers play a critical role in developing CT amongst students. They assert that critical thinking is very important in producing reflective scientists who able to engage in problem solving and decision making which affect human lives. Paul and Elder (2008) again contend that teachers are not engaging well with students in order to help them develop CT. Teachers must engage students in inquiry and deductive analysis to enable them develop high order level thinking, a prerequisite for the development of critical thinking (Ayçiçek, 2021). In our science classrooms, teachers only teach concepts and expect students to memorize answers to questions without subjecting it to any form of rational analysis (Antwi, 2017). This practice hinders retention and content application. This situation is breeding students who are incapable of thinking independently due to their inability to engage in scientific discussion.

How do critical thinking skills develop?

Inference is the process of drawing conclusion based on evidence and reasoning. It is a key component of the scientific method and allows use data to learn about observable phenomena through models. Inference is based on previous experiences, observations, and knowledge of students and it can be seen as an educated guess. The senior high chemistry curriculum prescribes that students should be involved in making inferences and predictions from written or graphical data by either extrapolating or deriving conclusions (MoE, 2010). Inference, a critical thinking indicator, increases students' ability to develop understanding of scientific knowledge, critical thinking, decision making, and problem-solving skills. Practical work enables chemistry students to collect information (data) in a systematic way to draw conclusions about phenomena. The conclusions go beyond the data collected by incorporating guesses. This suggests that Inferences are based on real, observed evidence but are still just guesses about the true relationship that exists between data. Scientists often make inferences based on assumptions made of small population and then argue that such assumptions are representative of the whole. Critical thinking develops when students are engaged observing details of characteristics about phenomenon, making assumptions, collecting information/data to substantiate the assumption made or otherwise, drawing conclusions based on assumptions. It must be emphasised that all the above skills require the use of high order thinking and reasoning for developing these indicators. Most research suggests a higher correlation between inference and hypothesis. When students are engaged in developing differencing and hypothesizing, then they are developing their critical thinking ability. Inference is a cognitive process whereby we derive conclusions, assumptions, predictions, and explanations based on our interpretations of observable data. Making inferences skill includes the action of using the observed information to interpret, or make an early conclusion. Evaluation, a critical thinking indicator, involves the process of examining evidence in making a judgment (MoE, 2010). Evaluation involves analyzing and assessing sources, data, facts, and phenomena. Evaluation helps to draw reasonable conclusions, solve problems, make decisions, and develop arguments (MoE, 2010). Evaluation develops during practical work when students are involved in examining important information, asking relevant questions, assessing findings objectively and in line with scientific knowledge. Analysing on the other hand is the ability to analyze and effectively evaluate a problem using facts collected from observation and personal experiences. Students who have developed analytical skills can examine information, understand what it means, and properly explain to others the implications of that information. Analysing develops when scientist conduct unbiased research, asking relevant questions, collecting accurate and relevant data, and assessing findings objectively (Creswell, 2012). People with analytical skills can examine information, understand what it means, and properly explain to others the implications of that information.

2.8 Measuring Critical Thinking in Science

Recognizing the value of critical thinking in the 21st century and the importance it brings regarding decision making and problem solving in science, most renowned science educationist have advocated for it to be developed and assessed in the teaching curricula around the world (Hidayati, & Sinaga, 2019). One major hindrance to the assessment of critical thinking is the exact cognitive construct that CT seeks to measure (Lederman, Lederman & Antink, 2013).

Generally, critical thinking is measured using a standardized tool which does not have any relationship with science (Walsh, Quinn, Wieman & Holmes, 2019). Lai (2011) posits that the challenge with these standardized critical thinking tools is the assumption that critical thinking is critical thinking irrespective of the particular subject area used in measuring it. Science in general and chemistry in particular, requires CT skills which pertain to content knowledge in science and skills development. Yu, Lin and Chang (2017) suggest that measurement of CT in science require both domain-specific knowledge and science content knowledge. However, most of the standardized CT tools do not exactly measure content knowledge in science. The Domain specific CT seeks to measure critical thinking from the point of view of subject specific knowledge and dispositions (Chattuchai, Singseewo & Suksrinarm, 2015). This implies, domain specific CT is measured from the knowledge of one subject area and transferred to general CT required for living in the 21st Century. However, the Domain general CT measures critical thinking from a general perspective (world view) and narrowed to specific content knowledge (Chaipichit, Jantharajit & Chookhampaeng, 2015; Santos, 2017). CT skills are actuated when students encounter unfamiliar problems, uncertainties, questions, or dilemmas. Successful application of CT skills in the science classroom results in explanations, decisionsand analysis. Using CT skills that are valid within the framework of available knowledge and experience promotes continued growth in intellectual skills. These skills require students to transfer the scientific knowledge and apply it to new situations (Gillies, Nichols, Burgh & Haynes, 2014). The idea of transferring knowledge from one subject content area to another is characterized with another type of critical thinking known as transferable Critical thinking skills. The use of transferable critical thinking is based on logic and one's ability to reason to issues which may apply. Science researchers involved in the assessment of student's critical thinking skills have developed critical thinking assessment instruments for measuring them. Bissell & Lemons (2006) opine that measuring critical thinking skills using an instrument allows for easy assessment of the students' performance on a task so that it can be rated. Santos (2017) asserts that one way of measuring critical thinking skills is by using validated and reliable instrument that focuses solely on the cognitive aspects of the student'scritical thinking. The instruments used in the assessment of critical thinking skills usually come in a form of a test. Some of the critical thinking testing instruments include: the California Critical Thinking Skills Test (CCTST), Watson-Glaser Critical Thinking Appraisal (WGCTA), Halpern's Critical Thinking Assessment (HCTA), Cornell Critical Thinking Test (CCTT) and the Lawson's Classroom Test of Scientific Reasoning (CTSR). These standardized tests consist of multiple-choice items with options or essay type open ended items. The test instrument measures scientific reasoning skills which include probabilistic reasoning, combinatorial reasoning, proportional reasoning, and controlling of variables. The critical thinking testing instruments also measures cognitive skills such as analysis, evaluation of argument, argument analysis, likelihood and uncertainty analysis, decision-making and problem-solving (Halpern, 2014). Most CT standardized tools are Domain-general (Tabach & Friedlander, 2017). The standardized test focuses on test taker's critical thinking skills in general, which has no connection to science concepts. However, critical thinking within subject-domain (science) enables students to think, evaluate, and solve problems in a scientific way (Santos, 2017). Critical thinking has to be measured in science and science related concepts if it is intended to measure one's ability to think and reason critically in science (Yu, Lin & Chang, 2017).

It is worth noting that all these standardized tools measure certain specific aspect of critical thinking within the cognitive domain. This suggests that most of the standardized tools used in the measurement of students' critical thinking are not contextualized and are particularly alien especially in the African setting (Facione, 2013). One can reasonably conclude that all the domain-general CT tests are diverse in terms of their formats, scope and psychometric characteristics. Such variations in CT tests have made the assessment of CT problematic and contentious (Ennis, 1993; Pascarella & Terenzini, 2005). To forestall this pitfall, teachers need to develop relevant but appropriate test items that seek to measure the exact cognitive construct expected of students. The subject content knowledge and scientific skills needed for the development of domain specific CT skills must be brought to bear during the assessment of CT skills in science (Gillies, Nichols, Burgh & Haynes, 2014). This is because science as a body of knowledge has peculiar reasoning patterns which might not always be applicable to the general world view because it follows the scientific process (Yu, Lin & Chang, 2017).

2.8.1 Critical thinking and meta-cognition

Critical thinking is the way the scientist is expected to think whereas meta-cognition deals with how individuals are expected to think according to a theorized frame (Zhao, Wardeska, McGuire & Cook, 2014). Meta-cognition is defined as the information that a person has about their cognitive processes and products of these processes (Guo, 2012).An individual acquires meta-cognitive knowledge as a cognitive creature related to the various cognitive tasks, goals, actions and experiences during learning. Meta-cognition is a mental activity in the cognitive structure that a person uses to consciously organize, control, and examine the processes of thinking (Mercier & Heintz, 2014). Thus the thinking skills of students affect the success of what is taught (Amponsah, Kwesi & Ernest, 2019). Meta-cognitive development and scientific reasoning are important in guiding students learning to be meaningful (Zhao, Wardeska, McGuire & Cook, 2014). Most research in meta-cognition suggests a higher correlation between critical thinking and meta-cognition. Senior high school students need to critically reflect on how they think. Students' inductive and deductive reasoning skills play a major role in developing their critical thinking skills.

If critical thinking is the expected thinking patterns of the scientist, then it is important students are taught how to think critically (Tabach & Friedlander, 2017). However, very little research has been conducted on the teaching of critical thinking in schools.

2.8.2 Blooms taxonomy and critical thinking

Bloom's taxonomy underpins the underlining behaviour for teaching and learning and assessment as expected of learners after going through instruction. Anderson and krathwohl (2001) theorized the modern and the current concept of learning as relating to cognitive structures ranging from simple to complex. The cognitive domain involves knowledge and the development of intellectual skills (Anderson & krathwohl, 2001). This includes the recall or recognition of specific facts, procedural patterns and concepts that serve to develop intellectual abilities and skills. Bloom catergorised the cognitive domain into six major processes from the simplest to the most complex. The six levels of thinking are as propounded by Bloom includes: knowledge, comprehension, application, analysis, synthesis and evaluation (Yahya, Toukal, & Osman, 2012).

The categorization in the Bloom's taxonomy for cognitive development is hierarchically ordered from concrete to abstract. The hierarchical progression identifies the lower level to higher level of cognitive processing (Gill, Johnson & Clark, 2010). The first three levels of Bloom's taxonomy require basic recognition or recall such as knowledge, comprehension and application and these have been regarded as lower order level of thinking (Yahya et al., 2012). In contrast, the other three levels of Bloom's taxonomy require students to use higher order level thinking skills (Mainali, 2012). The high order level thinking skills is necessary for students learning and performance. A study conducted by Clark, Garret and Leslie-Lecky, (2010) on the cognitive domain among secondary school students reveals that, the first three categories (knowledge, comprehension and application) measure students' lower level of thinking. The other three levels of analysis, synthesis and evaluation measure higher levels of thinking. From the review of Bloom's taxonomy above, it can be deduced that practical work which suggest opportunities to students' to solve problems and make decisions relates to high order thinking. During practical work students are engaged analysing, weighing options, making self-regulatory judgment, interpreting dataand drawing inferences (Darmaji et al 2020). All these processes require cognitive characteristics related to high order level of thinking. Higher order critical thinking skills can have positive impact on student's achievement in class (Yahya et al, 2012). Critical thinking engages students in open mindedness, logic thinking, evaluation of received information as well as being skeptical about information flow (Lynn, Lanning & French, 2017). It is imperative that practical work is conducted in an atmosphere which allows students to question events and observations made with an attempt to develop their critical thinking skills. Students must be guided to analyse and interpret their own data in an attempt to develop their critical thinking (Paul & Elder, 2019). Developing critical thinking among students require teachers to carefully scrutinize the information offered students. This is to enable students sift relevant scientific information from irrelevant ones by subjecting it to rationalization in science. Research on cognitive skills indicates that facilitating students' higher order thinking skills in the learning process helps to make them more aware of their own thinking (Saido, Siraj, Nordin & Al-Amedy, 2018).When students become aware of their own thinking it fosters effective learning(Facione,2015). When practical work is well planned and structured and enriched with the requisite apparatus and equipment, students are engaged holistically. Students develop their critical thinking skills when teachers design practical work that encourages analysing, evaluating and interpreting findings made by drawing their conclusions. Critical thinking thus develops students' to be independent learners and problem solvers, drawing their own meaning from scientific activities which make sense to them(Yu, Lin & Chang, 2017). It is important that science teachers engage students in practical pedagogies which allow students to be co-creators of scientific information. Students must develop the appropriate skills required for conducting effective practical activities by striving to make meaning from their own findings to solve assigned problems. Critical thinking as a skill helps students in developing innovative solutions to modern day problems (Rodzalan, & Saat, 2015).Teachers must guide students to develop their critical thinking competences while at school so as to become effective citizens capable of solving the problems of the 21st century.

2.8.3 A Case study design

According to Yin (2003), a case study is most appropriate to be used when: (a) the focus of the study is to answer "how'' and "why" questions; (b) when the researcher cannot manipulate the behaviour of the subjects involved in the study; or (c) when the researcher want to cover contextual conditions because the researcher believes they are relevant to the phenomenon under study; or (d) the boundaries are not clear between the phenomenon and context.

2.8.4 Types of case study design

Case study designs have been defined by many researchers looking at it from different perspectives. Most case study researchers have categorised case studies because of the use of the data obtained from the study. Yin (2009) propounded the explanatory, exploratory and descriptive case studies. This is because Yin (2009), believed that the intention for studying cases is either to explain, describe or explore the occurrence of relationships or interaction between subjects or units to the phenomenon being studied. Studying cases closely unlock certain insights that are held within the subjects of study. Yin (2009) again postulates case studies as single, holistic and multiple. Taber, (2014) contends that intrinsic case study should be used by researchers who have genuine interest in the case(s) with the view to revealing typicalness or particularity of the cases. He was of the view that the intrinsic case study approach should be used when the intent is to better understand the uniqueness of the case(s).The purpose is not to come to understand some abstract construct or generic phenomenon but to understand the distinctiveness or uniqueness within and between the subjects. Stake (2000) categorized case studies as intrinsic, instrumental or collective.

2.9 Theoretical Framework

This study is informed and built on the social constructivist theory of teaching and learning which explains that knowledge as a human product is socially constructed. The emphasis of the social constructivist theory is that the teacher is not a reservoir of knowledge (Adams, 2006). The teacher is responsible for providing learners with challenging opportunities and activities that promote higher order level thinking during instruction (Nghipandulwa, 2011). Teachers must provide materials and equipment and stimulate learner's interest during instruction to get learners to reason effectively and think critically in order to explain observed phenomenon (Nilson, 2016). The teacher's role in this regard is one of a facilitator, provocateur, and creator of opportunity and co-developer of knowledge (Gawlicz, 2022). Teachers must provide the enabling classroom environment for student/learners to understand that scientific knowledge is generated by individuals by engaging in deep seated; thought provoking thinking that gives insights to scientific investigations. Learners on the other hand are to collaborate with themselves and their teacher to conceptualize abstract scientific concepts, theories, facts and principles by developing their own practical solutions to problems. Learners must develop their own opinion of facts, concepts, theories and principles and constructing their own understanding of scientific knowledge. Teachers and learners must co-create knowledge construction by engaging students in relevant classroom activities which seek to develop understanding of scientific concepts in the perspective of the students (San Pedro & Kinloch, 2017).

2.9.1 Conceptual framework

The conceptual framework of science process skills and practical work is deeply rooted in developing information processing skills, reasoning skills, critical thinking skills, inquiry skills and problem solving skills. Students receive information and are expected to process the information based on their understanding (Jensen, McDaniel, Woodard & Kummer, 2014). In processing the information in science, students resort to critical thinking and reasoning which are born out of science process skills (Facione, 2015). A student is said to perform better in chemistry when involved in high order thinking by applying creativity to reasoning and thinking. Observing issues, collecting adequate information about the observed phenomenon, analysing the information by making measurement and weighing options in order to arrive at a logical conclusion (Yu, et al, 2017). This suggests that effective practical work engages students by providing them opportunities and experiences that draw on their ability to apply concepts. Engaging students in deep seated reasoning enrich them with the skills of problem solving.

Deep seated reasoning involved in practical work has a strong correlation with critical thinking (Zhao et al, 2014). It can be inferred that, effective practical work enables students to develop the requisite science process skills required for critical thinking. Students who are engaged in practical work by thinking critically to solve practical problems are very proficient at solving the problems of society (Facione, 2015). Practical work dispositions help students to develop critical thinking and problem solving skills required for 21st century living.

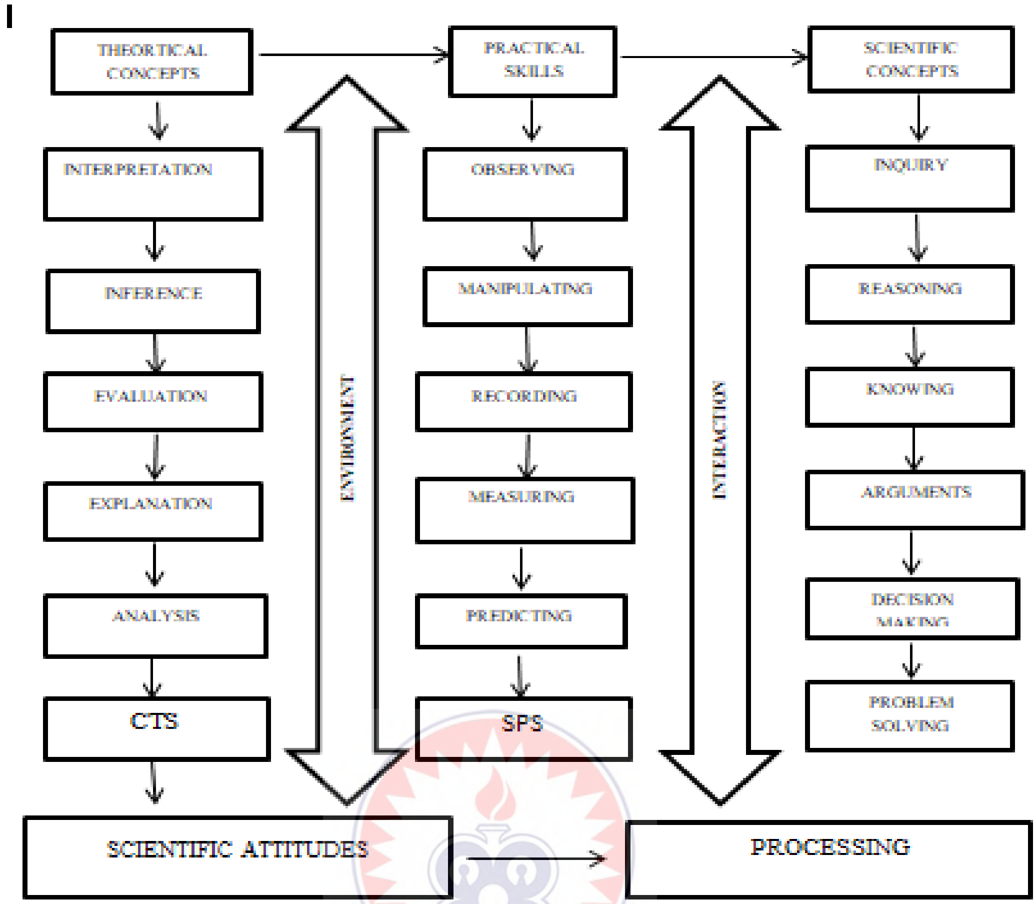

Figure 1: Diagrammatic Representation of the Conceptual Framework Employed in the Study

The researchers' construct is premised on the social constructivist's theory which posits that knowledge is co-created between the teacher acting as a facilitator and the learner through increased interaction. The teacher provides the needed materials by creating an environment which stimulates students learning through the conduct of activities aimed at helping the student explore through inquiry to discover scientific knowledge by them without being told. The teacher facilitates this learning by providing student's opportunities to interact with materials through practical activates to develop practical skills which drives the development of scientific attitudes and values. The attitudes and values are used by the students in processing scientific knowledge by applying the science process skills developed through practical activities. The processing of the acquired scientific knowledge facilitates the development of critical thinking indicators required for solving scientific problems, developing independent leaning and decision making.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Overview

This chapter looks at the research design employed in the study. The population and sampling techniques used as well as the research instruments designed for the study. Also presented in the chapter are the validity and reliability of the instruments, ethical consideration in the data collection process as well as the data analysis method used.

3.1 The Design of the Study

The intrinsic case study with multiple data source was employed by the researcher to conduct this study. A case study is a research strategy, an empirical inquiry and a naturalistic design which investigates a phenomenon within real life context (Cresswell, 2002). A case study describes an intensive but systematic investigation of a single individual, group, community, institution or organisation. In case a study, researchers examines in-depth data relating to several variables that reveals intricate insights (Yin, 2015). Case studies involve studying subjects of interest in their natural home without manipulating them. This is done with the intent to reveal intricate insights and understanding which are often difficult to be seen when other methods are used (Simons, 2014). The definitions of case study above clearly illustrates that case studies provide in-depth data and a whole picture of real life actions of humans in a social activity within a particular setting (Punch, 2009). Case studies when effectively conducted can reveal details of a study which are difficult to be seen casually if in-depth relationship is not established with the subjects (Stake, 2013).The closer relationship in case studies enable the researcher to determine hidden dynamics which exist within and between the subjects(Simons, 2014). The dynamics can be reported as they occur instead of predicting characteristics using some defined traits. Intrinsic case study is a type of case study employed in research when the aim of the researcher is to study the subjects closely with interest. The closer study reveal hidden details which otherwise cannot be seen when using other methods (Stake, 2010). Patton (2015), suggests that intrinsic case studies are valuable in creating deeper understanding of people, problems or situations in a comprehensive way. Intrinsic case study enables researchers to conduct in-depth exploration and analysis of deep seated intricate phenomenon. The study was conducted within specific context in order to reveal typicalness or uniqueness of the phenomenon (Stake, 2010). To reveal intricate details, Simons, (2014) contend that researchers need to form strong bonds with the subjects so as to study them. The data obtained from studying cases usually reveal insights and relationships which will be difficult to see when trusted relationship is not established between the researcher and the subjects. The data obtained from intrinsic case studies can also be used to either explain, describe or explore events or fill gaps identified in research studies (Yin, 2014). Ridder, (2017) contend that data obtained from intrinsic case studies can also be used to answer questions that are difficult to be answered by researchers using different methods. The variables usually studied in cases are in many ways similar and thus require deep seated insights, objectivity and skepticism to reveal details (Ridder, 2017).The hallmark of case study reporting is the use of multiple data sources, a strategy which enhances data credibility (Yin, 2003;Curry & Creswell, 2013; Ridder, 2017). Potential data sources may include, but not limited to: documentation, archival records, interviews, physical artifacts, direct observations, and participant-observation (Curry & Creswell, 2013). In case study investigations, researchers collect and integrate quantitative data with qualitative data to facilitate holistic understanding of the phenomenon being studied (Baskarada, 2014).Data from these multiple sources are then converged in the analysis process rather than handled individually. Each data source becomes one piece of a "puzzle" with each piece contributing to the researcher's understanding of the whole phenomenon. The convergence of data adds strength to the findings as the various strands of data are braided together to promote greater insights to the case being studied (Yin, 2013). Multiple data source is employed to ensure complementarity and triangulation of the data collected (Yin, 2015). Triangulation involves looking at something from several angles rather than to look at it in only one way (Neumann, 2000: Yin, 2013). It occurs when two or more strategies of data gathering and or sources of data are used to illustrate an authentic picture of a phenomenon under study (Patton, 2002; Lincoln & Guba, 2005; Silverman, 2010). One data source can be used to complement or consolidate the revelation from another data source. These data from different sources of the same study can then be used to substantiate insights which are difficult to be revealed by just one source. This goes to confirm that the information obtained from the study is not unidirectional but that the information comes from different sources which give credence to each other by revealing different aspects and insights. Case study approach is suitable for obtaining answers due to its three distinct features- Particularistic, Descriptive and Heuristic which differentiate it from other types of research (Merriam, 2009). Particularistic refers to specific contexts, programs, events and phenomena of everyday actions of people. Thus case study focuses on specific phenomena humans undertake and represent the problem or issue as it presents itself. Descriptive relates to the final outcome or end product of case studies, which often contain rich, thick descriptions of the phenomena under study. Heuristic means case studies illuminate the readers understanding of the phenomena understudy (Merriam, 2009).

3.1.1 Why the intrinsic case study design was used for the study

The researcher studied the subjects with interest, (third year elective chemistry Students) in their setting (chemistry laboratory) where practical work is conducted. The researcher conducted this study to reveal the uniqueness in the process of conducting practical work in the two Senior High Technical Schools selected for the study. The subjects of interest, the third year elective chemistry students, were also studied closely to identify how they analyse, evaluate and interpret their observation in line with scientific propositions (Ridder, 2017). The application of scientific reasoning needed to solve practical problems assigned as well as the opportunities created by teachers to engage the third year elective chemistry students in high order level reasoning. The intrinsic case study allowed the researcher to also identify the opportunities offered chemistry students to develop their own practical work as well as the procedures followed by students in solving the problems assigned. In their quest to explain findings from practical work in line with scientific reasoning, students draw on their critical thinking (Antwi, 2017). Critical thinking as a high order thinking enables students to offer explanations, evaluations, interpretation, inference and suggestive propositions (Lai, 2011). The suggestive propositions to findings reveals intricate details of reasoning processes engaged by students. The researcher is able to ascertain the dynamics within the students reasoning in relation to the findings obtained from the intrinsic study.

Justification for using the intrinsic case study design

The researcher employed the case study design in this study because the two schools sampled were in the third term of the final year. The chemistry teachers had put in place a rigid practical timetable which did not allow any space for the administration of intervention regarding the conduct of a research. This rigid practical time table (two periods per week per practical work) was not favorable for the collection of data regarding the development of science process skills. This is because for the full effect of an intervention to be noticed, it has to be monitored continuously by taking data at intervals (before and after the administration of an intervention). The collection of data at intervals would enable the researcher to ascertain the development of science process skills as well as how the skills developed could affect the development of the third year student's critical thinking. Another situation worth noting is the fact that the researcher conducted the study in a school different from the researchers' regular school of teaching. The regular teachers in the schools sampled concerted, allowing a study that involves data collection and the administration of intervention will drastically reduce the already constrained time they had for teaching the students. This posture by the regular teachers in the two schools sampled was premised on the fact that they had few weeks to prepare the third year chemistry students towards writing the final year examinations. The conduct of a rigorous study which would allow the administration of an intervention over a period of time followed by subsequent collection of data was simply impossible. Based on these reasons, the researcher resoughted to the use of the intrinsic case study design which had the characteristic of allowing the researcher to determine intricate details and typicalness of a study without necessarily the administration of an intervention.

3.2 Population of the Study

The third year students in the ten (10) public senior high schools offering elective chemistry in Sekondi-Takoradi Metropolis of the Western Region of Ghana formed the main units of population for the study. Four out of the ten schools are grouped as category A, and two schools in category B with the rest four out of the ten senior high schools in category C according to the Ghana Education Service categorization (GES, 2005). All the four category C schools are mixed schools (co-educational) with none being single sex. Three out of the four schools are offering elective science courses (Chemistry, Biology and Physics) whilst the fourth school offers agricultural science as major subject.

3.3 Target Population of the Study

The target population for the study consisted of 160 third year elective chemistry students in two senior high schools in the Sekondi-Takoradi metropolis of the western region of Ghana. The two senior high schools (Bompeh Senior Technical School) and (Adiembra Senior Technical School) used in the study were all grade C (GES, 2014). The two schools located in the Sekondi-Takoradi metropolis have similar conditions in terms of access to laboratory equipment and apparatus, infrastructure, students' population, educational governing authority and similar course structure. The two selected schools were all Science-Technical schools. The researcher selected the two schools with similar characteristics to obtain information that is valid and reliable and can be shared with the two schools to improve the conduct of practical work. The selection of two schools with similar characteristics was to ensure that one school does not have undue advantage over the other. The two schools were similar in terms of the content of practical work expected, availability of science apparatus and the conduct of practical work (GES, 2014). Studying samples with similar characteristics drawn from a population is key in generalizing for the population (Creswell, 2009). The researcher selected the two out of the ten schools to be studied so that that the findings obtained can be shared with the schools in order to improve the practice of the conduct of chemistry practical work.

3.4 Sampling of the Participants

Two elective chemistry classes consisting of third-year science students offering elective chemistry and third year Home Economics students offering elective chemistry were drawn from the two senior high schools sampled. The (stratified) purposive sampling technique adopting simple frequency counts was employed in counting40 chemistry students from each elective chemistry class. This made a total of four elective chemistry classes drawn from the two senior high schools. The four elective chemistry classes drawn formed four intact groups (strata). Each senior high school selected had two intact chemistry groups consisting of science group and the Home Economics group involved in the study.

In all, 160 third year students offering elective chemistry in the two senior high schools were selected for the study. The four intact groups were selected as appropriate for the study because each group had been engaged in a weekly practical section as a prerequisite for the completion of the senior high chemistry curriculum (MoE, 2010). This suggested that all the students selected possessed the characteristics the researcher was interested in.

3.5 Data Collection Procedure

To enable the researcher collect relevant data that reveals intricate details of the study, the researcher became a participant in the practical sessions that was facilitated by the regular teachers in the two senior high schools for a period of two weeks. Each selected school had one practical section per week where students were engaged in chemistry practical work. Two practical sections per intact group (stratum) were organized per school per week. During each practical session, a participant observation schedule (observation checklist) was used by the researcher in observing how the third year elective chemistry students made use of their science process skills. The skill of measuring, calculating and inferring were given special preference as these skills were enshrined among other skills in the SHS chemistry curriculum to be developed during practical work (MoE, 2010). The researcher adopted the participant observation checklist to enable a closer relationship with the subjects in order to study them.

A questionnaire was administered to collect data on students' practical competences during the two weeks. This was to enable the researcher determine the effectiveness of the practical work organised in the two Senior High Schools. Both the participant observation checklist and the questionnaire were used in collecting data on the development of science process skills to enable the researcher triangulate the findings. In determining the level of critical thinking development employed by the third year chemistry students at solving practical problems, the researcher adapted a close ended multiple choice critical thinking test originally propounded by (Ennis, 1993). This critical thinking test in acid base reactions/titrations was named Acid Base Critical Thinking Test (ABCTT) by the researcher. The acid base critical thinking test had five sections corresponding to the five critical thinking indicators. The five critical thinking indicators include interpretation, inferences, evaluation, explanation and analyses.

The first section of the acid base critical thinking test had items that relate to interpretation. Five items were set to determine how students employ interpretation in analysing and explaining observations made during practical sections. The second section of the critical thinking test had five items on how students made inferences and work towards achieving them. The five items tested student's ability to employ inferences during acid base reactions/titrations to draw meaning from findings and observations. This section of the test was intended to elicit students' effectiveness at making inferences based on assumptions or evidence collected. The third section, evaluation had five items eliciting students' ability to critically evaluate the effectiveness of their analysis and conclusions drawn from practical work. The fourth section of the acid base critical thinking test, explanation also had five items testing students' ability to apply high level thinking in explaining observations and conclusions drawn from practical work. The last section of the acid base critical thinking test had five items on analyses. The items were carefully calved out with the intension to determine how the third year elective chemistry students' analyse their findings in line with scientific concepts and thoughts (Simons, 2014). The responses to the items were rated based on a predetermined scheme. The mean score was calculated and converted to 100%. The percentage score is compared with a predetermined scale developed by (Widoyoko, 2015) as indicated in Appendix A. The acid base critical thinking test was administered to measure how the third year elective chemistry students applied critical thinking in analysing and solving practical problems in titremetry (simple titrations) and acid base reactions. The development of the acid base critical thinking test was premised on the fact that students who have developed critical thinking in the domain of science (acid-base reactions/titrations) are able to engage in high order level thinking required for decision making and for solving practical problems (Facione, 2015). After the critical thinking test, a feedback section was conducted to enable the students identify their weaknesses and learn from others to improve their approach at solving problem. An intact class discussion was then held to discuss how the third year chemistry elective students employed critical thinking in answering the items on the critical thinking test conducted. The reason for conducting the intact class discussion was to obtain at firsthand how the chemistry students applied their critical thinking in solving the acid base critical thinking test.

3.6.1 Observation checklist

A participant observation technique was employed by the researcher in collecting data using an observation checklist on the third year elective chemistry students during practical sections. The researcher facilitated a practical section together with the teachers to engage the students in Acid-Base titrimetry. The checklist had items on process skills (measurement, calculation and inferring) which are the skills specified in the SHS chemistry curriculum (MOE, 2010) with rating on them. The researcher's assertion of what constitutes a skill development to be checked is premised on seeing, hearing, touching of events engaged in by the students. The researcher went round the laboratory during the practical sections to observe how students employed measurement, calculating and inferring in performing practical activities to obtain the desired results. The researcher checked each skill appropriately as was used by the students. The checklist was then rated for each of the students and marks obtained compared with a predetermined rating scale developed by Widoyoko (2015), to determine the students' level of development of the science process skills. This was done on each student for two consecutive practical sections. The mean score of each student on the checklist was calculated in order to make a valid conclusion on the level of development of the science process skills by the students. (A sample of the observation checklist is attached as Appendix A).

3.6.2 Questionnaire

A questionnaire was developed and used by the researcher to collect data for the study**.** The development of the questionnaire was guided by all constructs to be measured. The constructs included regularity of conduct of practical work, process skill development as well as the use of practical knowledge in solving problems in chemistry. The questionnaire also sampled students' views on how they apply critical thinking in solving daily problems. In all, 36 items were set to gather data on the constructs listed above. Each construct had between 8 and 10 items set for which students were tasked to answer using a five- point likert scale. The responses to the questions were coded using SPSS version 21. The coded responses were cleaned and thoroughly check for accuracy. The responses were analysed to determine how chemistry practical work has developed the science process skills of third year elective chemistry students. (A sample of the instrument is attached as Appendix B)

3.6.3 Acid - base critical thinking test

Acid-Base Critical Thinking test (ABCTT) was conducted to determine the level of development of the student's critical thinking skills. In all, twenty-five (25) close ended multiple choice items on critical thinking were administered to the students. The solution to each item required students to employ explicit knowledge of use of the developed science process skills in solving the problems. The student's needed to think critically and creatively in order to interpret, draw inference, evaluate, explain and analyse the questions before applying scientific knowledge to logic reasoning to solve the problems. The items set also ensured compliance to Blooms taxonomy, the underlying behavior for teaching and learning and assessment.

The items covered the three domains of cognitive learning associated with high order thinking, namely analyses, syntheses and evaluation. However, there were items that needed direct recall and remembering but they were rated low. Items on analyses, evaluation and interpretation which demanded high other thinking skills were rated high. The items for each domain were carefully scrutinized by the science education experts at Holy Child College of Education to ensure it measured the constructs purported to measure. This was done to ensure face validity of the items. (A sample of the ABCTT tools is attached as Appendix C).

3.6.4 Intact group discussion

Intact group discussion was conducted following the conduct of the two weeks practical work. The main focus of the discussion was to determine how SHS students in the sampled population performed chemistry practical activity to develop their process skills. An Intact group discussion is a special form of communication that occurs between the researcher and the subjects to collect verbal and nonverbal data about a particular issue in a study (Punch, 2009). The discussion sampled the views of the students on how they employ process skills developed during practical work to engage in critical thinking. The discussions focused on the regularity of conduct of practical work, level of developing of student's process skill in chemistry as well as opportunities inherent in practical sections to enable students develop analytical and critical thinking disposition. Process skill development is linked to critical thinking which is a perquisite skill necessary for solving daily problems of society. The researcher identified two students each at random, from a practical bench of ten students each for the interview. This strategy was used to obtain a true representation of the students in order to get accurate information. During the discussion, structured questions relating to regularity of conduct of practical work, quality engagement of students by teachers during practical work were considered. The discussions also focused on science process skills targeted and developed by students during practical work and how students use practical knowledge to solve problems. This was done to ensure that students do not answer questions by memorizing but rather use deep seated experiences and knowledge to arrive at logical conclusions. In all, two rounds of discussions were held for each of the two Science and Home economics students offering elective chemistry groups. (A sample of the questions used in guiding the intact group discussions is attached as Appendix D).

3.7 Validity and Reliability

To ensure validity and reliability of the instruments used in collecting the data for the study, a pilot study was conducted at Diabene Senior High Technical School, Takoradi. The pilot study sampled 50 third year elective chemistry students. The sample selected for the pilot study was ideal because, Krejcie and Morgan (1970) assert that a sample of 30% of a total population is relevant for making generalisations about the population. All four instruments designed by the researcher were employed in collecting data for the pilot study. This was done to ensure that the instruments measured what it was designed to measure (Sullivan, 2011). After the pilot data collection, the responses obtained were used to modify some of the items in the instruments. This was done by cancelling out similar items which measured the same constructs while ensuring that every construct in the domain of practical work, process skills and critical thinking being investigated were sampled. Some of the items in the questionnaire were either reframed or new items were introduce to determine constructs which did not adequately capture the domains being investigated. Some items were modified to suite the construct being sort for. To achieve this objective, Science Education Professor at the Department of Chemistry Education, University Of Education, Winneba, the research supervisor and science experts at Holy Child College of Education brought their expertise to bear when they meticulously reviewed all the instruments.

The reliability coefficient value for the questionnaire on development of science process skills was calculated using the pilot study responses. A Cronbach alpha (ά) value of 0.78 was obtained. This indicated that the items on the questionnaire were related and adequately measured the constructs that it purports to measure.

To ensure reliability of the information collected with the instruments (observation checklist, questionnaire on process skills and the critical thinking test), the data obtained were analysed to complement each construct. Triangulation was done to reveal intricate insights of the problem under study using multiple sources of data which gave credence to the information collected. This enabled the researcher to identify close association and relations that exist between practical work, process skill development and use of critical thinking in solving problems.

3.8 Ethical Consideration

In order to ensure that this study did not contravene research ethics on data gathering, the researcher followed all the processes involved in data gathering. The chemistry teachers in whose domain the study was conducted were assured of confidentiality and anonymity. The two heads of department were assured by the researcher that the information collected will not be shared with any third party. The third year chemistry students were assured of confidentiality and anonymity during the observation. The questionnaire on science process skills and the ABCTT had sections seeking confidentiality and anonymity concerns for the respondents. The students who were the main respondents were also assured of their confidentiality and anonymity during the administration of the instruments. Both teachers and students were assured that the data collected will be used for academic purposes only.

3.8.1 Data analysis procedures

The qualitative data obtained with the intact group discussions were audio-taped and played back several times to get acquainted with the issues raised by the informants. The audio-tape recordings were transcribed and catergorised into themes which were related to the domains being investigated (regularity of conduct of practical work, SPS development and CT development). The coded data obtained from the qualitative analysis was used to support the analysis of the quantitative data in order to ensure credibility (Creswell, 2013). The insights revealed by the qualitative analysis were shared with the members of the science education department, Holy Child College of Education for their review in consonance with the themes raised by the informants. This was done to avoid researcher reflexivity and biases in the qualitative data gathering.

The questionnaires were used in collecting quantitative data on the impact of practical work on process skills development. The questionnaire was analysed using SPSS version 21.0. After coding, a Code-Book was developed, the data was cleaned, arranged and accuracy checks done. Simple frequency counts, percentages, means and standard deviation were run to determine how regularity of conduct of practical work develops SPS.

The acid base critical thinking test was administered on the third year elective chemistry students to measure the development of critical thinking skills in the subject (Acid-Base reactions/titremetry) domain of science. The test was developed on five main thematic indicators related to critical thinking dispositions. The indicators included inference, analysis, interpretation, evaluation and drawing conclusions.

The test conducted was rated using a predetermined scheme as propounded by (Widoyoko, 2015). The marks generated were coded using SPSS version 21.0. Simple frequency counts, percentages, means and standard deviation were run. This was used to determine whether science practical work conducted in the two sampled schools developed the third year chemistry student's critical thinking. It is important to note that the critical thinking test was done to determine students who had developed critical thinking disposition in the domain of chemistry but not general critical thinking.

Both the qualitative and quantitative data were analysed together with the intension to reveal typicalness or uniqueness of the information obtained (Simons, 2014). The different instruments were used in order to give credence to the naturalistic insights obtained from the study (Stake, 2010). The data for the study was collected over period of one month. This was done with the intension to ensure trustworthiness and rigor, transferability and authenticity of the insights inherent in the study.

3.8.2 Trustworthiness in the study

Trustworthiness or rigor of a study refers to the degree of confidence in data, interpretation and methods used to ensure the quality of a study (Yin, 2003, 2015; Pilot& Beck, 2014). Trustworthiness also refers to quality, authenticity and truthfulness of findings of a qualitative research. It relates to the degree of trust or confidence readers have in the results obtained from a study (Amankwaa, 2016). To ensure rigor in this study, the researcher used multiple instruments in collecting varied data from the same study so that detailed insights can be deduced. The process of using multiple instruments to collect data for the same study ensured authenticity of the information collected which gave credence to the findings made by the researcher. The credibility of the information obtained can be verified by other researchers/investigators using the same instruments (Bowen, Rose & Pilkington, 2017).

The researcher has high credibility or confidence in the findings revealed by the study because the revelations came from different sources of the same study using different instruments. This in the researcher's opinion makes the study very authentic. Rigor is again established in this study by the selection of appropriate subjects "third year SHS elective chemistry students" for the study sample which resulted in the provision of a rich, detailed description of the findings. These details brought out by employing the appropriate subjects in the study are difficult to determine when other methods which involve counting or making assumptions are used.

CHAPTER FOUR

FINDINGS AND DISCUSSIONS

4.0 Overview

This chapter considers the findings from the analysis of instruments employed in gathering data for the study. The instruments used for this study included Observation Checklist on the use of process skills for practical work, a questionnaire on science process skills development. An Acid Base Critical Thinking Test administered on third year elective chemistry students to determine the development of critical thinking in chemistry and an Intact group discussions carried out using prepared questions measuring all the constructs being investigated. The data obtained from intact group discussions were used in triangulating the data obtained with the questionnaire and the Acid Base Critical Thinking Test.

4.1 Demographic Characteristics of Respondents

Table 1 represents the demographic data of the students sampled from the two senior high schools (SHS) according to their gender and elective subject area. The respondents consisted of students pursuing Home Economics who offer elective chemistry (HE-Chem) and Science students also offering chemistry (SC-Chem) as their elective subject.

Table 1: Demographic Characteristics of Respondents

	Sex	Freq.	(%)	Class	Freq.	(%)
1.	Male	69	43.1	SC-Chem	57	35.6
2.	Female	91	53.9	HE-Chem	94	64.4
	Total	**160**	**100**		**160**	**100**

Source:Field data, 2022, SC=Science students, HE=Home Economics students, Chem=chemistry.

The study revealed that 91(53.9%) students were females aged between 18-20 years whereas the remaining respondents, 69 constituting (43.1%) of the students sampled were males between the ages of 18-20. This suggests that both boys and girls were adequately sampled for the study. There was gender parity in the selection of the sample for the analysis. The sampling did not offer any avenue for a particular gender to have undue advantage over the other. The sampled girls being more than boys were basically a matter of chance and the fact that most of the students offering Home Economics were girls. This dynamics in the population do not in any way affect the thinking and choice pattern of the students who were sampled for the study,

4.1.2 Category of abilities for measuring science process skills

The data on Table 2 represent the categories of abilities used in assessing students' science process skills development during practical work. The table was developed by Widoyoko, (2015) but has been adopted by the researcher in analysing the process skills development during practical work. The researcher adopted the table by using the ratings in analysing the science process skills developed by SHS chemistry students during the two weeks observation of the students at practical work sections.

Table 2: Category of Abilities and Skills Used in Assessing Process Skills Development by SHS Chemistry Students

No.	Interval	Category
1	>66.7%	High
2	> 33.3% - 66.7%	Medium
3	3 < 33.3%	Low

Widoyoko, 2015

It could be deduced that students were deemed to have developed "high" category of basic science process skills when their scores are above 67%. A high category of development of science process skills indicates that the students have mastered particular skills which could be applied during science practical work (Widoyoko, 2015). When the students score between 34 and 66% marks, it indicates that the students have not effectively developed the science process skills being assessed. The students must then be offered more opportunities during practical activities to enable the development of process skills (Jackson, Fleming & Rowe, 2019).

Table 3: Frequency Table showing Rating of the Participant Observation Checklist

No	Process Skills	N	Marks (%)	Rating
1	predicting	130	30	low
2	classifying	134	32	low
3	inferring	145	28	low
4	recording	138	48	medium
5	calculating	132	50	medium
6	measuring	145	70	high
7	observing	158	75	high

Source: Field data, August, 2022, N=Total number of participants observed

From Table 3 above, it can be deduced that most students exhibited high use of science process skills pertaining to measuring and observing during their practical work. This is because observing and measuring are basic SPS which involve much use of psychomotor domains of the body in performing science activities. The basic SPS form the foundation of skill development in science without which students cannot conduct most of the practical work (Darmaji et al, 2019). It was quite easy for students to observe a color change, record and measure the quantity of acid or base consumed in a titration. The students also exhibited medium use of science process skills dispositions relating to recording and calculating. The students were able to calculate titer values and use them in determining the volume of acid or base consumed in the chemical reaction. However, the third year chemistry students exhibited high level difficulty in science process skills relating to prediction, classifying and inferring. It is worth noting that predicting, classifying and inferring are basic science process skills which develops only when conscious efforts are made to interplay two or three basic science process skills at accomplishing a task (Ogunkunle, 2017). The high level of difficulty exhibited in prediction, classifying and inferring was as a result of lack of practice offered students during chemistry practical work. Jack (2018) contends that variations in difficulty level of science process skills exhibited by students are attributable to the type of science activities to which they are exposed. Ajaja & Eravwok (2010) postulate that the reason why students find some process skills difficult could be due to the persistent use of lecture methods for teaching Chemistry as against students centered approaches. The students centered approaches which are activity oriented includes laboratory and discovery/inquiry approaches which allow students to perform activities during practical work. The assertions of Jack (2018) and Ajaja & Eravwok (2010) are in tandem with Kinyota (2020) when he contends that chemistry needs a constant stream of practical or hands-on activities to explain abstract ideas and inculcate relevant scientific skills required for problem solving. The third year chemistry students had problems developing the required science process skills necessary for effective practical activity because their teachers did not adequately involve them in argumentative discussions which dwelt on students' practical experiences (Ogunkunle, 2017). It was difficult for students to make claims while using scientific concepts to consolidate or refute those claims. There are situations where chemistry students are told what to expect during chemistry practical work. Teachers could even go to the extent of giving titration values to students during practical activities for want of time. This observation confirms that chemistry practical activities conducted in the two SHS sampled were teacher centered. This assertion is in tandem with that of Byusa, Kampire, and Mwesigye, (2021) when they suggested that teacher centeredness in practical activities has dominated most chemistry practical work. Practical work in the two SHS sampled, did not allow students to explore chemical reactions in order develop their own findings. In addition, Mkimbili, Tiplic, and Ødegaard (2017) contends that teacher centeredness continues to dominate chemistry teaching and learning, despite the fact that most of the instruction is done theoretically, practical activities are rarely used in developing scientific attitudes in science. Where practical activities are used, they are ill conceived, ill planned and ill executed. The focus of the third year practical activities has been to prepare students towards writing the Practical Test in Chemistry organised by West Africa Examination Council (WAEC). This challenge has persuaded chemistry teachers to design rudimentary practical activities whose main purpose is to guide the students to pass their final WAEC examinations Taale et al, (2018) but not to engage them in activities that will develop scientific insights. The practice do not afford students the opportunity to investigate theories and concepts on their own by applying inquiry and experience in constructing their own meaning. Students' curiosity in practical work has not been harnessed and this has affected the students to the extent that their zeal and interests to excel in chemistry is seriously hampered (DeBoer, 2019). There is no doubt that the examination driven practical work conducted in SHS has affected the development of the requisite SPS needed for effective conduct of practical work in chemistry.

4.2 The Regularity of Conduct of Practical Work

Table 4 represents the data on the analysis of the questions on regularity of conduct of third year chemistry student's practical work. It compares the regularity of conduct of chemistry practical work in SHS one, SHS two and SHS three using frequency and percentages.

Table 4: Regularity of Conduct of Practical Work

Conduct of Practical Work	**SHS 1**		**SHS 2**		**SHS 3**	
	Freq.	**(%)**	**Freq.**	**(%)**	**Freq.**	**(%)**
Never conducted PW	154	86.5	140	78.7	8	3.4
Once a term	3	1.7	6	3.4	8	3.4
Once a week	3	1.7	14	7.9	144	80.9
Total	**160**	**100**	**160**	**100**	**160**	**100**

Source: Field data, August 2022, PW= practical work.

From Table 4 above, out of the 160 students sampled from the two SHS, 154 (86.5%) indicated that they were not engaged in any practical activity during their first year. A sizeable no of students 140 (78.7%) also confirmed that they were not engaged in any practical activity during their second year at SHS. Majority of the students sampled, 144 (80.9%) confirmed that they have been engaged in weekly practical activities during their third year at SHS. This revelation from table 4 above, depicts that practical work is not given the seriousness that it deserves during the first and second year in SHS. The third year chemistry students were not effectively engaged in practical activities in the first and second year and this has affected the development of SPS needed for the conduct of effective practical work. The situation does not allow the chemistry students to develop the practical experiences needed for mastery of SPS. Practical work enables students to link concepts taught in the classroom to real practice (Jack, 2018). In Science, students do practical work to expand their knowledge in an attempt to understand the world around them (Kolucki & Lemish, 2011). When students are not offered the opportunity to develop problem solving skills in science, it prevents them from developing the requisite scientific attitudes and fortitudes required for solving scientific problems.

The first and second year practical activities are aimed at helping chemistry students to develop their basic practical skills essential for use in the third year (MoE, 2010). Lack of practice in SHS chemistry practical work has de-motivated most students affecting their confidence and approach at answering questions through insightful intellectual discourse. The students find it difficult to navigate through third year practical activities conducted in chemistry because they lack the understanding of scientific concepts, theories and dispositions from first and second year. The teaching through practical work can motivate learners' self-learning to powerfully grasp scientific concepts (Abrahams & Reiss, 2012). Inadequate exposure to practical work affects students' confidence, hampering their ability to acquire SPS as well as their capacity to create knowledge rather than cramming it (Kalolo, 2015).

The observations made above were consolidated by the following issues raised during the intact group discussions (IGD) by the Home Economics (HE) elective chemistryand the science chemistry (SC) groups one and two (G1-2) during the first round of discussions.

> IGD-HE-G1 "When we were in first year, you will go and sit in the laboratory for the two periods and no teacher will come, I think it was a waste of time"
>
> IGD-HE-G2 "Anytime we went to the laboratory in first year, the teachers will drive us away saying that the final year students are coming to perform chemistry practical work"
>
> IGD-SC-G1 "The laboratory assistant told us in first year that, it was difficult to do practical work because the chemicals in stock were bought for the final year students"
>
> IGD-SC-G2 "Our teachers always complain that the apparatus for science practical work are not enough and so they are reserved for the final year students"

From the discussions above, it can be concluded that chemistry teachers do not attach any importance to practical work in the first and second year at SHS. SHS chemistry teachers do not engage first and second year students in practical work. This situation is buttressed and excused by a myriad of challenges confronting senior high school education in Ghana. The challenges include teacher apathy fueled by inadequate logistics, time constraints and unavailability of apparatus for the conduct of practical work (Kasiyo, Denuga & Mukwambo, 2017).Teachers only engaged chemistry students in active practical work only in the third term of the third year at SHS. This situation has prevented the students from developing their practical skills and attitude needed for reasoning and understanding of scientific concepts. Third year practical activities have been purely rudimentary aimed at helping students to pass their final WAEC examinations. This has prevented the third year chemistry students from developing the SPS needed for the conduct of practical work.

A chemistry student lamented “it is difficult performing third year back titration when we have not mastered the basic skills required for handling simple titration”.

Another student said “the reason I find third year chemistry practical very difficult is that we are not offered enough opportunities to conduct chemistry practical work from first year and second year”.

Asked why this situation exists, a student commented during the two week observation that there is lack of the schools commitment towards engaging the first and second year SHS chemistry practical work. “Our teachers always complain of unavailability of funds’’ to procure chemicals for practical work.

4.2.1 Students’ perception of science process skills in chemistry practical work

Table 5 represent the data on the question of SHS chemistry students’ use of science process skills for the conduct of chemistry practical work. The table compares students’ responses on the use of science process skills using frequencies, means and standard deviations.

Table 5: Students' perception of Uses of Science Process Skill in Chemistry Practical Work (PW)

Level of Development of SPS	Frequency				Mean	St. d
	SD	D	A	SA		
able to assign reasons to observations	59	72	3	26	3.58	.914
ability to interpret findings made in PW	73	65	3	19	3.62	.806
able to apply conclusion to solve problem	18	10	34	108	3.68	.932
able to design practical to solve problems	11	81	44	24	3.28	1.101
able to analyze findings from PW	4	77	57	22	3.49	.924
able to relate findings to everyday life	15	74	50	21	3.29	1.107
Collaborate with colleagues	6	55	70	29	3.62	1.014
Respect other people's views	6	74	49	31	3.49	1.058
Able to make inferences	47	80	3	30	3.50	1.003
Able to explain scientific basis of PW	4	29	36	20	3.373	.997

Source:Field data, August 2022.

From table 5 above, out of the 160 students sampled, 131 (81.1%) rated that even though they are able to record the exact observations during practical work, they are not able to assign scientific reasons to the observations made. This situation as it exists in the SHS is very worrying. A sizable proportion of the subjects sampled 138 (86.2%) were of the opinion that it was difficult for them to interpret findings made from the conduct of their practical work. Also, 126 (78.7%) students sampled rated that it was difficult for them to apply conclusions drawn from chemistry practical work in solving daily problems in life. Majority of the students 127 (79.3%) again rated very high that it was difficult for them to draw inferences from chemistry practical work conducted. The statistics above depicts a disturbing situation in the conduct of practical work in the two schools sampled. The situation is very disturbing owing to the fact that teachers are expected to emphasize the application of practical concepts during chemistry practical work to enable students to connect theory to the practical (MoE,2010). Lack of adequate exposure and effective practical engagement has affected the students' ability to integrate science process skills in practical work for optimum results (Darmanji et al, 2020). The level of use of process skills in observing, analysing, interpreting, making inference and drawing conclusions were very low. The ramifications for this situation stems from the fact that students lack adequate exposure to chemistry practical work. The situation prevented students from building experiences based on observations in forecasting intellectual practical expectations (DeBoer, 2019). It is important to note that effective engagement of students in practical work develops SPS (Abungu, Okere & Wachanga, 2014). Science Process Skills help students to understand scientific phenomenon being investigated, discover information and improve the sense of taking responsibility on their learning (Kim, 2018).

Science process skills facilitate science learning, develop students' sense of responsibility while learning, and increases permanence of knowledge by increasing the problem-solving capacity of students (Behera, 2014: Dogan, 2016). The unplanned process of teaching students in applying SPS lack value in fostering the SPS practices among students (Yumusak, 2016). Students had difficulty using science process skills because the practical's conducted did not take into consideration their intellectual ability. Procedural and rudimentary practical work conducted in the third term of third year at SHS did not involve the students in science knowledge creation but rather encouraged memorization borne out of word of mouth of chemistry teachers (Hanson & Sakyi-Hagan 2019). There exists nexus between active student involvement in learning process and the development of science process skills. When students are fully engaged in practical work, it promotes the use of their senses in reasoning to buttress their conceptual understanding. This is because, apart from learners constructing their own knowledge through practice, visualization, and association, it enhances concept formation and retention (Hanson & Sakyi-Hagan 2019). Where students are not fully engaged in practical activities, their orientation towards explaining observed phenomenon is impaired. This has serious implications developing student's ability to use conceptual understanding in science in dealing with solutions to problems.

The findings above were consolidated by the students during the intact group discussions (IGD) with the Science (SC) and the Home Economics (HE) groups three and four (G3-4) bythe following views.

> IGD-HE-G3 "Sometimes, during practical work, our teacher gives us the titer values to enable us do the calculations. The chemicals are not enough."
>
> IGD-HE-G3 "After the practical section, I consult practical books to enable me write answers to some of the questions. Where I cannot find the answer, I copy from a friend."
>
> IGD-SC-G3 "Our chemistry teacher does not engage us in critical discussion of findings, rather he gives us some of the answers to write if the questions center on discussion of findings from practical work".
>
> IGD-SC-G4 "Sometimes I "chew" some answers to memorize them during examination. I don't understand the scientific basis for the answer".

From the discussions above, it can be deduced that third year chemistry students in the two SHS sampled had difficulty assigning scientific reasons to observation made during practical work. The students had difficulty interpreting findings drawn from practical work. They could not apply conclusions to solve practical problems. The students had difficulty analysing issues in chemistry practical work and more importantly, could not draw inference from observations made during practical work. From these observations, one can conclude that the third year chemistry students have not adequately developed the SPS necessary for the conduct of effective practical work. This observation is consistent with the observation made by Kuswanto (2017), when he contends that students' SPS in the chemistry practical work is still very low. He reiterated that students have not been able to independently perform their practical activities and have little initiative in solving their practical problems. Students are expected to use SPS to analyse or explore a problem, issue, question, or scientific phenomenon that occurred throughout the learning process (Duruk, Akgün, Dogan & Gülsuyu, 2017). The situation clearly forebears the indication that students did not understand the main tenets of chemistry practical work. This has prevented the students from developing the skills necessary for the conduct of practical work. Jeenthong, Ruenwongsa and Sriwattanarothai (2014) postulated that there is the need for consistent and multiple practical sections to integrate science process skills. This will give the learners tools to interpret what they observe and to design investigations to test their ideas. Science process skills describe students' thinking activity and require reasoning. Most of the students lacked the cognitive thinking pattern and experiences required for integrating theory with practice (Rutto & Kapting, 2014). The students had difficulty thinking, organizing materials and equipment given for the practical work. Evaluating the entire process of the practical work with the main aim of formulating results was also a problem for the students.

4.2.2 Level of use of science process skills in chemistry practical work

Table 6 represents the responses of the elective chemistry students on the level of use of SPS during practical work. The table was used by the researcher to explore some of the ways by which the students apply the developed process skills during chemistry practical work. The table also gives how science process skills influence their level of effectiveness in the conduct of chemistry practical work.

4.2.2.1 Students opinion on use of science process skills during Practical Work

To enable the researcher determine the students use of science process skill during practical work, the researcher administered the questionnaire on science process skills. The responses of the chemistry students on the uses of science process skills are summarized on table 6 below.

Table 6: Students opinion on use of science process skills during Practical Work

Process Skills	Frequency	Percentage	Mean	St.D
Following procedures on task sheet	115	64.6	3.98	.863
Measures volume of acids correctly	137	77.0	4.41	.780
States observation correctly	107	60.1	3.64	1.102
Able to predict color of solution on adding an indicator	76	42.3	3.66	.990
Appling findings from PW	67	37.7	4.20	.937
Able to calculate volume of acid/ base used correctly	126	70.8	4.20	.937
Recording exact findings from PW	114	64.1	3.91	.882

Source:Field data, August 2022. SPS=Science process skills PW=Practical work

From table 6 above, majority of the students sampled 115 (64.6%) were of the opinion that they conducted chemistry practical work by following procedures on the task sheet to the latter. The students however, could not explain why they are made to follow laid down procedures during practical work. A sizable proportion of the students 137 (77.0%) rated highly efficient the question of measuring the volume of liquids with the desired skill using the appropriate instruments. A higher proportion of the students 107 (60.0%) sampled were of the opinion that they could record accurately observations made during chemistry practical work.

However, majority of the students rated low the question of making prediction 76 (42.3%) during practical work and applying 67 (37.7%) findings from practical work to solve problems. This assertion by the students is consistent with the data collected using the observation checklist. The situation above attests to the fact that most of the third year chemistry students sampled in the two schools have not fully developed the basic SPS required for performing effective practical work. It is evident from Table 6 that the students have developed SPS relating to observation, measuring and recording but not prediction and applying. In prediction, students determine whether what happens in practical work is what is expected to happen. It involves asking students to make individual guesses based on observed reaction by citing what will happen as a result of the acid–base reaction taken place (Coştu & Bayram, 2021). Prediction thrives on using evidence to preempt or determine the end results of a reaction. As a technique, it develops on practice because it is a skill which encapsulates more practical experiences to develop (Rutto & Kapting, 2014). Prediction was difficult among the students because of lack of extensive practice required for developing the skill. There is no doubt that prediction in practical activities guides in theorizing scientific concepts which can be argued out using hypothesis (Okam & Zakari, 2017). This goes to suggest that prediction is important in advancing scientific knowledge which can boost the confidence of students when it is gotten right. In completing scientific procedures during practical work, students must combine their hands-on skills and minds-on abilities to control equipment in order to acquire a better understanding of scientific concepts without prejudice (Taale et al, 2018). It was difficult for third year chemistry students to apply practical findings to solve problems because their teachers did not discuss practical applications of some of the practical work engaged by students. This confirms the earlier findings made by the researcher on the students using the checklist. The findings confirm that practical work in chemistry has become rudimentary and procedural because it does not require students to reason to events. Students perform practical work without knowing how it can be employed to solve the problems in life. This situation is very worrying since the main import of practical work is to solve problems and be involved in decision making. If students are not able to use practical solutions to solve assigned problems, they would not develop the analytical and deductive insights required for solving them. The students have become the receptacle for scientific theories but lacking the initiative to apply those theories in solving the problems of society (Murawski, 2014). Ensuring students develop simple practical work on their own helps them appreciate the integration of the practical concepts in solving the problems of society as against the attitude of continuously mastering theoretical concepts without the requisite practical disposition. When students do not develop practical work competences it does not promote active science in the classroom and this may stifle students' creativity and innovation as well as students' achievement (Abungu, Okere & Wachanga, 2014).A close observation of the students during the two weeks practical work revealed that most of them had difficulty using pipette to measure with accuracy. One can conclude that even though generally, students were good in measuring the volume of liquids, they had some challenges when the use of instrument for measuring requires a special skills. The following comments were made during the intact group discussion sections organised for the Home Economics (HE) and Science (SC) groups one and two (G1-2) in support of the above assertions during the second round (B) of discussions.

> IGD-SC-G1-B "Although following procedures is good, sometimes it is difficult to for me to understand exactly what the practical procedures require me to do. It is confusing when I do not understand what the procedure is intended to achieve".

IGD-HE-G2-B "Sometimes it is difficult to determine the kind of solution you are dealing with and so it is quiet difficult to predict it or determine the concentration"

IGD-SC-G2-B "The only time I was allowed to design my own practical work was when the school organised a science fair".

IGD-HE-G3-B "If I add an indicator to a solution and it changes color predictive of an acid, I will write the reaction without actually observing the reaction to the end. This is because I know the reaction is between an acid and base which will always produce salt and water only". This situation is very dangerous because it does not fulfill the scientific attitude of respect for evidence (McIntyre, 2019). Scientific knowledge is empirical. It is important students are engaged through practical work to understand that scientist have keen interest in the processes leading to the results and not just the end results. Practical work in SHS should be developed along student's experience of using their conceptual knowledge to buttress experimental observation that follows the scientific process of respect for truths.

From the analysis of the questions, the researcher deduced that practical work conducted in the two SHS sampled in the Sekondi-Takoradi Metropolis is not helping the students to develop the requisite SPS needed for conducting practical work effectively. This assertion is based on the fact that practical work conducted in the two schools only helped the students to develop the ability to observe and measure. Students did not develop the SPS relating to inferring, prediction, recording and application which are the major skills required in analysing and problem solving.

Student's engagement during practical work was woefully inadequate and this had affected their ability to conceptualize scientific concepts using practical activities in science.

4.3 The Influence of Science Process Skills on Critical Thinking Development of SHS Students

In determining the influence of Science Process Skills of third year SHS chemistry students on their critical thinking, an Acid- Base Critical Thinking Test was developed, administered and analysed. Five main indicators adapted from the model propounded by Ennis (1999) was employed. Critical thinking relating to interpretation, inference, evaluation, explanation and analysis were used in exploring the critical thinking ability of the third year SHS chemistry students. Table 7 represents the data on the analysis of the critical thinking test taken by the students. The critical thinking indicator scores were analysed to determine how they contribute to the overall development of critical thinking among the students.

Table 7: Analysis of SHS Chemistry Students' acid Base Critical Thinking Test

CT indicator	Score (%)	df	Mean diff.
Inference	37.86	159	7.48
Evaluation	30.53	159	9.00
Analysis	45.75	159	9.06
Explanation	54.15	159	16.02
interpretation	47.00	159	6.92

Source: Field data, August 2022, $p>0.05$

The performance of the students in the critical thinking test was generally weak suggesting that the third year SHS chemistry students were not developing the totality of their critical thinking skills. There was a general gradation in performance from average (54.15) through medium average (45.75-47.00) to below average (30.53-37.86) scores. The students' performance on the critical thinking indicator related to explanation (54%) was higher compared with the scores obtained in the other indicators. The students scored (47%) and (45%) on critical thinking indicators related to interpretation and analysis respectively. The students scored very low marks (30%) and (37%) on critical thinking indicators relating to evaluation and inference respectively. From the analysis of the test results, it could be deduced that out of the five indicators that students were examined on, only one of the indicators (explanation) has been mastered by the students in relation to their critical thinking development. This situation is very worrying and requires a new pedagogical approach in overturning the practice in order to make gains. It can be argued that practical activities conducted in the two schools do not foster the development of critical thinking skills as enshrined in the tenets of the SHS chemistry curriculum (MoE, 2010). Practical work conducted in the two schools did not adequately help the students to master the scientific skills needed by the students for the conduct of practical activities. The scientific skills are intended to help the students to master bits and pieces of the practical experiences as they move from simple practical work to more complex ones (Darmaji et al, 2019). The practical experiences of the SHS chemistry students are intended to guide the students in mastering Science Process Skills as they apply them in practical work. When students are able to apply their developed science process skills with finesse, they are able to engage in effective reasoning of phenomenon observed (Abungu, Okere & Wachanga, 2014).

From the analysis of the data on table 7,(in the previous page), it can be deduced that the practical work conducted did not allow the students to engage in intellectual discourse. Practical intellectual discourse includes arguing and analyzing arguments, judging the credibility of a source and making inferences (Holt & Pache, 2012). This would enable the students to draw conclusions based on sound evidence and reasons in deciding on action.

This situation has affected the students' ability to understand scientific concepts in relation to their own understanding. The students' inability to engage in scientific reasoning with deep sated thoughts has prevented them from developing the totality of their critical thinking (Irwanto et al, 2017).

4.4 Impact of Critical Thinking Indicators on Critical Thinking Development of SHS Chemistry Students in Practical Work

In exploring which critical thinking indicator (CTI) strongly influenced the development of the overall critical thinking of the third year chemistry students, the researcher conducted a relationship study to determine the contribution of each CTI in the total development of critical thinking of the students. Table 8 represents the relationship (between and within the critical thinking indicator groups) and its effect on the overall development of critical thinking.

Table 8: Exploring Impact of Critical Thinking Indicators on Critical Thinking Development

Indicator	Relationship	df	Mean square	F	Sig
Inference	Between groups	1	638.029	275.534	.000
	Within groups	159	2.316		
Evaluation	Between groups	1	1.844	.131	.718
	Within groups	159	14.083		
Analysis	Between groups	1	3.927	.444	.506
	Within groups	159	8.845		
explanation	Between groups	1	540.440	50.091	.000
	Within groups	159	10.789		
interpretation	Between groups	1	953.106	.644	.506
	Within groups	159	.000		

Source:Field data, August 2022, p value<0.05

From Table 8 above, the indicators influencing critical thinking development exist more between the groups than within the groups. With a higher f values (50.091) and (275.534), p value>0.00. There is a stronger relationship existing between explanation and inference which impacts more on critical thinking development than the other three critical thinking indicators (evaluation, analysis and interpretation). This suggests that practical work conducted in the two senior high schools sampled related more to the development of science process skills which induces explanation and inference more than the other three indicators (evaluation, analysis and interpretation). It can be said that the conduct of practical work in the two senior high schools did not engage the students in activities that will stimulate their critical thinking skills (Eilks & Hofstein, 2017). Senior high schools chemistry teachers in the two schools need to redefine their conduct of practical work to cater for the development of the totality of the SPS. This will result in the total development of the students' critical thinking skills needed in solving practical problems.

4.4.1 Analysis and discussion of research question one: **What is the effect of practical work on science process skills development**

Analysis of data in Table 3, indicated that most of the students in the two schools sampled have not developed the science process skills needed for the conduct of effective practical work. This assertion is based on the fact that students were not engaged in practical activities during the first and second years at SHS. Lack of exposure to effective practice in practical work has prevented most of the students from developing the skills required for handling apparatus during practical work. Students also lack the precision and accuracy needed for skillful handling of equipment during practical activities. Continuous practice is key in perfecting students' skills of handling apparatus (Geleta, 2015). When students are not given the medium to use practical apparatus with the desired skills, it hinders their mastery of SPS which most often affects their ability to conduct practical work efficiently. The main aim of conducting practical work in SHS is to guide students in developing competences required for solving practical problems confronting society (MoE, 2010). Students' ability to use the skills acquired through practical work develops their interest and confidence in undertaking further challenging problems which aids their development of scientific attitudes (Shana & Abulibdeh, 2020). Lack of effective students' engagement by teachers during practical work prevent them from developing the required skills needed in solving practical problems (Jack, 2020). Lack of access to chemicals and practical exposure also prevents students from developing their SPS. One can assert that ineffective teacher engagement and lack of practice in practical work has prevented the SHS students in the sampled schools from developing the required process skills and the scientific attitudes needed for working effectively (Brobbey, et al, 2020). This situation no doubt, has affected the students' ability to conduct practical work effectively. Lack of students' exposure to practical work has prevented them from mastering the SPS. Analysis of students' questionnaire indicated that students could not use the skill of observation effectively. They allowed what they knew already to influence their observations during practical work. It can be said that the students recorded their findings from memory without actually observing the chemical processes taken place (Maranan, 2017). Students lacked the ability to make inference due to lack of practice. Inferences are both psychomotor and cognitive process. It starts from observing what is happening during a practical and uses the evidence at hand in making intellectual guesses. This skill requires exposure to facts, effective observation and analysis of observed phenomenon backed by analysis of deep seated thought to confirm or refuse an assertion made. Students who are offered the chance to develop and use their SPS in conducting practical activities are resilient and very persistent in the face of failure (Darling-Hammond, Flook, Cook-Harvey, Barron& Osher. 2020). Inadequate exposure to practical work promotes passivity and aids memorization of scientific concepts and thus prevents students from being engaged in the scientific process of developing concepts. From the discussion so far, the researcher concludes that practical work conducted in the SHS sampled had not impacted positively in helping the students to develop their SPS.

4.4.2 Analysis of research question 2: to determine whether regularity of conduct of practical work develops students' SPS

The SHS Chemistry Curriculum posits that chemistry students should be engaged in practical work once a week from the first to final year to enable them develop practical experiences. The curriculum also indicates that practical work is needed in furthering students' academic work and most importantly, being involved in solving daily problems of society (MOE, 2010)**.** The curriculum also expects students to be taken through the rudiments of chemistry practical work in the first year to enable them develop the skills needed for manipulating and handling apparatus and chemicals, observe chemical reactions as it precedes, record observations made from chemical reactions accurately and be able to draw inferences by making intellectual conjectures (MOE,2010). These activities are meant to enable the students develop practical competences as they move from the introductory practical work in first year to actual practical work in the third year. Practical work is also intended to enable the students develop their SPS and practical competences by constant practice weekly. However, a clear observation made from the analysis of the questionnaire on regularity of conduct of practical work by SHS students revealed that most of the students were not engaged in science practical work during the first and second years. This practice did not allow the students to develop the skills and competences expected from practical activities. Lack of effective engagement of students in practical activities coupled with inadequate practice in the use of the content knowledge prevented the students from developing the requisite SPS needed for independent learning in science (Sunyono, 2018). The assessment of science process skills is not only influenced by the ability to use these skills, but also by the knowledge of a particular subject in which the process skills are used Irwanto et al, (2017). Process skills are important because they help students to implement sciences in real world learning and in everyday life. They guide students in the application of concepts, serve as a basis to generate theories and rules in learning (Rohaeti, & Prodjosantoso, 2018).Process skills also aids the internalization of concepts learnt.

It comes as no surprise that third year chemistry students continue to perform poorly in the Test of Practical Work at WASSCE. The ineffective use of practical work in developing students' understanding and appreciation of scientific concepts relevant for solving problems in science has resulted in apathy among them. The practice of not engaging SHS students fully in practical activities does not help them in developing basic SPS needed for understanding scientific theories, facts and principles. This is because in the absence or poor implementation of practical work, learners' performance in science would be poor and they may lose interest in science (Chala, 2019). Effective practical work enhances learner participation rather than passivity and develops their confidence in using scientific concepts and theories while explaining observation made in science (Babalola, 2017). Practical hands-on activities in chemistry produce learners who have the ability and capability in manipulating and observing the expected outcomes with the intent to develop SPS (Kibirige & Maponya, 2021). This assertion by Kibirige & Maponya is consistent with the observation made by Omeodu & Utuh (2018) when they contend that practical work increases knowledge acquisition, develops skills and competencies required in meeting scientific and technological demands of nations. Darmaji, Kurniawan, & Irdianti (2019) explained that SPS if well-developed facilitates science learning and increases students' responsibility for their learning. These skills are also useful in getting information, thinking about problems and formulating conclusions. Science Process Skills make science learning easier, increase the students' activities, and the students' responsibility toward learning. It is very important to note that practical work when well conducted develops SPS of students.

Another worrying situation revealed by the study was the fact that students could not offer suggestive scientific explanations to observations made during practical work. The study of science thrives when students use the practical skills acquired with science content knowledge to analyse situations(Glen, Suciu, & Baughn, 2014). This is done with the intent to have control over the situation by applying the best possible ideas developed from study.

The students again lamented during the intact group discussions that after performing the practical work and recording in groups. "We are left alone to report on the findings and the implications of the practical work conducted". This, the students contend has been reduced to copying since majority of them attested they do not know what to write. When practical work is not taught systematically, students are not able to develop the reasoning behind their observations. This is because the students do not understand the concepts being developed with the practical work. The students opined that their chemistry teacher discusses the theoretical basis of practical work before engaging in practical activity. Even though this practice is good, the practice failed to examine some of the industrial applications of the practical work. The act of not engaging students in the discussion of industrial application of practical work may elude them from knowing the importance of what is done in the classroom. Students needed to understand the totality of the practical activity conducted in order to connect with the use (Elliott, 2012). Students could not connect between theoretical concepts and practical application of facts, a situation that has characterized the study of science in most SHS in Ghana. The students again affirmed that they are not able to draw conclusions from practical work conducted. They intimated that they find it difficult to draw inferences during practical work and as such are not able to interpret the results obtained from practical work. It is therefore not surprising that majority of the students reported not being able to make conclusions. This suggests that the chemistry teachers did not engage the students in discussing the findings of practical work by putting the findings in perspectives. The students were not exposed to the intellectual discourse of making meaning from practical work conducted in line with their conceptual understanding of theories learnt. The students observed, wrote their conclusions relating to the practical work even before the chemical reaction ended. The students have allowed what they knew already to influence their observation. It is important students are guided to develop not only SPS but also the scientific attitudes needed for the development of the SPS. It can therefore be concluded that practical work seeks to develop science process and the scientific attitudes required for the development of those skills. From the analysis above, one could easily conclude that the regularity of conduct of practical work in the two SHS sampled was not adhered to. This situation affected the students SPS development.

4.4.3 Analysis of research question 3; To what extent does science process skill development influence the chemistry student's critical thinking?

Science Process Skills offer avenue for students to explore their environment, analyse issues so as to deduce their own meaning (Vieira, 2016). SPS are the tools used by students to conduct activities, investigate phenomenon and draw conclusions. To effectively learn science with meaning and understanding students need control over their SPS because it is the skills that guide the development of scientific theories and concepts. This suggests that process skills do not develop on its own but rather requires content knowledge in science to guide its development (Maranan, 2017). Analysis of the questionnaire on process skills and development of critical thinking revealed that most of the students are not developing the totality of their critical thinking skills due to lack of exposure and avenue to practice and develop the concepts taught in the classroom. The students marks obtained from the test is indicative that they have not fully developed the totality of the critical thinking skills in chemistry required for solving problems and for taking meaningful life changing decisions (Facione, 2015). This condition prevailing among the third year chemistry students is attributable to undeveloped SPS borne out of inadequate practical engagements in their schools. This means that the students have not been able to independently perform their practical work by assigning reasons to their observations made using scientific theories. Students have not been engaged in reflective practices that seek to answer confusions which may have occurred during the conduct of practical work.

According to a Lai (2011): Bati, Kaan, Kaptan & Fitnat (2015), practical work aimed at developing critical thinking must equip students with the propensity to seek reason, a desire to be well-informed, and a respect for and willingness to entertain diverse viewpoints. This suggests that practical work must offer avenues for students to be able to question issues with the reason to obtain answers that satisfy their curiosity by providing exposure to scientific knowledge. When not properly thought out and executed, practical work can stifled students' confidence, enthusiasm and their ability to apply scientific knowledge in reasoning required for developing critical thinking in chemistry (Babalola, 2017). Santos(2017) postulates that critical thinking in chemistry must urge students to be “habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, and fair-minded in evaluation. Critical thinking as a skill develops when SPS of students’ develops. The students did not develop all the indicators necessary for critical thinking because the practical work conducted in the two schools did not equip them with the ability to manipulate scientific apparatus with dexterity and skill. Students could not develop control over practical problems by collecting data, offering suggestive explanation, drawing influences from observations made in order to argue consistently on insights made. To have control, students need to be able to ask a myriad of creative or critical thinking questions that can provide them with scientific insights. However, Osborne (2014) contends that opportunities for students to ask questions in science are rare. Instead somewhat strangely, it is the teacher, who knows all the answers and commonly asks all the questions. Osborne (2014) again contends that the reason why students’ questions, argumentation and critique are often absent from the science practical work is that students’ competencies are not developed during practical work. Students’ competencies are not a feature of what teachers expect students to learn. There has been a tendency to focus on content geared towards passing examinations rather than developing the skills needed to do science which involves critical thinking. The desire to query and imagine is often not cultivated during science practical work. The focus of practical work in the two schools has been the propensity to neglect critical thinking by concentrating more on providing answers to practical examination questions (Santos, 2017). Science students need to be trained through science processes to think creatively and critically from a scientific viewpoint so that they can see events from different perspectives in science to develop their critical thinking ability (Demi, 2015). This suggests that practical activities must be designed to guide the development of students' thinking skills which is highly important for gaining the ability to see, think, research, question, and resolve events in a scientific way. SPS must encourage exploration, and investigation with the intent to solve societal problems. Chemistry research suggests a strong positive correlation between Critical Thinking and SPS development. SPS emphasizes the process of seeking knowledge actively while conducting the practical work in chemistry rather than the transfer of knowledge from the teacher Osborne (2014). Critical Thinking ensures the utilization of scientific knowledge gained in explaining observed phenomenon based on conceptual understanding of the students.

If students could not develop their Critical Thinking, it can be said that they have not had access to adequate laboratory equipment/apparatus that can serve as a basis for conducting practical work in developing their SPS. Practical work are mostly carried out in the laboratories where students are allowed to go through the processes of science in order to produce scientific knowledge (Abungu, Okere & Wachanga, 2014). Nkechi (2012) contends that material resources play an integral role in science instruction as they stimulate Critical Thinking processes in students by making the learning interesting and meaningful. This suggest that to enable students develop adequate SPS which could culminate into Critical Thinking, teachers need to provide adequate scientific apparatus and guide students during practical work to develop the skills and competences inherent in solving problems in life. Opara (2015) contends that the availability and effective use of science resources facilitate active involvement of students during science instruction and therefore improves learning. It is worth noting that, the two schools sampled had very modest scientific apparatus making the conduct of practical work very difficult and daunting for the chemistry teachers in the schools. Effah (2018) opines that most senior high schools in Ghana have inadequate laboratory resources which make the conduct of practical activities very difficult. This assertion is in tandem with Okeke & Okoye (2013) when they stated that the extent of acquisition of knowledge, skills and values by science students depends on the quality of instructions that take place in the classroom as a result of effective interaction with teaching and learning resources. The assertions above can highly inform one to conclude that adequate SPS development of students' results in the totality of the development of Critical Thinking in chemistry.

4.4.4 Analysis of Findings from Research Question Three

Research Question Three: To what extent does science process skill development influence students' critical thinking?

The development of critical thinking skills in science is inextricably linked with the development of science process skills (Darmaji et al, 2022). Science process skills development form the basis for the development of critical thinking in science. The development of critical thinking abilities form the foundation for the development of innovation through collaboration, problem solving through inquiry and decision making. The senior high curriculum prescribes the development of critical thinking through the analysis of data, application knowledge, planning investigations as well as communication of findings made to be made from the practical work (MoE,2010).

The analysis of the statistics on Table 3 indicates that the third year chemistry students in the two senior high schools sampled, have not developed the basic science process skills such as needed for conducting effective science practical work and to be involved in critical thinking. The third year chemistry students sampled were rated low on the science process skills related to (predicting-30%, classifying-32% inferring-28%, recording-48% and calculating-50%) using the participant observation schedule. This observation is in tandem with the study conducted by Shofwa, Rochintaniawati and Rusyati, (2018) on the profiling of students science process skills in biology among junior high schools in Pakistan. Their study also revealed that students science process skills were not developed in 3 key areas namely communicating, measuring and classifying. It is imperative to note that, when student's science process skills are not developed, it hampers the development of their critical thinking skills. Science process skills have great influence in science practical work because of the propensity to develop higher mental processes such as problem-solving, critical thinking and making a decision (Facione, 2015). SPS are the building blocks of critical thinking and inquiry in science (Raj and Devi, 2014). This suggests that science process skills are the main facets that guides the development of student's critical thinking in science. However, analysis of data on critical thinking indicators on Table 7, (critical thinking indicators) revealed that the third year senior high students scored very low marks on the Acid-base critical thinking test conducted to determine the student's critical thinking skills. The students scored (31%, 37%, 45% and 47%) corresponding to evaluation, inference, analysis, and interpretation respectively. The scores indicated that the senior high students have not developed the totality of the critical thinking skills required for solving problems and making meaningful decisions. The results also indicates a positive correlation between sciences process skills and critical thinking skills. This is because as the scores obtained in the science process skills were low, the scores obtained in the acid-base critical thinking test were also low. Dwyer, Hogan & Stewart (2014) contend that critical thinking has much importance because it enables students to think and analyse issues constructively so that they can make informed judgments. The propensity for the senior high students becomes impaired when they are not able to develop their science process skills. Science process skills are the activities which scientists employ in carrying out scientific investigation in order to arrive at new knowledge (Obialor, 2016).

The Effect of Science Process Skills on Critical Thinking Development.

Predicting, a science process skill, involves making scientific guesses backed by data and evidence collected (MoE, 2010). Predicting was not developed by the students in relation to the practical work conducted in the sampled schools. The situation had affected the development of inference, a critical thinking indicator. The fact that the students scored low marks on the acid-base critical thinking test relating to inference (37%) is indicative of the their inability to forecast by making scientific guesses based on data collected from the practical work. Most research suggests that prediction, a science process skill emanates from questioning, observing, forecasting, hypothesizing and making conscious effort to reason to the hypothesis made by weighing evidence gathered against predictions made. This points to the fact that prediction contributes to the developmentof hypothesis, a critical thinking indicator.The mastery of prediction form the foundation for the development of hypothesis.Ajaja (2010), have opined that the reason why students find some process skills difficult could be due to the persistent use of lecture methods for teaching chemistry as against the recommended use of laboratory and discovery/inquiry approaches which are student-activity centered. This assertion is supported by an observation during the intact group discussion that practical work conducted by the two senior high schools sampled, did not offer opportunity to the students to use data and information collected in making wild guesses. This lack of practice has affected the development of the critical thinking indicator, inference.

Calculating; during acid- base titrations, calculations are done not only on the quantity of titrant consumed or the concentration of the analyte, calculations are done to relate smaller quantities of the titrants to the ratio of the analyte consumed. This suggests that the students sampled, should be able to relate the calculation of the concentration of titrants to the concentrations of the analyt in order to establish ratios and bring meaning to the calculations done. This can only be achieved when students have the ability to interpret data based on information collected during practical work in accordance with the scientific method. The students were not able to analyse the values obtained from their calculations relating to the analyte and the titrant and this made it difficult for them to interpret (47%) the findings obtained from the conduct of the practical work.

Classifying; the third year chemistry students' inability to be engaged in the basic science process skill of classifying has affected the ability of being critically involved in both analysis and evaluation. Analysis and evaluation are critical thinking indicators which are highly cognitive in nature.Analysis and evaluation require analytical thinking processes to be developed. Lack of development of the science process skills of classifying has affected the critical thinking indicator of evaluation (31%) and analysis (37%). This observation is in line with the assertion made by Holt &Pache, (2012), when they concerted that analytical thinking ability is required in analyzing, assessing, evaluating, comparing and contrasting abstract concepts in science. The observation is also in tandem with the study conducted by Zubaidah, Corebima, Mahanal & Mistianah, (2018) when they concluded that the development of critical thinking skills results in improved quality of thinking needed for reasoning and logic in problem solving. The student's inability to develop the analytical thinking process of classifying using some defined traits and characteristics backed by data has affected thedevelopment of the critical thinking indicators such as evaluation and analysis. This could be the basis for the third year chemistry students' low performance in the acid-base critical thinking test relating to evaluation and analysis.

Recording; a psychomotor and cognitive process is related to observation, communication and reporting. As a psychomotor process, it involves the use of the muscles in imprinting on a medium the information taken with the senses during practical work. As a cognitive process, recording encompasses the use of the senses in analysing facts, observing details and making inferences by drawing or printing the findings made. Recording enables scientist to keep accounts of scientific knowledge which can be reproduced and the results compared. This suggests that as a process skills, recording aids in inference, analysis and interpretation of scientific findings. Research suggests that scientist who record objectively is very proficient at analysing problems (Rothe, 2017). Recording enable students to have access to new information which can be verified, modified or adapted in developing scientific knowledge. Analysis of the third year student's responses on Table 3, indicated that the students were rated medium on the science process skills related to recording. This suggests that the students were able to use their senses in collecting scientific information during the practical work but were unable to subject the information so collected to high order reasoning. The students' inability to develop high order reasoning in this regard affected their ability to give details which in effect impaired the development of interpretation.

From the observation made so far, it could be deduced that the develop of science process skills has positive effects on the development of critical thinking indicators. However, research suggests a high positively correlation between critical thinking indicators and the development of critical thinking skills. It must be emphasised that the development of a particular process skills affects the development of two or three other critical thinking indicators.

4.5 Summary of Analysis

From the analysis conducted so far, it is eminent that practical work in chemistry when seriously conceived and well thought out and conducted, aids the development of SPS. SPS development also positively influence the development of critical thinking required for solving problems and making meaningful decisions in life. It must be emphasised that the regularity of conduct of practical work in the first and second years in the SHS form the basis for the consolidation of actual practical work employed in solving problems in the third year of SHS (MoE, 2010). However, it must be noted that to get the best out of the SHS chemistry practical work, students need to have access to practical apparatus and equipment to interact with so as to develop the intellectual and practical skill of questioning, observations or assigning reasons that aids the development of scientific insights. The practice of engaging in practical activity that has examination oriented objective does not help the students to develop the Critical Thinking skills and attitudes needed in solving the numerous problems confronting the society. Chemistry teachers needed to effectively engage with first, second and third year chemistry students to develop their competences in practical work so that the students can develop all the SPS required for developing the totality of their Critical Thinking skills.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter looks at the summary of findings drawn from the study, the conclusions that were obtained from analysis of data as well as some recommendations that is needed to improve the conduct of practical work in the two SHS sampled. The researcher has put forward some suggestions that could be of help to other researchers who would be interested in further research in a similar study. This study sought to determine the effect of chemistry practical work on Bompeh Senior High Technical School and Adiembra Senior High Technical Schools' third year chemistry student's science process skills (observing, measuring, inferring and calculating) development using titrimetry.

The study also examined whether regularity of conduct of chemistry practical work influence third year chemistry students science process skills development in the two SHS sampled. The study again considered whether effective student's engagement during practical work develops science process skills.

Finally the study sought to examine the level of use of science process skills during practical work which develops the critical thinking skills required for solving scientific problems.

5.1 Summary of Findings

1. The study revealed that the third year chemistry students sampled from the two senior high schools have not developed the totality of the science process skills needed for effective conduct of practical work. The statistics indicated that the

students exhibited high use of science process skills pertaining to measuring and observing, medium use of SPS dispositions relating to recording and calculating and high level difficulty in SPS relating to prediction, classifying and inferring.

2. The study again revealed that the third year chemistry students sampled from the two senior high schools in Sekondi-Takoradi metropolis, had not engaged their first and second year students in regular practical work. This situation has affected the development of the required science process skills such as recording, calculating, predicting, classifying and inferring which form the basis for effective practical work in third-year. The third year students struggled during practical work because they lacked the skills and experiences needed to be developed in the first and second years'.

3. The study also revealed that chemistry teachers in the two schools sampled, dedicated most of the time for practical work focusing on development of the students' ability to answer questions on test of practical work conducted by West African Examinations Council to the neglect of helping the third year chemistry students develop the scientific insights essential for developing understanding of scientific concepts. Instead, the students were exposed to strategies that helped in the memorization of scientific facts/concepts without understanding. The situation has serious ramifications for developing the skills, attitudes and dispositions needed for the conduct of effective practical work in the two SHS sampled.

4. The study further indicated that the third year chemistry students were not developing their critical thinking skills needed for solving challenging societal problems, making decisions and becoming independent learners. Critical thinking indicators such as inference, evaluation, analysis and interpretation relating to critical

thinking skills were not developed by the students. The students have not been engaged in practical work which focuses on the development of the totality of their science process skills which has implications for the development of critical thinking.

5. The students could not use experimental data in making claims or refuting the claims in rebuttals that can consolidate their understanding of scientific phenomenon. This condition made the understanding of scientific concepts, theories and facts very difficult for the third year chemistry students. The situation made it difficult for the students to apply their critical thinking in solving practical problems.

5.2 Conclusions

It can be concluded from the study that practical work conducted in the two SHS sampled did not developed the third year chemistry students' Science Process Skills. Since science process skill development is positively correlated to critical thinking skills, practical work conducted in the two SHS sampled also did not develop the third year chemistry students' critical thinking skills.

The researcher again concludes that regularity of conduct of practical work in the two SHS sampled prevented the development of science process skills of the chemistry students. The conduct of practical work in the two schools has been reserved for the third years. This situation has reduced the number of contact hours stipulated by the SHS curriculum for the development of SPS. The study again revealed that ineffective students' engagement during chemistry practical work prevents the development of science process skills. Th e researcher again concludes that the low level of use of science process skills in practical work prevented the development of the totality of critical thinking skills among the chemistry students. SPS are the scientific skills used by science practitioners to conduct study into science phenomenon with the intension of revealing insights that can be explained. Explaining scientific insights demand that students use their knowledge of use of science process skills in making meaning from findings deduced from practical work. The findings from the study indicated that the students were either not effectively engaged or that they were not offered the opportunities to deduce their own meaning from the findings obtained during practical work.

From the observations made above, the researcher concludes that effective practical work that aims at developing students' science process skills and critical thinking must be highly engaging and well planned. The totality of the development of students' critical thinking skills and disposition is a function of the students' ability to master the basic science process skill use with finesse. This is because there is a higher correlation between mastery of process skills in the conduct of effective chemistry practical work and the development of critical thinking skills. The development of science process skills forms the basis for the development of critical thinking ability of the chemistry students.

5.3 Recommendations

The researcher has put forward the following recommendations based on the study findings to help improve the conduct of chemistry practical work among the third year chemistry students in the two SHS sampled.

It is recommended that Chemistry teachers in the two SHS sampled, exposed the third year chemistry students to scientific concepts in chemistry by buttressing their teaching of theory in the classroom with effective practical work through proper engagement of the students. Teachers must endeavor to engage in more practical activities with the students to ensure use of and practice of the students' science process skills. This will afford the students the opportunity to develop the totality of the skills needed for conducting practical work by effectively using their hands, mind and heart. This will motivate the students by developing their interest in the subject resulting in the students willing to take professions in chemistry and science in general.

Chemistry teachers in the two schools sampled must employ innovative modern pedagogies to teaching the science process skills during practical work to guide the students to develop their critical thinking skills.

The SHS chemistry students in the two sampled schools must be taught holistically from first year to third year through engaging them in argumentative academic discussions during the post practical work discussions. This can help the students in making claims with experimental data collected or refuting claims based on evidence collected. This practice has an advantage of increasing students' critical thinking ability.

Chemistry teachers in the two schools sampled must allow students opportunity during practical work to deduce meaning from their findings. This can help the students to use their own scientific insights to explain findings made during practical work. The practice could spur up students interest in the study of chemistry especially when they are able to explain their own findings.

5.4 Suggestions

Management and administrators of SHS must allocate the needed resources to Chemistry laboratories to enable SHS chemistry students have access to chemicals and apparatus for use during practical work in first year, second and third years.

Directors of studies, Heads of Departments, Assistant Headmaster Academic as well as the Headmasters of Senior High Schools must do effective monitoring of chemistry teachers practical teaching to ensure that first and second year chemistry students' practical work are not sacrificed for the third years on the excuse of absence of space and apparatus.

Senior high school chemistry teachers must desist from the habit of teaching examination focused practical work which has become a panacea for memorization of scientific concepts without understanding. Teaching chemistry must take full advantage of the totality of the development of scientific concepts by offering students opportunities to develop their own understanding of scientific concepts.

The researcher suggests that chemistry teachers in Senior High Schools attach great importance to practical work from the first year through to the final year by engaging the students in effective conduct of practical work at all times. This could assist in developing the student's science process skills and critical thinking. This can be achieved by engaging in post practical discussion of students findings after the practical work and marking of students responses to enable them reflect on their feedback.

SHS chemistry teachers must always relate practical work conducted to the industrial applications of the concepts developed. This could motivate chemistry students to develop their own innovative practical activities to solve societal problems by developing critical thinking skills and dispositions.

5.5 Suggestions for Further Research

The researcher suggests that researchers interested in extending this study could look at the impact of first and second year chemistry practical work on the development of science process skills in the final year at SHS.

Other researchers could also conduct a comparative study on the practical competencies of male and female SHS chemistry students and its effects on critical thinking development.

Further research is also suggested in the area of pre-and post-laboratory discussions of third year SHS chemistry students' findings and its effects on the development of science process skills and critical thinking.

Researchers could also explore the effect of SHS chemistry student's gender on science process skills and critical thinking development.

Finally the researcher proposes that further research can be conducted to ascertain which of the two cohorts of students sampled (science students pursuing chemistry as elective subject and Home Economics students pursuing elective chemistry) have developed the totality of their critical thinking skills.

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APPENDIX A

Observation Checklist

The essence of this checklist is to collect data on the use of science process skills by SHS students during practical work. The checklist aims at enabling the researcher obtain valid information which will reveal insights on science process skills development.

Kindly observe and check [√] appropriately student's use of science process skill development exhibited during practical work on titration.

Statements	**High**	**Medium**	**Low**
1. Student follows the appropriate instructions on the task sheet to the latter in conducting a practical work.			
2. Student possesses the skill to measure accurately, the volume of acids and bases using burettes and pipettes.			
3. Student possesses the manipulative skills required for using laboratory apparatus (burettes, pipette, or cylinder) with precision and accuracy to measure the desired volume of acids and bases.			
4. Student possesses the skill required for running off the volume of acid and bases without reducing the expected volume.			
5. Possesses the skill needed for running off whilst meticulously swirling to locate the exact change in color.			
6. Student is able to calculate the volume of base accurately used in performing practical work. i.e. determining titer values			

7. Student is able to calculate accurately the concentration of the acid used by relating it to the concentration of the base used in titration			
8. Student is able to calculate the accurate concentration of the acid used by relating the amount of base and volume used in titration.			
9.Student is able to relate the color change (end point) to calculate the accurate volume of acid used in neutralizing the base and vice versa			
10. Student is able to state the exact observations made during practical work (titration) e.g. Effervescence of a gas, color change, etc			
11.Student states the exact observations made without allowing what they know to cloud their observations			
12. Student relates observation made during the practical work to theories and concepts in science.			
13. Student is able to record accurately the findings made during the practical work (color change, end point, volume of acid/base used).			
15. Student draws accurate conclusions from practical work conducted using the data obtained and observations made in reporting.			

APPENDIX B

Students Questionnaire

The essence of this questionnaire is to collect data on how practical work by SHS students develops their science process skills and critical thinking. Your candid responses to the questions will go a long way to enable the researcher obtain valid information which will give insights on the issue being investigated.

Kindly bear in mind that your anonymity and confidentiality of the information provided is assured.

Bio-Data

Sex of Respondents: [ ] male [ ] female

Age of respondents: [ ] 14-16 [ ] 17-19 [ ] 20-22 [ ] above 23

Major elective area: [ ] Science-chemistry [ ] Home economics - chemistry

Kindly answer the following questions on process skill by [√] ticking appropriately

(VE)Very efficient=5, (E) Efficient = 4, (SWE) somewhat efficient =3, (NE) Not Efficient = 2, (NAE) Not at all efficient =1

a. How efficient are you:	VE	E	SWE	NE	NAE
1. In following procedures on the task sheet to the letter during practical work?					
2. In measuring the volume of liquids using burettes and pipettes.					
3. In using the desired skill required for measuring the volume of liquids using burettes and pipettes.					
4. In stating the exact observations made during practical work without allowing what you know to cloud the observations?					
5. In observing chemical reaction by satisfying the senses (touch/texture, sound, color, smell/scent) before recording?					
6. In predicting the color of the solution to be formed					

based on reagents used?					
7. In predicting the concentration of the unknown solution using the reagents used?					
8. In calculating accurately the volume of liquids using the appropriate apparatus?					
9. At recording the exact findings from the practical work without being influenced by what you know?					
10. at discussing the findings of the practical work with colleague/s before agreeing on best answer					
11. at applying the findings from practical work in solving daily problems.					
12.in being able to design you own practical work to solve assigned problem					

B. *Kindly respond to the following questions on conduct of practical work by [√] ticking the option that best describes the situation in your school.*

13. How often did you perform chemistry practical work when you were in SHS One?

[ ] once a week [ ] once every two weeks [ ] once a month [ ] once a term

[ ] never conducted a practical work

14. How often did you perform practical work when you were in SHS two?

[ ] once a week [ ] once every two weeks [ ] once a month [ ] once a term

[ ] never conducted a practical work

15. How often do you perform practical work in SHS three?

[ ] once a week [ ] once every two weeks [ ] once a month [ ] once a term

[ ] never conducted practical work

(SA) strongly agree=5, (A) agree=4, (N) neutral = 3, (D) disagree =2, (SD) strongly disagree =1

Statements	SA	A	N	D	SD
16. Your chemistry teacher discusses the theoretical basis of the practical work with you before the practical sections.					
17. Your teacher discusses some applications (industrial or biological) of the practical work with you after every practical section.					
18. You always write a report on findings on practical work to your teacher for assessment after every practical section.					
19. You usually read on the theoretical basis or the scientific concepts of the practical work to be conducted before or after the practical work?					
20. Your chemistry teacher discusses with you practical applications of the findings in practical work?					
21. You are able to identify some applications of your findings from practical work?					
22. Your chemistry teacher always goes round the laboratory to monitor during practical work?					
23. Your teacher sometimes direct or give an alternative option to guide you when you get stuck during a practical section.					
24. You are able to draw conclusions from practical work conducted?					
25. You are able to interpret findings obtained from practical work?					
26. You are able to use the results obtained in practical lessons to draw inferences?					
27. Your inferences most often turn out to be true.					

C. *Kindly respond to the following questions on science practical work by ticking [√] the option that best corresponds to your feelings.*

(SA) strongly agree =5, (A) agree = 4, (N) neutral = 3, (D) disagree =2, (SD) strongly disagree =1

Statements	**SA**	**A**	**N**	**D**	**SD**
28. You are able to assign reasons to observations made during practical work?					
29. You are able to interpret findings made during practical work by deducing from observations made with data obtained?					
30. You are able to draw conclusions from findings made during practical work?					
31. You are able to apply conclusions arrived at during practical work to create new way of solving practical problems?					
32. You are able to analyse findings in order to assigning reasons to observations made?					
33. You are able to relate and apply findings from practical work in your daily life?					
34. You are able to design your own practical method(s) to solve practical problems?					
35. You are able to identify applications of practical work in our daily lives?					
36. You are able to collaborate with your friends during practical work to discuss findings?					
37. In discussing findings from practical work, do you believe in other peoples view or your conclusions are always the best?					
38. You are able to make inferences based on observations made to arrive at conclusions					
39. You are able to explain the scientific basis of the practical work conducted to your colleagues.					

APPENDIX C

Acid Base Critical Thinking Test

The essence of this test is to collect data on SHS chemistry students to enable the researcher predict the critical thinking ability of the students in acid base reactions/titrations. Your candid responses to these questions will enable the researcher to make better inference on the critical thinking abilities of the students. Kindly note that confidentiality of the information provided is assured.

Bio-Data

*Kindly tick appropriately***.**

Sex: Male [ ] Female [ ]

Class: Chemistry – Science [ ] Chemistry – Home economics [ ]

Time: 40 minutes

Indicators of critical thinking

A. Interpretation

Kindly answer the following questions on critical thinking in acid and bases by circling the best option.

1. Which of the following is the correct classification of Dolomite?
   - a. An acid salt
   - b. mixed salt
   - c. normal salt
   - d. double salt

2. Which of the following industries are likely to use titration in their operation?
   - a. Pharmaceutical industry
   - b. geological survey
   - c. cosmetics industry
   - d. agrochemical industry

3. What is the concentration in moldm^{-3} of a solution in which 0.40 mol of alkali is dissolved in 250cm^3 of solution?

a. 1.60moldm-^{3}

b. 0.10moldm-^{3}

c. 0.0015moldm-^{3}

d. 0.025moldm-^{3}

	Titration 1	Titration 2	Titration 3	Titration 4	Titration 5
Volume of 0.100 mol / dm^3 sulfuric acid in cm3	27.40	28.15	27.05	27.10	27.15

4. What is the correct titre value for the 5trial titrations on the table above?

a.136.86 cm^3

b. 27.37 cm^3

c. 27.10 cm^3

d. 27.56 cm^3

5. Acetic acid is a weak acid because

a. Its aqueous solution is acidic

b.It is highly ionised

c.It is weakly ionised

d.It contains the COOH group

B. Inference

6.Which of the following titrations will have the equivalence point at a pH more than 8?

a. HCl and NH_3

b. CH_3COOH and NH_3

c. HCl and NaOH

d. CH_3COOH and NaOH

7. The pH of a solution obtained by mixing 50.00 cm^3 of 0.20 M weak acid HA (K_a = 10^{-5}) and 50.00 cm^3 of 0.20M NaOH at room temperature is

a. 2

b. 3

c. 5

d. 9

8. Which of the following can be considered as an example of olfactory indicators?

a. Onion

b. Methyl orange

c. Turmeric

d. China rose

9. Which of the following compounds is most acidic?

a. Cl_2O_7

b. P_4O_{10}

c. SO_3

d. B_2O_3

10. Why is it necessary to place a white tile or paper at the base of the conical flask during titration?

a. to detect slight color changes in the solution

b. to determine the color of the of the salt formed

c. to determine the color at which the equivalence point is noted

d. to determine the color change of the

C. Evaluation

11. The difference between strong and weak acid is

(a) Presence and absence of halogen ions

(b) Negative and positive pH

(c) Complete and partial ionization

(d) Proton donation and electron acceptance

12. Which of the following is not an amphiprotic species?

a.HCO_3^-

b.HPO_4^{2-}

c.OH^-

d.$H_2PO_4^{2-}$

13. If the start reading in a titration is $0.50cm^3$ and the end reading is $26.96cm^3$, what is the titre?

a.$30.10cm^3$

b.$13.48cm^3$

c.$26.46cm^3$

d.$27.46cm^3$

14. Identify the basic salt from the following.

a.Na_2CO_3

b.$NaNO_3$

c.KCl

d.NH_4Cl

15. Which of the following salts do not contain water of crystallization?

a) Baking Soda

b) Gypsum

c) Red vitriol

d) Copper sulphate

D. Explanation

16. What does the endpoint in titration indicate?

    a. The exact quantity of acid that neutralizes the base

    b. The exact quantity of base that neutralizes an acid

    c. The point at which the color of the reaction changes

    d. The point at which neutralization of acids occur.

17. What is the importance of swirling the content in the beaker during titration?

    a. Effective mixing of both acid and base

    b. Reaction of the acid and base

    c. All the acid is used in the reaction

    d. All the base is used in the reaction

18. A 15.5 cm^3 sample of 0.215 M KOH was titrated with a weak acid. It took 21.2 cm^3 of the acid to reach the equivalence point. What is the morality of the acid?

    a. 0.157M acid

    b. 0.28M acid

    c. 0.057M acid

    d. 0.029M acid

19. Which of the following ions are present in a dilute aqueous solution of ammonia?

    a.$OH^- + NH_3$

    b.$OH^- + NH_4^+$

    c.$H_3O^+ + NH_2^-$

    d.None of these

20. Which of the following products does not involve use of Bleaching powder?

    a.Bleaching agent

    b.Oxidizing agent

    c.Used in soda-acid fire extinguishers.

    d.Disinfectant

E. Analyses

21. What is the purpose of acid base titration?

a.To find the pH of an acid

b.To determine the concentration of an unknown acid or base

c.To find the volume of an unknown acid or base

d.To find the pH of a base

22. What is the purpose of an indicator in the solution with the unknown concentration?

a. It tells when there is enough acid in the solution.

b. It tells when the equivalence point is obtained.

c. It tells when there is enough base in the solution

d. It tells when the endpoint is attained.

23. What happens when an acid solution is combined with a base solution in a test tube?

a.The solution's temperature rises.

b.The temperature of the solution drops.

c.The solution's temperature remains constant.

d.The production of salt occurs

24. What is the amount in mol of sodium hydroxide in 25.00 cm^3 of a solution of concentration 0.10 mol/dm^3?

a.2.5mol

b.10.25mol

c.0.025mol

d.0.0025mol

25. A solution of 25.0 cm^3 of hydrochloric acid was titrated against a solution of 0.100 mol dm^{-3} NaOH and 12.1 cm^3 were required for complete reaction. Which indicator can best be used to locate the end point and why?

a.Litmus paper

b.Phenolphthalein

c.Methyl orange

d.Bromothyl red

APPENDIX D

Interview schedule for Intact Groups

1. 1.Which of the following skills are easy for you to perform during practical work?

   a. observing b. measuring c. predicting d. calculating e. recording
2. Are you able to analyse your findings with data gathered in practical work? Why?
3. Does analyzing your findings in practical work require you to think critically? Why?
4. Are you given the chance to create your own practical method in solving practical problems? Why?
5. Are you able to explain your observations in line with scientific concepts? Why?
6. Are you able to interpret your findings in the light of other findings from your friends? Why?

APPENDIX E

LESSON PLAN

ACID-BASE TITRATION (PRACTICALS)

CONSOLIDATED LESSON PLAN FOR TWO SENIOR HIGH TECHNICAL SCHOOLS IN TAKORADI.

Subject; Chemistry

Topic; Acid Base Titration

Form; SHTS 3

Objective; by the end of the lesson, the students will be able to;

i. Perform an acid base titration experiments involving acids (HCl, H_2SO_4) and bases (trioxocarbonate iv, $CO3_{2-}$ hydrogentrioxocarbonate iv HCO_{3-}).

ii. Determine an appropriate indicator for a titration given the equivalent point for the titration.

iii. Using methyl orange and phenolphthalein as indicators, discuss titre values, endpoint, equivalence point, precise values and average titre values.

iv. Determine mole ratios and concentrations of acids, and bases.

Teaching Learning Resources:

Retort Stands, Pipettes, Burettes, Funnel, Conical Flasks, Beakers, Wash Bottles, Calculators, A4 sheets.

Teaching-learning Activities:

I Students define the following terms;

i. Titre Values, ii. End Point, iii. Equivalence Point,

II Students find the concentration of an unknown solution using hypothetical equations.

III Using the same hypothetical equations, students work through the steps for determining the concentration of the unknown substance from the a sample titration data.

IV. Based on calculations, students predict the type of indicator relevant for the acid-base titration.

V. Students give reasons on the use of the appropriate indicator.

VI. Students to relate calculations to real situations.

Practical Session

1. Students measure 25ml of sample A using a pipette and gentle release it into a flask.
2. Students fix the burette onto the retort stand making sure it is firm in the grip of the fork.
3. Students place the flask containing sample A under the burette making sure the pipe does not flow out side.
4. With the aid of a clean funnel, students fill the burette with the sample B provided.

5. After filling the burette, students remove the funnel immediately and take accurate reading on the burette. (Be mindful of lower meniscus).
6. Students Add. Phenolphthalein indicator to the sample in the flask and identify any colour change.
7. Students place the flask directly under the burette on the A4 sheet.
8. Students gentle ran sample B into the flask while swirling.
9. As soon as there is a colour change, stop running and note the volume of sample B consumed.
10. Students repeat the process 3 times to generate the titre values.

Post Practical Assignment- Evaluation

1. Identify sample A and sample B
2. Calculate the volume of B used in the reaction
3. What type of reaction has taken place?
4. Calculate the concentration of the B using that of A.
5. State any 4 applications of the concept of titration in the life of man
6. State three precautions to be taken during this practical work.