UNIVERSITY OF EDUCATION, WINNEBA

COOPERATIVE LEARNING STRATEGY: TOWARDS EFFECTIVE TEACHING AND LEARNING OF CHEMICAL BONDING

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

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DECLARATION

Student's Declaration

I, **Mershack Osei Agyemang**, 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, **Prof. Ruby Hanson**, hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

SIGNATURE:………………………………………………………….

DATE:………………………………………………………………..

DEDICATION

To my lovely late grandmother, Mama Beatrice Afia Ahi**.**

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I wish to express my profound gratitude to the Almighty God for the protection He gave to me through my years of study and the knowledge given to me to finish this work. I also thank Prof. Ruby Hanson for taking the pain and time off her busy schedule to go through this work, and make in-depth and constructive criticisms and suggestions for this work to become a reality. God bless her for a good job.

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GLOSSARY/ABBREVIATIONS

Cooperative learning- learning together in a group to attain a common goal.

Subpar – using a teaching method that is not a modern acceptable standard.

GES – Ghana Education Service

WASSCE -West African Senior School Certificate Examination

GSI- Graduate Student Instructor

CBAT- Chemical Bonding Achievement Test

NCE -Nigerian Certificate of Examination

STAD- Student Teams Achievement Divisions

TAI – Teams Assisted Individualization

ABSTRACT

This study investigated the use of cooperative learning strategy towards effective teaching and learning of chemical bonding. The action research approach and case study research design were used. The accessible population was 72 students was the sample 26 students comprising all form two science students at Boso Senior high technical school. A pre-test was administered to all the students followed by interviews to know their prior conceptions, misconceptions, and causes of their misconceptions on chemical bonding. After that, the cooperative learning strategy was used as an intervention to solve the problems the students had on the topic followed by administration of post-test to all the students. Paired sample t-test was used to analyze the pre-test and the post-test to find out whether there was a significant difference in students' academic performance. From the paired sample t-test it was found that the t-statistics (14.748) was greater than the t-critical (2.060) which means there was a statistically significant difference in students' academic performance. This shows that students performed better in the post-test as compared to the pre-test and the cooperative learning strategy had a greater effect on the students. After that, the results from the post-test were grouped into males and females and an unpaired sample t-test was used to determine whether there was a statistically significant difference between the performance of males and females when the intervention was employed. From the unpaired sample t-test, t-statistics (1.207) was less than t-critical (2.064), which means there was no statistically significant difference. It is therefore recommended that teachers should use a cooperative learning strategy to effectively teach chemical bonding, which will help eliminate misconceptions, improve the understanding of students and establish gender

CHAPTER ONE

INTRODUCTION

1.0 Overview

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

1.1 Background to the Study

A method of teaching is a set of guidelines and techniques used by instructors to facilitate student learning (Westwood, 2008). An effective teaching method unites the efforts of the teacher and the student to organize learning. For teachers to adopt and integrate these teaching strategies, creativity, and professional development are crucial (Ordu, 2021). Students learn differently, hence, effective teaching strategies are essential (Lernify, 2022).

Teaching and learning chemistry which is a central science needs teaching methods that will make students understand the concept effectively. The effectiveness of students' retention of science especially chemistry can be linked to teaching strategies employed by teachers, according to a research team's experiences over the years as students (Mak-Mensah, Hanson & Sam, 2018). These instructional methods include the lecture method, demonstration, activity-based instruction, and cooperative learning.

To encourage independent concept learning and develop students who can apply their knowledge and abilities in real-world settings, a student-centered approach must be used

(McCombs, 2023). Cooperative learning, which consists of many connected strategies for organizing classroom instruction to achieve common learning goals through working together is an effective educational strategy that supports such an approach (Dörnyei & Ushioda, 2011). Small groups of students are engaged in cooperative learning situations to maximize both their own and each other's learning (Mak-Mensah, et al. 2018). It entails learners cooperating to achieve shared objectives or fulfill group assignments that they could not otherwise have completed independently (Fekri & Gillies, 2016). At Agortime-Ziope district in Ghana, Mak-Mensah et al. (2018), employed cooperative learning to improve the comprehension of students in the solar system. The results revealed an improved ability of students in problem-solving and comprehension of the subject matter. The laboratory competency and performance in biology improved significantly after exposure to cooperative learning in Ethiopian schools (Molla & Muche, 2018), suggesting the effectiveness of cooperative learning in subject-matter content. In another study, cooperative learning helped motivate instructors towards teaching and raised general interest in science education, research, and the nature of science (Wolfensberger & Carnella, 2015), adding to the importance of cooperative learning in enhancing instruction and learning.

Chemical bonding is an aspect of chemistry that involves the force of attraction between atoms (Petrucci et al., 2017). Almost everything a person sees or touches in daily life, the air we breathe, the food we eat, and the clothes we wear are the results of a chemical bond, or, more accurately, many chemical bonds (Science Clarified, 2023). Several researchers have employed various intervention strategies to help students who struggle with chemical bonding. Joki and Aksela (2018), employed modified curricula as an intervention strategy to address students' chemical bonding issues and found that the modeled approach greatly aided students in comprehending the concept of chemical bonds. Moreover, Zohar and Levy (2019), employed simulation to help students comprehend chemical bonding in their lessons. The study revealed an improved performance of students' grades in chemical bonding.

Cooperative learning has also been employed to teach chemical bonding. Jigsaw cooperative learning, for instance, was utilized by Doymus (2008), to help students better comprehend chemical bonding issues. Also, Frallich, Kesner and Hofstein (2009) employed interactive website exercises to improve the understanding of students in chemical bonding and the results revealed a successful outcome. To the best of the researcher's knowledge, few research works have been focused on the effectiveness of cooperative learning toward academic achievement in chemical bonding in West Africa, specifically Ghana. Therefore, the focus of this research is to fill the gap by employing cooperative learning (panel discussion cooperative learning strategy and cooperative group in share class) to teach chemical bonding and to ascertain the effectiveness of cooperative learning on the topic at Boso senior high technical school.

1.2 Statement of Problem

According to Coll and Taylor's (2010) research, students have misconceptions as well as learning challenges about atomic structure, chemical bonding, and matter. Hanson (2017b), also claimed that although being taught at junior secondary schools, chemical bonding still presents challenges for students.

These difficulties claimed by Coll and Taylor (2010), and Hanson (2017b) about challenges students faced concerning chemical bonding are true for form two science students of Boso senior high technical school. When the researcher examined the exercise books of the form two science students of Boso Senior High Technical School it was observed that their performance on the topic of chemical bonding was very poor. Also, when they were asked to explain some concepts in chemical bonding, they were unable to do so and those who tried to explain gave simplistic explanations full of misconceptions. For example, when the researcher asked the form two science students of Boso senior high technical school the number of types of chemical bonds and the name of those types of bonds found in NH_4Cl, their response was that the compound has only one (1) type of bond which is a covalent bond. The researcher asked the student whether there is an ionic bond in the compound, and they chorally responded "no Sir". This proved that the students do not understand the topic and had a lot of misconceptions about the topic. This learning challenge can be addressed by employing various teaching strategies. To help students with their chemical bonding challenges, this study adopted the cooperative learning strategy.

1.3 Purpose of the Study

The main purpose of the study was to use a cooperative learning strategy towards effective teaching and learning of chemical bonding (ionic bond, covalent bond, metallic bond, hydrogen bond, and Van Der Waal's forces) at Boso Senior High Technical School.

1.4 Research Objectives

The objectives for the study were to:

1. Unearth students' prior conceptions about chemical bonding.

2. Ascertain the causes of identified misconceptions by analyzing students' answers.
3. Explore the extent to which the cooperative teaching strategy could affect students' academic performance in the principle of chemical bonding.
4. Investigate how cooperative learning affects the academic performance of males and females.

1.5 Research Questions

The study was guided by the following research questions:

1. What are students of Boso senior high technical school's prior conceptions about the concept of chemical bonding?
2. What are some of the causes of the identified students' misconceptions about chemical bonding?
3. To what extent would the cooperative learning strategy affect students' academic performance in the concept of chemical bonding?
4. How would the cooperative learning strategy affect the academic performance of males and females?

1.6 Null Hypotheses (H_0)

1.6.1 H_01

There is no statistically significant difference between students' academic performance in the concept of chemical bonding before and after the intervention.

1.6.2 H_02

There is statistically no significant difference between the academic performance of males and females in the concept of chemical bonding.

1.7 Significance of the Study

The study will inform colleague teachers at Boso senior high school to take cooperative learning into account while planning lessons. The research findings will also encourage chemistry instructors to use cooperative learning when instructing students on chemical bonding. This research will give curriculum designers the information they may use to think about implementing cooperative learning in senior high schools. Finally, it will encourage book writers to use cooperative learning strategies in the student activities they place in their books.

1.8 Delimitation

Only form two general science students of Boso senior high technical school were engaged in this study. The topic's placement in their work plan, the location of the problem's identification, and how serious the issue was in that class were the factors that led to this decision. Additionally, only chemical bonding was included in the research because it is a topic that students struggle with and yet it is crucial to understanding chemistry. Subtopics covered include ionic bonding, covalent bonding, metallic bonding, hydrogen bonding, and Van Der Waal forces. Additionally, only a cooperative learning approach was employed.

1.9 Limitation

Some students' academic performance was impacted by their illness because they did not receive the benefits of the intervention. Absenteeism of some students also affected the result because they did not participate fully in the intervention. A thorough study on this subject would have limitations due to the time constraints involved. Another barrier was the cost of printing test questions for a large class as well as instructional and learning materials. Stakeholders would, nonetheless, find the overall results valuable.

1.10 Organisation of the study

1.10.1 Chapter One: Introduction

Chapter one contains the background to the study and the statement of the problem. This was followed by the purpose of the study, the research objectives, the research questions that guided the study, and the significance of the study. The chapter ended with limitations, delimitations, the outline of the thesis, operational definitions, and abbreviations.

1.10.2 Chapter Two: Review of Related Literature

This chapter looks at the related literature in the field of psychology, education, and science. The following were discussed in this chapter, conceptual framework, and theoretical framework which is made up of: constructivism theory, social-constructivism theory, cooperative learning, and social interdependency theory, how gender affects science learning and cooperative learning, chemical bonding and teaching strategies, and students' misconceptions on chemical bonding. The empirical framework was also discussed.

1.10.3 Chapter Three: Methodology

In Chapter Three, the study first presented the methodology, research design and approach, and lessons designed to carry out the study. Secondly, the researcher discussed the population and the sampling technique used for data collection, followed by the validity and reliability of the various instruments and the trustworthiness of qualitative research. The chapter continued with the classroom process, looking at the interventional strategies (using cooperative strategies) designed for the study. The chapter concluded with content analysis, thematic analysis, and the data analysis that guided the study.

1.10.4 Chapter Four: Results and Discussion

This chapter presented the results and discussions of the findings of this study. The findings provided the prior conceptions, misconceptions, and causes of students' misconceptions. It also presented the effect that the cooperative learning strategy had on students' academic performance. Finally, it presented the effect of cooperative learning on the academic performance of males and females.

1.10.5 Chapter Five: Summary of findings, conclusion, and recommendations

The chapter dealt with the summary of the main findings and conclusions derived from the study as well as recommendations and suggestions for further studies.

1.11 Operational Definitions

Cooperative learning- learning together in a group to attain a common goal.

Subpar – using a teaching method that is not a modern acceptable standard.

1.12 Abbreviations

GES	- Ghana Education Service
WASSCE	-West African Senior School Certificate Examination
GSI	- Graduate Student Instructor
CBAT	-Chemical Bonding Achievement Test

NCE	-Nigerian Certificate of Examination
STAD	- Student Teams Achievement Divisions
TAI	-Teams Assisted Individualization

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Overview

This chapter looks at the related literature in the field of psychology, education, and science. The following are discussed in this chapter: conceptual framework, theoretical framework comprising constructivism theory, social-constructivism theory, cooperative learning and social interdependency theory. It also looks at how gender affects science and cooperative learning, chemical bonding and teaching strategies, and students' misconceptions on chemical bonding. The empirical framework has also been discussed.

2.1 Conceptual Framework

A conceptual framework shows how variables are related to one another (Bas & Tega, 2023). The conceptual model underlying this study is concerned with the effectiveness of cooperative learning towards the teaching and learning of chemical bonding. The conceptual framework of this study is rooted in the following representation of activities:

1. Students interacting with group members- This is where students have conversations with one another about chemical bonding.
2. Group work and presentation- This is where students are given assignments to read about chemical bonding and then present their findings in class.
3. Engagement- This is where the researcher acts as a facilitator to guide students in their respective groups to answer questions.

All the above activities culminate into a cooperative learning strategy. When the cooperative learning strategy (the independent variable) is manipulated, it affects the academic performances of the students (the dependent variable). The independent variable (cooperative learning strategy) is related to show how it affects the dependent variable (students' academic performance) and forms the conceptual framework of the study. The relationship between the variables involved is shown in Figure 1.

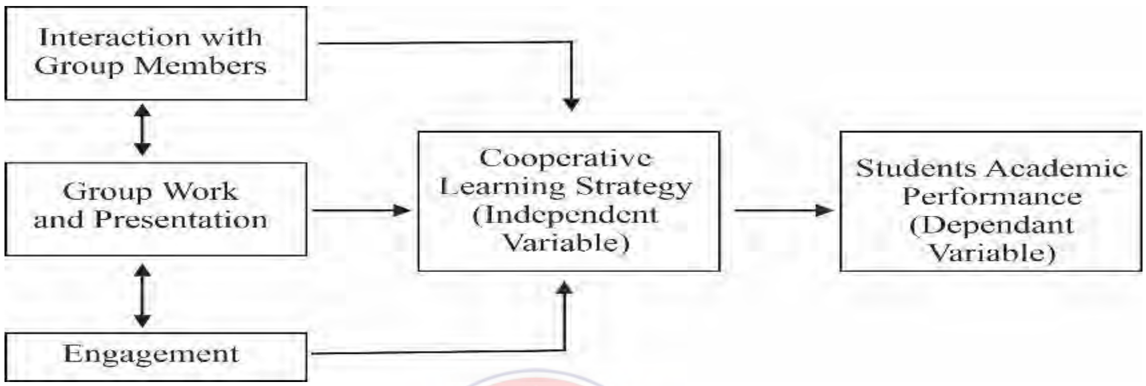


Figure 11: Flow chart representing the study's conceptual framework

From Figure 1, when the activities of cooperative learning strategy are manipulated, it affects the academic performance of students. This means for the academic performance (dependent variable) of a student in chemical bonding to increase or decrease it depends on how effective the cooperative learning strategy (independent variable) is in the study.

2.2 Theoretical Framework

2.2.1 Constructivism theory

Constructivism emerged in the writings of Jean Piaget (1896-1980), who proposed that learning is modeled, transformed, and created. The word "constructivism" in the theory refers to how a person builds knowledge in their thoughts based on already-acquired knowledge, which is why each person learns differently (Alhabib, 2023). According to Elliot et al. (2000), constructivism is a learning ideology that maintains that people actively create or make their knowledge and that the learner's experiences shape reality. By interacting with the environment, we change the way we see the world and give our experiences significance. This suggests that knowledge is built by students based on prior knowledge (McLeod, 2023). In contrast to being natural or passive, it implies that learning is manufactured. Constructivism holds that knowledge is formed through engaging with the outer environment. Although passive, comprehension calls for making connections between previously learned material and incoming knowledge (McLeod, 2023), suggesting that the process of learning is dynamic.

The three main schools of constructivism are cognitive constructivism, based on Jean Piaget, as well as radical constructivism, and social constructivism based on Lev Vygotsky's theory. The GSI Teaching and Resource Centre (2023) described cognitive constructivism as the idea that students actively construct knowledge using their pre-existing cognitive structure. Learning thus depends on a person's level of cognitive development. As a result, when they learn something new, students make comparisons to what they already know, create connections, and develop an understanding of how the old and new information related to one another.

Von Glasersfeld (1917-2010), agreed with Piaget that humans develop concepts and understanding of the world over time (Slezak, 2010). Instead of adhering to the traditional philosophical view that knowledge is a component of truth, that is, that it corresponds to objective reality, knowledge is classified according to its applicability in the field of experience (Walshe, 2020). This suggests that all knowledge is created, rather than sensed. This is called the radical constructivism theory.

According to the social constructivism idea, learning is a cooperative process in which knowledge is formed through exchange or interaction between individuals and their culture and society. It is believed that every function of a child's cultural development occurs twice, first on the social level and then on the individual level, or between the inter-psychological and intra-psychological (Vygotsky, 1978). According to Tam (2000, p.35), the following four significant characteristics of a constructivist classroom must be taken into account if constructivism is to be used in teaching:

1. Teachers and students will exchange knowledge.
2. Students and teachers will share power.
3. An instructor's role is that of a facilitator or a guide.
4. Learning groups will consist of a small number of different students.

According to social constructivism theory, the interaction between two people or a group of people is necessary for learning to take place. In other words, social engagement is required.

2.2.2 Social constructivism theory

The social constructivism learning theory was put forth by Lev Vygotsky in 1968. According to Vygotsky (1968), language and culture are important for a person's intellectual growth as well as how they perceive the world. This indicates that ideas are communicated through language and subsequently understood through personal experience and social engagement within a particular cultural context (Akpan et al., 2020). Social constructivists argue that in addition to making meaning for oneself in a vacuum, humans also learn from their relationships with other people. According to Hein (as cited in Akpan et al., 2020), the level of potential prospects (academic performance) is the level of development that the learner is capable of obtaining with the aid of teachers or in partnership with peers. Hence, education is a social activity that entails interactions with peers, family, and even strangers.

It could be done through group discussions, teamwork, or any kind of educational interaction in a setting for education or training, on social media, in houses of worship, or in the marketplace. All of these call for cooperation and coordination between people who want to achieve a common objective. Also emphasizing the collaborative character of learning is social constructivism (Western Governor University, 2020). The core of students' knowledge is their interactions with one another as they work toward a common goal; this also enables them to learn from their classmates. Before achieving objectives, social constructivism insists on social interdependence and cooperation.

2.2.3 Cooperative learning and social interdependency theory

To encourage independent language learning and develop students who can use their knowledge and skills in real-world circumstances, a student-centered approach must be employed (McCombs, 2023). An effective educational strategy that supports such an approach is cooperative learning, which consists of several connected strategies of structuring classroom instruction to meet common learning goals through cooperation (Dörnyei & Ushioda, 2011). Cooperative learning and constructivism in the classroom have an effect on students' learning results across a variety of subject areas, according to recent studies (Fekri & Gillies, 2016). Cooperative learning is the method of learning whereby individuals or small groups work together to gain new information (Singh &

Agraval, 2011). It requires students to work together to accomplish common goals or complete group assignments — goals and assignments that they could not complete on their own (Gillies, 2016). Students collaborate in groups to finish a task. Cooperative learning is based on the idea that for group activities to be successful, "I cannot do a task without someone." In cooperative learning, there is no rivalry; instead, everyone works together to attain the same objective, ultimately enhancing the students' performance or accomplishment. In connection with this idea, Roseth, Johnson and Johnson (2008) stated that:

> "*the more cooperatively early adolescent teachers structure students' academic goals, (a) the more students will tend to achieve, (b) the more positive students' relationships will tend to be, and (c) the higher levels of achievement will be associated with more cooperative peer relationships" (Roseth et al., 2008, p. 242).*

Slavin (2013), discovered that well-structured approaches, such as cooperative learning, create higher favorable effect sizes than those evaluating other instructional practices, like the use of technology in reading and mathematics classes or the use of innovative curriculum textbooks.

Slavin et al. (2014) best-evidence synthesis of elementary science curricula produced similar findings. They claimed that, science teaching methodologies that give instructors technology tools to enhance education, such as cooperative learning and science-reading integration, have substantial potential to boost science learning.

In summary, there is ample proof that using cooperative learning in the classroom has a significant impact on students' learning and socialization (Slavin et. al., 2014).

Another idea that underlies cooperative learning is social interdependency. Interdependency created by the shared aim is what makes a group work. The interdependent teams operate faster and more efficiently in day-to-day operations (Mertz, 2023). According to Johnson and Johnson (2009), the three categories of interdependencies are positive, no, and negative goal interdependency.

> *A negative goal interdependency occurs when a group member believes that his or her goal can be reached while other group members are unable to accomplish task. When a person believes he or she can accomplish their objective without the assistance of others, there is no goal interdependency. A member can attain goal when other group members achieve goals, according to the concept of positive interdependency (Johnson & Johnson, 2009, p. 265).*

Positive goal interdependency and group accountability are two fundamental concepts in cooperative learning. According to Anderson (2023), group success depends on contribution from all group members, making each learner accountable for both their learning and the group's requirements as a whole.

2.3 How Gender Affects Science and Cooperative Learning

To differentiate between males and females in terms of their distinct responsibilities and obligations, sociologists use the term 'gender'. Gender is more frequently mentioned in more recent studies on science education. One goal of this study is to find a solution to the gender participation gap in science education, particularly chemistry education. Gender difficulties are significant in the performance of Nigeria's educational system in chemistry as well as their incapacity to answer questions, according to Akinsola and Igwe (as cited in Eze, 2008). Also, it has been noted that fewer women enroll in scientific and technology courses than men do, and fewer women pursue careers in these fields. Eze (2008), noted that several additional hypotheses for gender disparities in science and technology have been put forth. Takyi et al (2021) also noticed that there is a disparity in Ghana's educational system regarding gender, and as the level of education increases gender parity worsens in Ghana. Among other things, these explanations include:

1. **Biological determinism:** According to this hypothesis, biological causes account for gender disparities in science and technology. It is biologically inherited. This suggests that while spatial aptitude is sex-linked in favor of men, verbal expression is sex-linked in favor of women. It is biologically inherited. Okeke (as cited in Eze, 2008), disputes this claim and shows that empirical evidence has disproved the biological theory that males are innately more intelligent than females.

2. **School type:** This variable contrasts single-sex and coeducational schools. It is said that the type of school female students attended has a direct impact on their interest in and performance in science-related subjects. When it comes to science, it was once thought that girls in single-sex schools had an advantage over those in coeducational schools. The praise given to single-sex schools for educating females, according to Seeker (as cited in Eze, 2008), has less to do with the fact that they are single-sex schools than it does with their ability to expose women to superior learning environments. According to Nkpa (as cited in

Eze, 2008), single-sex schools have a challenge with persuading girls to enroll and perform well. Further research is therefore needed to settle this difference.

3. **Teacher impact**: The gender of the science teacher, the standards of the teacher, and the way the scientific teacher interacts with students in the classroom are all examples of how the teacher has an influence. The majority of the world's science teachers are men, which gives science a masculine aspect, including Ghana and west African countries. Observation shows that in the majority of Ghana's regions, culture plays a key part in this mismatch. Women had to go to school before they could decide whether or not to study science, they used to be looked down upon for their knowledge. Nonetheless, as more girls enroll in school, there are an increasing number of female science teachers.

Based on the analyses presented, teachers' methods would have differing effects on male and female students. Effective teaching methods promote contact between the teacher and the class, but some of these methods may result in learning settings that are not equally supportive of both sexes. Students' participation is essential to learning, and active learners may retain more information. This study sought to find a realistic method that gave boys and girls an equal chance to understand chemical bonding.

Most studies have concentrated on how gender affects cooperative learning. Adigwe (2002), did a study at the Umar Ibo Ibrahim El-Kanemi College of Education, Science, and Technology (UIECEST), Bama in Borno state to determine the relationship between gender and chemical proficiency among pre-NCE students. The study's sample of 270 students consisted of 177 men and 93 women. This was a case study. It was found that there was no correlation between gender and chemistry achievement among pre-NCE students at UIECEST, Bama, according to the data analysis and hypothesis testing.

Olson (2002), who studied gender inequalities and the effects of cooperative learning in college-level mathematics, concluded that while there were no statistically significant gender-related differences, there were patterns nonetheless. Females had significantly higher course grades and somewhat larger decreases in mathematics anxiety than males, but smaller attitude changes.

According to Gupka, Jain, and Passrija (2014) study into the gender-related effect of cooperative learning strategies on mathematics achievement, females have more positive attitudes toward cooperation and social interdependence than males. Therefore, learning techniques for the development of trusting and interdependent relationships among students and between students and teachers should be used, concurring with Olson's (2002) findings.

Additionally, Mobark (2014) examined how using cooperative strategies affected graduate students' academic performance and gender differences and concluded that, when students are taught using cooperative learning strategies, there is no gender difference in students' academic performance. According to these studies, female students occasionally outperform male students when cooperative learning strategies are applied. It should be emphasized that this is likely because cooperative learning strategies are participatory and female students are typically better communicators. Thus, Mobark (2014) disproved what Gupta, et. al. (2014), and Olson (2002) found out in their studies, because even though females participated well they did not outperformed the males because there was no statistically significant difference. From these findings, there is a need for more research to be done to find out how cooperative learning strategy affects gender to settle the puzzle and fill the existing gap.

2.4 Chemical Bonding and Teaching Strategies

Several researchers have employed various intervention strategies to help students who struggle with chemical bonding. Jigsaw cooperative learning, for instance, was utilized by Doymus (2008), to help students better comprehend chemical bonding issues.

Also, Frallich, Kesner and Hofstein (2009), employed interactive website exercises to improve students' understanding of chemical bonding. The study revealed that when this strategy is applied, students comprehend the topic more fully.

Together with the aforementioned, Joki and Aksela (2018), employed modified curricula as an intervention strategy to address students' chemical bonding issues and found that the modelled approach greatly aided students in comprehending the concept of chemical bonds. Finally, Zohar and Levy (2019) employed simulation to help students comprehend chemical bonding in their lessons. The study revealed that when simulation is employed as a teaching strategy, students score well academically on chemical bonding.

In this study, the researcher used cooperative learning strategies (panel discussion cooperative learning strategy and cooperative groups in class share) towards the effective teaching and learning of chemical bonding. The goal was to find out a teaching method that can improve students' academic performance, maintain gender balance and eradicate students' misconceptions.

2.5 Misconceptions Students have on Chemical Bonding

It is commonly recognized that students build new information during the learning process using their prior concepts, skills, and experiences (Perez et al., 2017). Also, as part of the learning process, students must combine their previously acquired knowledge with new knowledge. It frequently presents some challenges for students (Fahmi & Irhasyuarna, 2017). However, in other instances, they were unable to fully integrate the new knowledge they had received with their past understanding to develop an in-depth understanding. Students who do not understand a topic may have some trouble understanding the more difficult and complex concepts at the following level (Muchtar & Harrizal, 2012). It generates certain misconceptions and the creation of various conceptual understandings in the minds of the students (Fahmi & Irhasyuarna, 2017).

One of the fields of knowledge is chemistry, which deals with nature, structure, reaction, energy changes, and material transformations. It also contains facts, concepts, laws, and theories produced through processes and scientific analysis (Fahmi & Irhasyuarna, 2017). The chemistry concepts were systematically related to one another and tended to combine to generate abstract concepts (Unal, Costu & Ayas, 2010). Perez, et al. (2017) stated that;

> *comprehending is challenging because chemical concepts involving bonds between atoms and/or molecules are sufficiently abstract and far from everyday experience. Given the critical significance of the chemical bond concept for successfully addressing the study of other areas of chemistry such as chemical reactions, the structure of matter, organic compounds, proteins, and polymers, these difficulties are an important source of misconceptions that must be minimized, as much as possible (p. 21).*

Today's literature, according to Ozmen (as cited in Perez et al., 2017), contains some pertinent studies on students' misconceptions about chemical bonding. Some of these problems include:

1. Students do not comprehend the chemical bond's electrical nature (Taber, Tsaparlis & Nakiboglu, 2012)
2. Students are unable to distinguish between ionic and covalent bonding (Luxford & Bretz, 2013)
3. Students misrepresent the melting and boiling temperatures of substances as well as their solubility and electrical conductivity (Cooper, Corley & Underwood, 2013).
4. Students have errors concerning the polarity of molecules as well as their shape (Uyulgan, Akkuzu & Alpat, 2014).
5. Students are confused about intra- and intermolecular forces (Vladusic, Bucat, & Ozic, 2016).

In addition, Hanson and Oppong (2015, p.3), observed that some misconceptions that students have about chemical bonding include the following:

1. Sodium atom and sodium chloride lattice share the same type of chemical bond
2. Covalent bonding exists in sodium chloride.
3. Covalent bonds have an equal distribution of electrons.
4. The bulk of substances contain ionic bonds.
5. All chemicals have ionic bonds.
6. Iodine lattice is metallic in nature

7. There are no chemical bonds in the iodine lattice.
8. Ionic bonds form in metals.
9. Metals do not contain any bonds.

According to Fahmi and Irhasyuarna (2017), students' prior conceptual understanding and the teachers' insufficient explanation contributed to the misconceptions surrounding the sub-concept of bonding. Fahmi and Irhasyuarna (2017) also noted that pupils' misconceptions regarding lattice or space (lattice) were brought on by their underdeveloped cognitive abilities, which made it challenging for them to comprehend a notion the teacher had explained. Also, it was brought on by the teacher's oversimplification of abstract and vague notions. According to Perez et al. (2017), students' misconceptions about chemical bonding are a result of the unclear terminology employed in classrooms, which is unable to articulate the notions of elements, simple substances, and compounds with great precision. According to Hanson (2017b), students' misconceptions about ionic and metallic bonds are the result of "familiarity confusion." They immediately think of metallic and ionic bonding when they see the words "sodium" or "sodium chloride," regardless of the states in which the species is presented. This study further identified some students' misconceptions and their causes.

2.6 Empirical Framework

Between 2014 and 2022 many studies have been conducted on cooperative learning. In courses on educational statistics and educational research methodology, Mobark (2014), examined the impact of implementing a cooperative learning strategy on graduate students' academic performance and gender inequalities. The King Saud University Faculty of Education's convenience sample included 23 master's students (18 females and 14 males), who were enrolled in the educational statistics course, and 24 master's students (13 females and 11 males), who were enrolled in the educational research technique course. The results of this study showed that there was no significant difference between male and female students' academic performance at the levels of the pretest, posttest, and delayed posttest, respectively. The researcher recommended that additional studies and analyses be conducted to fully understand the cooperative learning method for graduate students and to invest in more empirical research on teaching and learning techniques.

Also, the impacts of the cooperative learning strategies (STAD and TAI) on mathematics achievement were examined (Gupta, Jain & Pasrija, 2014). A total of 144 ninth graders, including 74 boys and 70 girls, participated in the study. Boys and girls taught using cooperative learning methodologies performed better on TAI and STA tests, clearly demonstrating cooperative learning's superiority to the traditional teaching approach. So, compared to traditional teaching approaches, cooperative learning was determined to be a more successful instructional paradigm for mathematics. This indicates that Gupta, et al. (2014) filled the gap left by Mobark (2014), in that the study demonstrated the superiority of cooperative learning over other teaching strategies.

Together with the aforementioned, Gull and Shehzad (2015), analyzed the impact of the cooperative learning approach on students' academic performance in the field of education. The study employed a quasi-experimental design with pre-and post-tests for the experimental and control groups, 63 female students in grade 12 at a public college made up the sample. The study revealed, there was a substantial difference in post-test results between the experimental group and the control group. To compare how the intervention affected the achievement scores of the experimental group, a paired sample t-test was used. Their research led them to the conclusion that cooperative learning activities enhanced the academic performance of students majoring in education.

Furthermore, Molla and Muche (2018) conducted a study to assess the effects of cooperative learning strategies on students' academic performance and laboratory competency in the biology field. Based on the study's findings, it was determined that using successive score assessments to expose students to cooperative learning resulted in significant gains in biology accomplishment and laboratory proficiency compared to the traditional method.

In the Agortime-Ziope District of Ghana, Mark-Mensah et al. (2018) employed cooperative learning to improve students' comprehension of the solar system. The study which involved 32 students, discovered that students who were taught through cooperative learning outperformed those who were taught through the lecture technique.

Hung (2019), also conducted a qualitative study with English as a Foreign Language (EFL) students and instructors at a Vietnamese college to examine the effects of cooperative learning. The findings demonstrated that pupils improved their capacity for problem-solving, group collaboration, and confidence. Unfortunately, they encountered difficulties when it came to relationships and reporting.

At Saint Monica's College of Education, Amoako et al. (2020), employed a cooperative learning strategy to improve the academic performance of teacher candidates in a few chosen courses in integrated science. A total number of 80 teacher candidates were utilized in the study, with 40 serving as the control group and 40 as the experimental group. According to the study, cooperative learning was a useful and relevant technique for improving the performance and attitudes of the teacher candidates at St. Monica's College of Education for teaching and studying integrated science.

While the experimental-control group method that is quasi-experimental research design was employed in all of the studies above, this study took an action research approach and used cooperative learning as an intervention to address the issues students had with chemical bonding. Additionally, their strategy exclusively examined the impacts of cooperative learning on students' academic achievement rather than finding a teaching strategy that will solve the problem. This study used cooperative learning to address the issue that students had with chemical bonding. This fills in the gaps of other findings and resolves the students' chemical bonding difficulty and help to find the best way to solve chemical bonding difficulties among students.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter provides information on the research design and approach, population, sampling and sample techniques as well as research instruments. Additionally, this chapter shows extracts on the validity and reliability of the instruments utilized followed by the trustworthiness of qualitative research the data collection procedure and the interventional strategies used. This chapter's conclusion includes an explanation of the content analysis, thematic analysis, paired and unpaired t-test used in the analysis, and the study's ethical considerations.

3.1 Research Design

The study adopted a case study research design. A case study is an in-depth examination of a particular subject, such as a person, group, location, occasion, business, or phenomenon (McCombes, 2023). This study gave a detailed investigation of a group of students. The action research approach was used. According to Figueiredo (2023), action research in education is the practice of analyzing a school environment to comprehend and enhance the effectiveness of the educational process. The general steps of action research according to Panda (2023, p. 12) comprise of:

1. identifying the problem
2. deciding on the requirements or methods of gathering and analyzing data
3. creating an action plan
4. outlining how the results will be used

5. writing a report, and planning for the future.

The study being action research was appropriate because it solved the chemical bonding issue the subjects were facing. The study was done in five phases.

The first phase of the study concerned the design of the instrument; the interview guide and the tests. The tests were pilot-tested by using test-retest techniques on students from different school and the result was used to refine the tests. This was followed by the second phase which involved pre-intervention activities, where the research subjects were briefed on what the study was about as well as administration of the pre-intervention test to the subjects, followed by interviewing the research subjects. The third phase was implementation of the intervention, where cooperative learning strategies (cooperative group in class share and panel discussion cooperative learning strategy) were used followed by organizing the post-intervention test. In the fourth phase, data were analyzed, while in the fifth phase conclusions and suggestions were made. The flow chart of the research approach is shown in Figure 2.

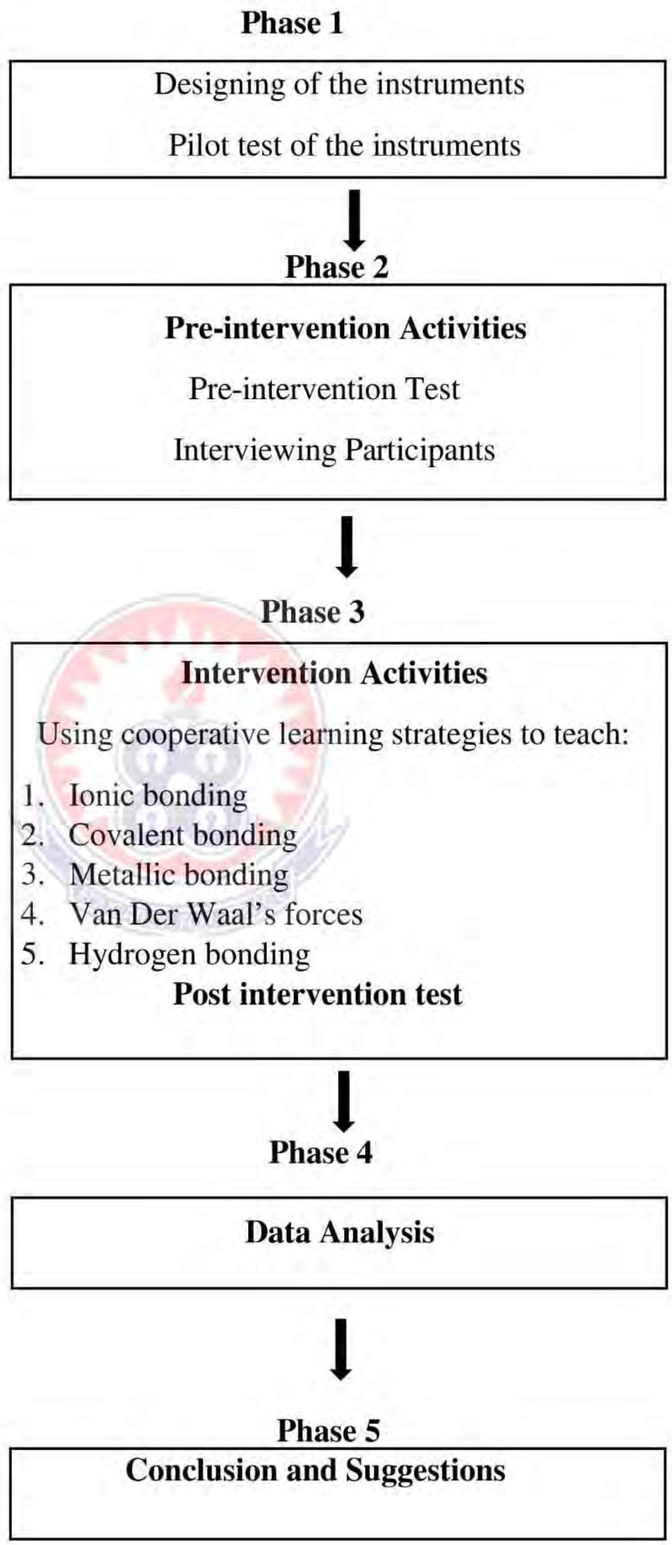


Figure 12: Flow Chart Showing the Research Approach

3.2 Population

The entire group about whom one wants to conclude a study, is referred to as a population (Bhandari, 2023). In other words, it is the entire group that the researcher is curious about. This is also known as the target population. The study's target population was 72 students, comprising all chemistry students of Boso Senior High Technical School for the 2022/2023 academic year. Table 1 shows the breakdown of the targeted population.

Table 1: Total Population of Participants

Class	Number of students
Form 1	24
Form 2	26
Form 3	22
Total	**72**

3.3 Sampling and Sampling Technique

Purposive sampling was used to select the participants for the study. According to Nikolopoulou (2023), in purposive sampling, the objective is to identify people in the population who are most likely to have certain traits that one can narrow one's emphasis to a relatively small sample size and choose the subjects that fit the study. Based on this population, the Form Two General Science students of Boso Senior High Technical School were the sample for this study. The class had a total number of 26 chemistry students, 13 male students representing 50% and 13 are females representing 50 %. This was necessary because the topic under investigation was a chemistry topic. The researcher also teaches at Boso Senior High Technical School hence, it was convenient for the researcher to gather data.

The ages of the students ranged from 16 years to 19 years. Out of the students who took part in the study seven (7) students were 16 years old, eight (8) students were 17 years

Table 2: Ages of Participants shown in Table 2.

Table 2: Ages of Participants shown in Table 2.

Ages	Frequency	Percent	Valid percent	Cumulative percent
16 years	7	27	27	27
17 years	8	31	31	58
18 years	5	19	19	77
19 years	6	23	23	100
TOTAL	26	100	100	

Furthermore, the participants in the study were divided into groups using a simple random sampling procedure. The simple random procedure was applied by asking each participant to select one piece of card numbered 1 to 6 from an enclosed envelope. Each participant was instructed to select one piece of card to display to the class. Those that had identical cards were grouped. The researcher, who also functioned as the subject facilitator, then assigned specific tasks to the members of each group, consisting of 4 to 5 students. This connection facilitated the administration of intervention and data collecting for the study.

3.4 Research Instruments

The instruments used to gather data for this study were semi-structured interview guide and test. According to Tegan (2023), in a semi-structured interview, questions are posed inside a prepared thematic framework as a means of gathering data. Yet neither the order nor the wording of the questions is predetermined. The interview was done by having an interview guide (Appendix A), which those questions in the guide were posed to some students selected using simple random sampling from each group to answer. However, the questions were asked randomly and different words were used to ask each student, making it a semi-structured interview. The interview was conducted just after the pre-test and was conducted before implementing the intervention. The interview was done to know the students' prior conceptions, misconceptions and causes of their misconceptions.

A test called the Chemical Bonding Achievement Test (CBAT) was used to determine the student understanding about chemical bonding. The CBAT comprised six levels of the cognitive domain (knowledge, comprehension, application, analysis, synthesis, and evaluation). CBAT was developed on the topic of chemical bonding. There were twenty-five (25) multiple-choice questions, ten (10) fill-in-the-blank spaces, and five (5) essay-type questions carrying forty (40) marks in total. The CBAT was in two sets, the pre-intervention test and the post-intervention test (Appendices B and C), which had the same content but different questions. The CBAT measured participants' understanding of chemical bonding.

3.4.1 Validity of the Instruments

According to Brown (2023), the degree to which a research instrument measures what it is intended to measure is known as its validity. The degree of accuracy in the results is what validity measures.

To ensure validity the researcher used some related WASSCE past questions. The CBAT was given to an experienced chemistry teacher to edit and proofread. The research instruments were given to the researcher's supervisor to review concerning content, construct, and criterion validity.

3.4.2 Reliability of Instruments

The degree to which an instrument consistently measures what it is designed to measure is known as reliability (Brown, 2023). Reliability was ensured through the test-retest reliability technique. The CBAT was distributed among 26 students of another school who did not form part of the study sample. The same test was given to these same students after two days. Pearson's product-moment correlation was applied between the results of the tests and the reliability coefficient was determined. When the correlation coefficient was computed using Microsoft Excel version 2019, it was noticed that the correlation between the day one test results from the students and the test result after two days was 0.894, which showed that there was a strong positive correlation. Hence, the test items were reliable. This is shown in Table 3.

Table 3: Pearson's product-moment Correlation Co-efficient of the test items

	Day 1 Test Results	*After 2 Days Test Results*
Day 1 Test Results	1	
After 2 Days Test Results	0.894	1

Microsoft excel version 2019

3.4.3 Trustworthiness of qualitative data

3.4.3.1 Credibility

According to Statistic Solution (2023), credibility is a measure of a qualitative researcher's trust in the accuracy of the study's findings. It relates to the positivist idea of internal validity (Gunawan, 2015). To ensure credibility of this research, analyst triangulation, and member-checking were used. In analyst triangulation, colleague teachers were given the responses from the interviewees and the researcher's interpretation to review and corrections were made. After that, the researcher shared the interpretation with the participants or interviewees to check whether the interpretations corresponded to their intentions, after which errors were corrected, and additional information was added to make the study credible.

3.4.3.2 Dependability

When doing a qualitative study, "dependability," which is thought to be challenging to quantify, is needed to ensure the consistency of the research (Shanton as cited in Chowdhury, 2015). According to Shanton (as cited in Chowdhury, 2015), identical results would be produced if the work were repeated, in the same setting, with the same methodology, and with the same participants. To ensure "dependability", an inquiry audit was used. The researcher's work was given to a research auditor to look into the data, findings, and interpretation to check whether the study supported or was consistent with the findings.

3.4.3.3 Confirmability

According to The Farnsworth Group (2023), confirmability in qualitative research is to show that the study is impartial and unaffected by the researchers' assumptions or biases. To ensure "confirmability" each response obtained by the researcher during the interview was summarized to eliminate all biases, beliefs, and assumptions. Also, the researcher provided an audit trail, which described the steps used for data collection, analysis, and interpretation.

3.5 Data Collection Procedure

3.5.1 Pre-intervention activities

The researchers met all the twenty-six (26) students and briefed them on the purpose of the study, how long the study would take, and the need for them to remain in the study till the end. The researcher then put the students into six groups with each group having four members and the remaining two participants were added to the fifth and sixth groups making those groups have five members each.

The students were given two weeks to revise the topic of chemical bonding. At the end of the two weeks, the pre-intervention test items were administered to the twenty-six (26) students to answer within two hours**.** The answers were collected and marked using the pre-intervention test marking scheme (Appendix D).

Two students from each group were selected randomly and interviewed using the interview guide (Appendix A). Also, group representatives provided responses on the group's behalf that were audio and visually recorded using recorders in response to the interview questions, and a few excerpts were written down (Appendix F). The interview was brought to an end because the data collected got a point of saturation. The answers from the participants were analyzed using content and thematic analysis. After that, the researcher implemented the intervention. Figure 3 shows some pictures of the interview sections with some students.

Figure 13: Pictures of some interview sections with some group representatives (pictures taken on Monday, 13th March 2023, and Tuesday, 14th March 2023 respectively)

3.5.2 Intervention activities

3.5.2.1 Teaching ionic bonding by using cooperative groups in class share

Students were given a worksheet containing the concept of ionic bonding to complete the bonding in their various groups. The worksheet was on the formation of MgO followed by some questions on ionic bonding (Appendix G). An appropriate time was allocated for group discussion, students were asked to share their discussion points with the rest of the class (Figure 4). The researcher took the worksheets and marked them.

Figure 14: Students working together in their groups on a worksheet on ionic bonding (picture taken on Sunday, 19th March 2023)

3.5.2.2 *Teaching covalent bond using cooperative group in class share*

The formation of methane (CH_4) and some questions on a sheet were given to each group (Appendix H). Each group was asked to model the CH_4 using thread and beads given to them by the researcher and also asked to discuss and present their answers to the questions on the paper (Figure 5).

Figure 15: Students arranging beads and thread to form CH_4 covalent bond (picture taken on Monday, 20th March 2023)

Students were asked to share their discussion points with the rest of the class during the allotted time for discussions. At the end of the class, the researcher took their exercises and marked them.

3. 5.2.3 *Teaching metallic bonds using panel discussions cooperative learning strategy*

Students were given projects on the topic of the metallic bond to go and read and discuss in their various groups. After four days students met in class and were asked to select a representative to present on metallic bonding (Figure 6).

3.5.2.4 *Teaching hydrogen bonding using cooperative group in class share*
The researcher made the students sit in their respective groups and gave each group a

Figure 16: Some group representatives presenting on metallic bond (picture taken on Thursday, 24th March 2023)

After each presentation, the other groups and the researcher who served as facilitator asked that particular group questions. Students were given assignments on metallic bonds to discuss and provide answers in their groups (Appendix I).

3.5.2.4 ***Teaching hydrogen bonding using cooperative group in class share***

The researcher made the students sit in their respective groups and gave each group a periodic table and on the back page of the periodic table, the group members were to select a very electronegative but small sized element(s), (Appendix J). Students were asked to share their discussion points and answers with the rest of the class during the allotted time for group discussions. When the elements were identified the researcher defined hydrogen bonding to the students and students were asked to discuss the rest of the question on the back page of the periodic table, (Appendix J), and submit their answers for discussion the next day.

3.5.2.5 *Teaching Van Der Waals forces using cooperative group in class share*

Students' answers on hydrogen bonds were discussed. A video on Van Der Waals forces that is dipole-dipole interactions and induced dipole- induced dipole interactions was projected to students who were already seated in their respective groups. Students were then made to discuss what they saw in the video and share their findings with the whole class. Students were then tasked to answer questions given to them (Appendix K).

3.5.2.6 *Summarizing the topic*

The researcher then summarized the subtopics to the students by asking each group to place each type of bond under interatomic and intermolecular bonds and discuss the reason behind their groupings. The researcher then explained why some bonds are referred to as interatomic and others intermolecular. Students in their groups were given two diagrams to complete, (Appendix L).

3.6 Post- intervention Activities

Students were given post-intervention test questions measure their conceptual growth following the usage of the interventional tools. The students' answers were marked by using the marking scheme prepared by the researcher, (Appendix E). Excerpts of students' group work answers during the intervention are shown in (Appendix M).

3.7 Data Analysis

Data analysis is the process of analyzing data with analytical or statistical techniques to find usable information (Grant, 2023). Therefore, in data analysis, and statistical techniques both descriptive and inferential used should be indicated. This study employed mixed method approach (both qualitative and quantitative) and so used both descriptive (content and thematic analysis) and inferential (paired and unpaired t-test) for analysis of the data.

3.7.1 Content analysis

The goal, which emerged from the content analysis, was to examine the breadth and nature of students' learning as well as the connection between students' learning of chemical bonding that has been identified (Sam, 2021). To identify scientific knowledge and the depth of the student's prior misconceptions, the qualitative content analysis (QCA) method was used to examine the students' responses to the interview questions. Also, to know the effect of cooperative learning on students' academic performance and gender, quantitative content analysis was used. In all the content analysis, the deductive analysis was carried out methodically.

3.7.2 Thematic analysis

In thematic analysis, the researcher collected the data and carefully re-examined it several times to look for new patterns, themes, and sub-themes (Anuradha, 2023). This is what the researcher of this study did for the answers obtained from the interviews. The answers were collected and patterns were established and later on interpreted to get a general or prior knowledge that students had about chemical bonding and their general misconceptions were identified.

3.7.3 Paired and unpaired sample t-test

The paired and unpaired t-tests with an alpha value of 0.05 and a confidence level of 95% were used to analyze the tests. The paired sample t-test was used to analyze the effect that the cooperative learning strategy had on students' academic performance in chemical bonding. This was done by comparing the results of the pre-intervention test with the post-intervention test. The unpaired sample t-test was used to analyze the effect that cooperative learning had on males and females performance in chemical bonding. In the unpaired sample t-test, only the students' result of the post-intervention test was used. The students' results were grouped into males and females.

3.8 Ethical Considerations

In research, it is unethical to enter an organization or social group without authorization from the officials of the organization to gather data (Creswell, 2008). Although the researcher identified himself as an "insider researcher," the students who participated in the study were given assurances of confidentiality and anonymity when submitting the information required for the study (Cohen, Manion & Morrison, 2007). In this wise, the students were given serial numbers as index numbers when writing the test instead of writing their names. Also, the consent of the student was sought for before their pictures were added to the work.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

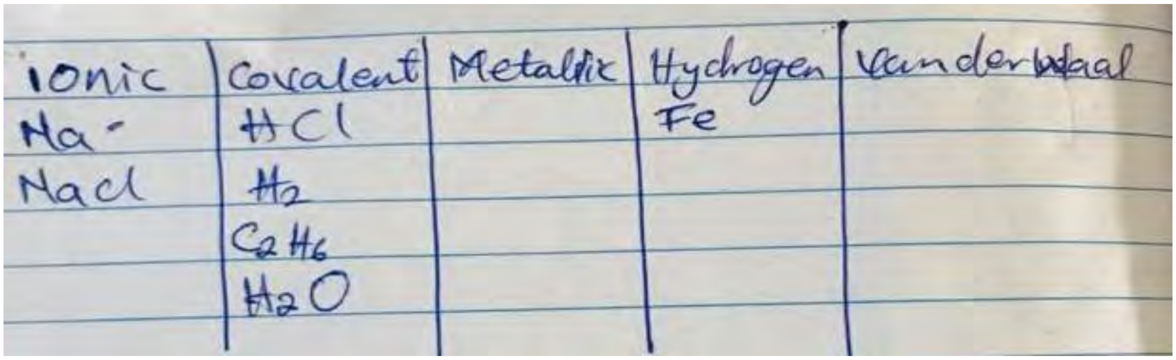
This chapter presents the results and discussion of the findings of this study. The findings unmasked students' prior conceptions, misconceptions, and causes of their misconceptions. It also presented the effect of cooperative learning strategy on students' academic performance. Finally, it presented the effect of cooperative learning on the academic performance of males and females. The results and discussion are presented in the order of the research questions.

4.1 Research Question One

What are students of Boso Senior High Technical School's prior conceptions about the concept of chemical bonding?

This research question was aimed at unearthing students' prior conceptions, which served as a good platform for introducing an intervention that helped solve the identified issue of chemical bonding. For the researcher to know the students' prior conceptions about chemical bonding, an interview was conducted with representatives from the six groups. From the interviews conducted, students were asked to group some elements and compounds under the types of chemical bonds to know their pre-knowledge on the topic.

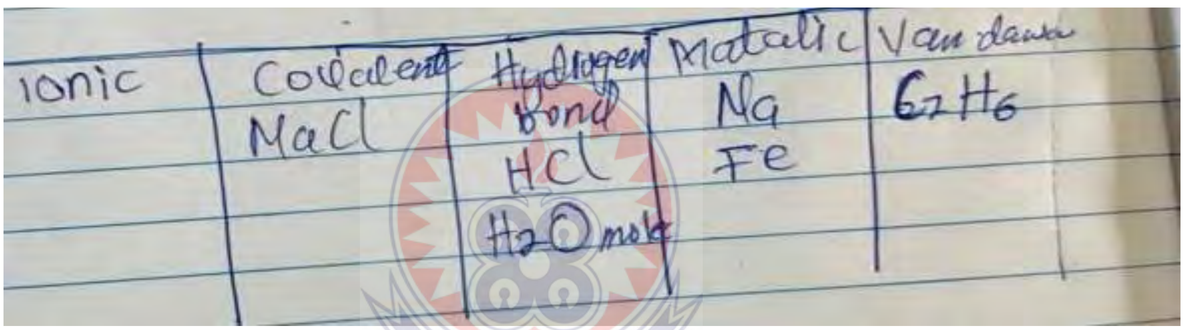
The third interviewee's grouping is shown in Figure 7.



ionic	Covalent	Metallic	Hydrogen	Vanderwaal
Na	HCl		Fe	
Nacl	H_2			
	C_2H_6			
	H_2O			

Figure 17: The answers obtained from the third interviewee

From Figure 7, it is noted that the student placed Na under ionic bonding and Fe under hydrogen bonding. Also, the fourth interviewee's grouping is shown in Figure 8.



ionic	Covalent	Hydrogen Bond	Matalic	Van dawa
	MaCl		Na	C_2H_6
		HCl	Fe	
		H_2O mol		

Figure 18: The answers obtained from the fourth interviewee

From Figure 8, the student placed NaCl under covalent bonding and HCl under hydrogen bonding. The fifth interviewee's grouping is shown in Figure 9.

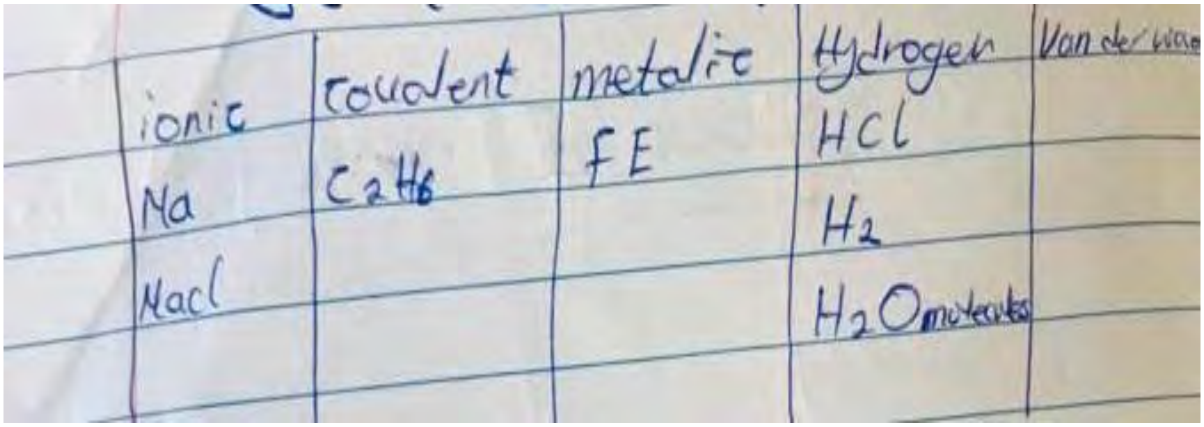


Figure 19: The answers obtained from the fifth interviewee

From Figure 9, the interviewee placed Na under ionic bond just like what the third interviewee did. Also, HCl and H_2 were placed under hydrogen bonding by the same student. The sixth interviewee's grouping is shown in Figure 10.

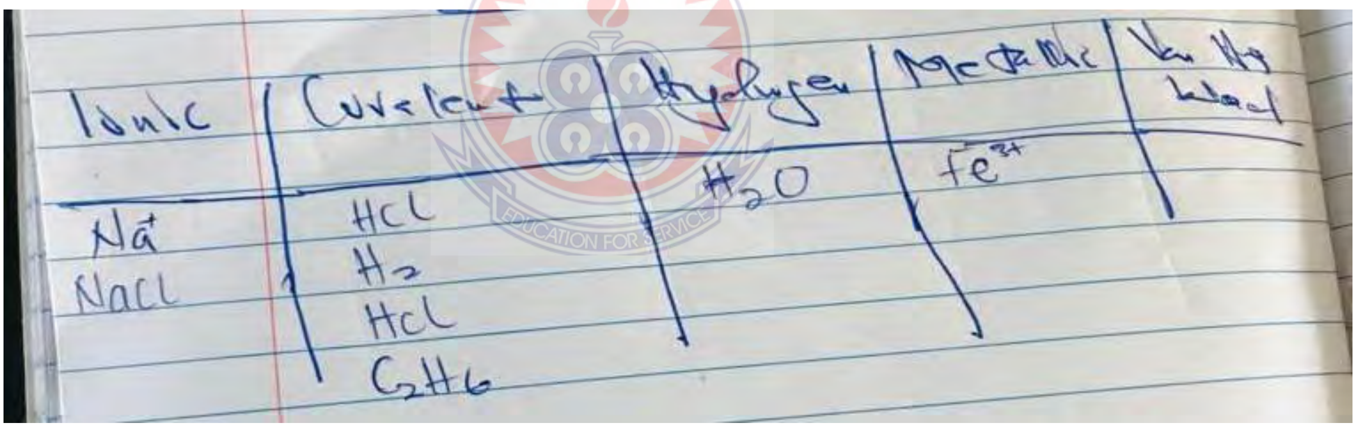


Figure 20: The answers obtained from the sixth interviewee

From Figure 10, the interviewee placed Na under ionic bond and C_2H_6 molecules under covalent. The student placed Na under ionic bonding just like what the third and fifth student did.

From their answers above it was noted that students have a partial understanding of the concept of chemical bonding because students were placing Na under ionic bonding (third, fifth, and sixth interviewees' groupings), HCl and H_2 under hydrogen bonding (see fifth interviewee's groupings), Fe under hydrogen bond (see third interviewee's groupings) and NaCl under covalent bond (see fourth interviewee's groupings). This conforms with the response the interviewees gave when they were asked whether they understood the topic. The first student interviewee who grouped the elements and compounds correctly said "somehow" when asked whether he understood the topic (Appendix L, excerpt from the first student interviewed).

From students' responses given in the interview, the researcher noted that they had a lot of misconceptions about chemical bonding. Some of these identified misconceptions are indicated below:

Ionic bonds always exist between metals and non-metals only (Appendix L). The third student explained that it is a metal that assumes a positive charge and non-metals assume a negative charge and they come together to form the ionic bond, but did not know that NH_4Cl contains ionic bonds. This conformed with the observation of Hanson and Oppong (2015), who in their research conducted on 'Ghanaian high school chemistry students' conceptual understanding of stoichiometry and their translations of problems' found that most students think that ionic bonds are formed in metals only.

Also, students stated that chemical bonds occurred between only two or more elements (Appendix L). This was because they explained bonding as the forces of attraction between elements, neglecting the fact that there is a bond called a metallic bond which involves only one element.

Moreover, students also stated that bonding in metals are ionic. This is also in conformity with what Hanson and Oppong (2015), observed in their study on 'Ghanaian high school chemistry students' conceptual understanding of stoichiometry and their translations of problems'. The reason was that metals become ions as they bond with non-metals.

Furthermore, students in the study always stated that there is equal sharing of electrons in covalent bonds. They said that in covalent bonds atoms share electrons. They did not understand that some molecules in covalent bonds have different electronegativities and demonstrated their misunderstanding of the polarity of bonds by covalent compounds. This problem was also identified by Uyulgan, Akkuzu, and Alpat (2014), who noticed that students had errors concerning the polarity of the molecule.

In addition to the above, students stated that solid NaCl conducts electricity. As the first student interviewed said, "it is because in solid NaCl there is the transfer of electrons and electricity is the flow of electrons" (Appendix L). This problem was also identified by Cooper, Corley, and Underwood (2013), who identified from their study that students have misrepresented the melting and boiling temperatures of substances as well as their solubility and electrical conductivity due to their thinking that solids conduct electricity.

Finally, students also stated that the bond between the H_2O atoms and H_2O molecules is the same. To justify this claim, the second interviewee said, "both H_2O and H_2O molecules have covalent bonds". Also, the fourth interviewee explained that both have electrostatic forces of attraction (Appendix L). This misconception was also seen in the study conducted by Vladusic, Bucat, and Ozic (2016), who noticed that students were confused about intra- and intermolecular forces.

The major finding which answered research question one was that students had partial understanding of the concept of chemical bonding and this was due to students' misconceptions which are as follows:

1. Ionic bonds always exist between metals and non-metals only.
2. Chemical bonds occur between only two or more elements.
3. Bonding in metals is ionic.
4. There is equal sharing of electrons in covalent bonds.
5. Solid NaCl conducts electricity.
6. Bonds between H_2O atoms and H_2O molecules are the same.

4.2 Research Question Two

What are some of the causes of the identified students' misconceptions about chemical bonding?

This research question was aimed at ascertaining the causes of identified misconceptions when students' answers from the interview were analyzed. The answers to the questions from the interviewees were critically analyzed.

From the responses that students gave during the interview section it was found that students' inability to distinguish between the bond in Na and NaCl was due to what Hanson (2017b), called "familiarity confusion". Students demonstrated wrongly that Na and NaCl were the same. They were not able to distinguish ionic bonds from metallic bonds because, they immediately think of metallic and ionic bonding when they see the words "sodium" or "sodium chloride," regardless of the states in which the species is presented.

Also, students' misconception that ionic bonds occur between only metals and non-metals may be due to "partial explanation and representation of concept by teachers". This is in line with Fahmi and Irhasyuarna (2017), finding that teachers' insufficient explanation contributed to the misconceptions surrounding the sub-concept of bonding. Chemistry teachers and books present the concept of ionic bonds incompletely. Most chemistry instructors and books only use metals and non-metals to depict examples of ionic bonds. They neglected to explain to students that two or more non-metals can form an ionic bond because ionic bonds can form between any two ions of opposite charges.

In addition to the above, students' misconception about solid NaCl conducting electricity was caused by "wrong transfer of knowledge". When asked the second interviewee, the answer obtained was, "NaCl is solid like metals hence it will conduct electricity" (Appendix L). This student thought solid NaCl and metals are the same or that any solid may conduct electricity. Also, the fourth interviewee made the cause of their misconception clear by saying, "because their particles are packed together" (Appendix L).

Moreover, the misconception that there is equal sharing of electrons in covalent bonds was due to the "static representation of electrons in covalent bonds by teachers and books," because the fourth interviewee justified this misconception by telling the researcher, "because in H_2O the two hydrogens donate two electrons and O also donates its electrons to form the bond. Therefore, there are equal sharing of electrons in covalent bond" (Appendix L). In the student's mind, the hydrogens and oxygen share the bond in a static manner, forgetting that they have different electronegativity.

Furthermore, the cause of student misconception that the bond between the atoms in H_2O molecules and H_2O molecule is the same was also due to “familiarity confusion”. Students did not analyze the question and jump to conclusions when they saw both were H_2O molecules. Also, it is due to students not understanding interatomic bonds and intermolecular bonds as identified also by Vladusic, Bucat, and Ozic (2016), who noticed that students were confused about intra- and intermolecular forces.

Finally, the misconception that chemical bonds exist between only two or more elements was caused by not understanding the concept of metallic bonds. This may be grossly caused by the lecture teaching approach used by their instructor.

The major findings which answered research question two are about the causes of students’ misconceptions about chemical bonding and are as follows:

1. Familiarity confusion.
2. Partial explanation and representation of concept by teachers.
3. Wrong transfer of knowledge.
4. Static representation of electrons in covalent bonds by teachers and books.
5. Students unable to comprehend interatomic and intermolecular bonds.
6. Lecture teaching methods by teachers.

4.3 Research Question Three

To what extent would the cooperative learning strategy affect students’ academic performance in the concept of chemical bonding?

This question aimed to explore the extent to which the cooperative teaching strategy would affect students' academic performance in the concept of chemical bonding.

The null hypothesis formulated to answer the question was: There is no statistically significant difference between students' academic performance in the concept of chemical bonding before and after the intervention. To test the null hypothesis a paired or dependent sample t-test was used to analyze the performance of the student using the marks obtained from the pre-intervention and post-intervention tests. The significant level was at alpha (α) = 0.05 with a confidence level of 95%. The pre-intervention and post-intervention tests were analyzed using Microsoft Excel version 2019. The decision rule was that: If t statistics > t critical (+2.060) the null hypothesis is rejected. Students' marks obtained from the pre-intervention test and the post-intervention test were used for the paired sample t-test and were computed using Microsoft Excel version 2019 the results are as shown in Table 4.

Table 4: Paired or dependent sample t-test

Test	Mean	df	t statistics	t critical	p-value
Pre-intervention test	13.000	25.000	14.748	2.060	0.000
Post-intervention test	26.769				

From Table 4, the mean difference was 13.769. This shows that the students did well in the post-intervention test as compared to the pre-intervention test.

The t statistics (14.748) > t critical (2.060), hence the null hypothesis which states that: There is no statistically significant difference between students' academic performance in the concept of chemical bonding before and after the intervention, was rejected. This means that there was a statistically significant difference between students' academic performance in the concept of chemical bonding before and after the intervention.

The researcher then calculated the Cohen d to know the effect size, the result is as shown in Table 5.

Table 5: Cohen's d results

	Pre- intervention test	Post intervention test
Mean	13.16	26.64
Standard deviation	5.30	5.14
Cohen d	2.5	

From Table 5, the Cohen's d value of 2.5 means there is a great effect size which means the effect that the cooperative learning strategy had on student academic performance was great. In other words, there is a massive statistically significant between the academic performance of form two science students before and after the intervention. This is because according to Frost (2023), if the cohen d is 0.2, 0.5, 0.8, and above 0.8 the effect size is small, medium, large and very large or great respectively.

These four analyses showed that the cooperative learning strategy had an effect on the academic performance of the form two science students of Boso Senior High Technical School. In other words, the cooperative learning strategy helped the students to understand the concept of chemical bonding which helped to improve their academic performance on the topic.

The result of this study is in line with other research findings. For example, Molla and Muche (2018), also found out that using successive score assessments to expose students to cooperative learning resulted in significant gains in biology accomplishment and laboratory proficiency compared to the traditional method. Molla and Muche (2018), noted that there was a statistically significant difference in student laboratory proficiency when cooperative learning is used compared to individualistic learning, with P value $(0.000) < 0.05$. It was also noticed that higher mean value (66.1 ± 12.2) was recorded in cooperative learning as compared to 58.9 ± 13.7 for individualistic learning.

Also, this study result also lends support to the claim made by Mark-Mensah, et al. (2018) in their study, which involved 32 students. They discovered that students who were taught through cooperative learning outperformed those who were taught through the lecture method. Mark-Mensah, et al.'s (2018) study, found out that descriptively the mean value for students taught using cooperative learning strategy and lecture methods were 13.19 and 7.81 respectively. This means students who were taught using cooperative learning outperformed those taught using the lecture method. Also, P-value $(0.000) < 0.05$ and t statistics $(5.299) >$ t critical, hence there was a statistically significant difference between the academic performance of students when cooperative learning was used other than lecture method.

In addition to the above, the effect of the cooperative learning strategy on students' academic performance in the field of education was also examined by Gull and Shehzad

(2015). The experimental and control groups had pre- and post-tests as part of the study's quasi-experimental design. The sample consisted of 63 female students in grade 12 at a public college. The study found that the post-test outcomes between the experimental group and the control group were significantly different. A paired sample t-test was applied to compare how the intervention changed the achievement scores of the experimental group. They came to the conclusion from their research that students majoring in education performed better academically when they engaged in cooperative learning activities. This indicates that the conclusions of this study are supported by Gull and Shehzad's (2015) findings.

Also, According to Amoako et. al. (2020), cooperative learning was a useful and relevant technique for improving the performance and attitudes of the student teachers at St. Monica's College of Education for teaching and studying integrated science.

Furthermore, the impacts of cooperative learning strategies (STAD and TAI) on mathematics achievement were examined by Gupta, Jain and Pasrija (2014). A total of 144 ninth students, comprising 74 boys and 70 girls, participated in the study. Boys and girls who had received cooperative learning instruction performed better on TAI and STA assessments, demonstrating the superiority of cooperative learning over traditional teaching methods. According to the study's findings, cooperative learning is a more successful instructional strategy for mathematics than normal teaching techniques. As so, the results of this investigation are consistent with those of Gupta, Jain, and Pasrija (2014).

The finding of this study shows that to effectively teach and learn the topic of chemical bonding one needs to resort to a cooperative learning strategy. The finding obtained from research question three was that:

1. The academic performance of the students improved when a cooperative learning strategy was employed because there was a statistically significance difference.

2. The effect that the cooperative learning had on the form two science students of Boso Senior High Technical School was large.

4.4 Research Question Four

How would the cooperative learning strategy affect the academic performance of males and females?

The objective of this question was to investigate how cooperative learning affects the academic performance of males and females. To achieve this objective the null hypothesis formulated was:

There is no statistically significant difference between the academic performance of males and females in the concept of chemical bonding.

To test for the null hypothesis unpaired or independent sample t-test by Microsoft Excel version 2019 was used. The significance level was at alpha (α) value of =0.05 and a confidence level of 95%. In this case, students' post-intervention test marks were grouped into males and females. The decision rule was that: If t statistics > t critical (+2.064), the null hypothesis is rejected.

The post-intervention test scores of students were grouped into males and females and Microsoft excel version 2019 was used to compute for unpaired or independent sample t-test. The results are shown in Table 6.

Table 6: Unpaired or independent sample t-test

Sex	Mean	df	t statistics	t critical	P-value
Male	27.923	24.000	1.207	2.064	0.240
Female	25.615				

From Table 6, t statistics (1.207) < t critical (2.064), hence we fail to reject the null hypothesis. This means there was no statistically significant difference between the academic performance of males and females in the concept of chemical bonding when a cooperative learning strategy was used.

From the unpaired or independent sample t-test, it was noticed that there was no significant difference between the performance of the males and females when the cooperative learning strategy was used as an intervention. This means that the mean difference was insignificant. This conformed with other research findings about cooperative learning strategies.

For example, the study conducted by Olson (2002), who studied gender inequalities and the effects of cooperative learning in college-level mathematics, concluded that there were no statistically significant gender-related differences.

Additionally, Mobark (2014), examined how using cooperative strategies affected graduate students' academic performance and gender differences and concluded that, when students are taught using cooperative learning strategies, there is no gender difference in students' academic performance. According to these studies, female students occasionally outperform male students when cooperative learning strategies are applied. It should be emphasized that this is likely because cooperative learning strategies are participatory and female students are typically better communicators.

This study concorded with Olson (2002) and Mobark's (2014) findings, in the sense that there was no significant difference between the academic performance of males in females in the concept of chemical bonding when cooperative learning was used. This was because when the intervention was implemented it was noted that the females were actively participating in the activities and communicating amongst themselves and with their male counterparts unceasingly about the tasks on hand.

Adigwe (2002) also conducted research to ascertain the relationship between gender and chemical proficiency among pre-NCE students at the Umar Ibo Ibrahim El-Kanemi College of Education, Science, and Technology (UIECEST), Bama in Borno state. Among the 270 students who made up the study's sample, 177 were men and 93 were women. A case study like this one. The data analysis and hypothesis testing revealed that there was no correlation between gender and chemical proficiency among pre-NCE students at UIECEST, Bama. From Adigwe's (2002) study, there was no correlation means the males did better in the test than the female, and this disagreed with Olson (2002) and Mobark's (2014) findings because from these studies there was no significant difference between males and females' performance in chemical bonding when the cooperative strategy was used.

The researcher's study agreed with Olson (2002) and Mobark's (2014). Hence, to ensure gender equality in the classroom one of the ideal methods of instruction that instructors should use is cooperative learning.

The finding obtained when research question four was answered was that there was no statistically significant difference between the performance of males and females regarding chemical bonding when the cooperative learning strategy was used.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS

5.0 Overview

This chapter deals with the summary of the main findings and conclusions derived from the study as well as recommendations and suggestions for further studies.

5.1 Summary of the Main Findings of the Study

The main aim of this study was to use cooperative learning strategy towards the effective teaching and learning of chemical bonding. The main findings of this study based on the research questions are as follows:

The findings that were drawn from the research question one were that students stated that:

1. Ionic bonds always exist between metals and non-metals only.
2. Chemical bonds occur between only two or more elements.
3. Bonding in metals are ionic.
4. There is equal sharing of electrons in covalent bonds.
5. Solid NaCl conducts electricity.
6. Bonds between H_2O atoms and H_2O molecules are the same.

Misconceptions among form two science students at Boso Senior High Technical School were caused by:

1. Familiarity confusion.
2. Partial explanation and representation of concept by teachers.

3. Wrong transfer of knowledge.
4. Static representation of electrons in covalent bonds by teachers and books.
5. Students unable to comprehend interatomic and intermolecular bonds.
6. Lecture teaching methods by teachers.

The finding drawn from the research question three were:

1. When a cooperative learning strategy was used, form two science students at Boso Senior High Technical School did better academically on the concept of chemical bonding.

2. The effect that the cooperative learning had on the form two science students of Boso senior high technical school was large.

The finding drawn from the research question four concerning this study was that:

There was no statistically significant difference between males and females of form two science students at Boso senior high technical school on the concept of chemical bonding when cooperative learning was employed.

5.2 Conclusion

Findings gathered from the obtained data indicated that the intervention helped the students to clear up some misconceptions that they had about chemical bonding, as this helped them perform better academically on the topic by the end of the intervention period. The results showed that students taught using cooperative method had a deeper understanding of the material they had learned and clearing up misconceptions, that is the reason why their academic performance improved after the intervention. One of the advantages of the cooperative learning strategies, as cited by the majority of authors, is that the intervention may prompt students' interaction concepts. This interaction with themselves contributed to the improvement in their academic performance. It appears that teaching chemical bonding effectively can be accomplished through the use of cooperative learning strategies. However, caution must be exercised to avoid overgeneralizing the cooperative learning strategy because the intervention has the potential to convince students that learning and understanding chemistry concept problems cannot be accomplished just through individual problem-solving.

Additionally, it was discovered that the cooperative learning strategy is a good teaching option if one wishes to retain gender equality in the teaching and learning of chemical bonding. These results confirm that employing an effective teaching and learning method during the teaching and learning of chemical bonding cannot be completely ruled out.

5.3 Recommendation

The following recommendations were given based on the study's findings and the conclusion reached:

1. Cooperative learning strategies should be used more frequently in chemistry classes in Boso Senior High Technical School because they have a variety of advantages, including improved academic achievement and ensuring gender equality. However, it is well recognized that students have a variety of learning styles, which should be supported, because of this cooperative learning technique should not be used in isolation.
2. Chemistry teachers at Boso Senior High Technical School must be familiar with applying the cooperative learning model in addition to having knowledge of it. As a result, the Boso Senior High Technical school management should plan seminars

for chemistry and science instructors so that they become acquainted with the method.

5.4 Suggestions for further studies

To provide information or greater enlightenment on the usage of cooperative learning strategies in Ghanaian schools, the following areas might be looked into:

1. A study should be conducted to determine the relationship between student satisfaction with their team's work and academic outcomes as well as attitudinal changes.
2. Other municipalities and districts should follow suit to determine how cooperative learning strategy would impact students in rural and urban settings,
3. A similar study should to determine whether any teachers in Eastern region of Ghana use a cooperative learning strategy when delivering lessons.
4. To offer thorough information on the cooperative learning strategy, the study should be reproduced in tertiary institution.

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APPENDIX A

INTERVIEW GUIDE

This interview guide is used to unearth students' prior conceptions and misconceptions they have on chemical bonding.

(1) Tell me what you know about chemical bonding.

(2) a. Group the following Na, NaCl, HCl, Fe, H_2, HCl, C_2H_6, and H_2O molecules under ionic, covalent, metallic, hydrogen, and Van Der Waal forces.

b. How were you able to come out with your groupings?

(3) Are there covalent characteristics in ionic compounds? Explain your answer.

(4) Is there any bond in Na? Why are you given such an answer?

(5) Does the bonding of atoms occurs only between two or more atoms? Explain your answer.

(6) What is a covalent bond? Is there equal sharing of electrons in a covalent bond?

(7) Which bonds occur in a majority of compounds?

(8) Is bonding in metals ionic? Explain your answer.

(9) Which form of NaCl will conduct electricity, molten, solid form, or both? Explain your answer.

(10) Does a hydrogen bond exist between the molecules of atoms of H and S? Why?

(11) Always ionic bond is formed between metals and non-metals. True/ False.

Explain the reason you chose your answer.

(12) Is the type of bond that exist between the atoms in H_2O and H2O molecules the same? Explain your answer.

(13) Between NaCl and CH_4 which of them has the highest melting and boiling point and why?

(13) Do you understand the topic 'chemical bonding'? If NO

What is the reason for lack of understanding?

APPENDIX B

PRE-INTERVENTION -TEST

This test has sections A, B, and C, and answers all questions in each section.

SECTION A

Choose from the options lettered A – D the correct answer

GENDER: *MALE* [ ] *FEMALE* [ ] *Thick where which is appropriate* (√)

1. In which of the following chlorides is the bonding covalent?

A. CCl_4

B. NaCl

C. $MgCl_2$

D. $ZnCl_2$

2. At ordinary temperatures, H_2O is a liquid whereas H_2S is a gas. This is because H_2O has

A. weak intermolecular forces holding its molecules together

B. strong hydrogen bonds holding its molecules together

C. induced dipole-induced dipole forces between its molecules

D. ionic forces between its molecules

3. Factors that influence the dissolution of ionic solids include(s)

I. lattice energy

II. electron affinity

III. hydration energy

A. II and III only

B. I and III only

C. I and II only

D. I only

4. Which of the following compounds is covalent?

A. sugar

B. sodium hydroxide

C. ammonium chloride

D. silver nitrate

5. Which of the following compounds has the strongest Van der Waal forces?

A. Cl_2

B. O_2

C. CH_4

D. CO_2

6. The types of bonds found in ammonium ions (NH_4^+) are

A. covalent and ionic

B. covalent and dative

C. ionic and dative

D. ionic and metallic

7. Which of the following statements about metallic bonding is/are true?

I. it is formed by electrostatic attraction between the delocalized electrons and fixed positive metal ions

II. the strength of the metallic bond depends on the atomic radius

III. the metallic bond strength depends on the number of valence electrons

A. I only

B. II only

C. I and II only

D. I, II, and III only

8. The most polar of the following bonds is

A. H – Cl

B. H – F

C. H – Br

D. H – I

9. Which of the following substances contain metallic bonding?

A. silicon

B. diamond

C. vanadium

D. alumina

10. Which of the following compounds does not exhibit hydrogen bonding?

A. H_2O

B. HF

C. C_2H_5OH

D. C_2H_4

11. In which of the following elements is the metallic bond strongest?

A. $_{11}Na$

B. $_{12}Mg$

C. $_{13}Al$

D. $_{19}K$

12. Van der Waal's forces are the dominant attractive forces in

A. water

B. sodium chloride

C. chlorine

D. hydrogen chloride

13. A metal Z forms two chlorides, ZCl_2 and ZCl_3. What type of bond exists between Z and chlorine?

A. covalent

B. dative

C. ionic

D. metallic

14. Covalent compounds have relatively low melting points because they

A. are organic compounds

B. possess weak intermolecular forces

C. are non-polar compounds

D. are volatile liquids

15. The polarizing power of a cation is enhanced by its

A. high charge and large size

B. high charge and small size

C. high ionization energy

D. small charge and small size

16. Sodium forms an ionic bond with chlorine because

A. sodium has low first ionization energy and chlorine has a high electron affinity

B. sodium accepts an electron from chlorine

C. sodium has a high first ionization energy and chlorine has a low electron affinity

D. an electron pair is shared between sodium and chlorine

17. The metallic bond in potassium is weaker than that in sodium because potassium has a

A. larger atomic size

B. smaller atomic size

C. greater number of valence electrons

D. higher melting point

18. Which of the following does not have covalent bonding?

A. carbon (IV) oxide (CO_2)

B. ammonia (NH_3)

C. sodium chloride (NaCl)

D. nitrogen (N_2)

19. Which of the following bonding types are inter-atomic?

I. hydrogen bond

II. ionic bond

III. covalent bond

IV. metallic bond

A. I and II only

B. II and III only

C. II, III, and IV only

D. I, II, III, and IV only

20. A substance has high vapor pressure, soluble in tetrachloromethane, and does not conduct electricity. The substance could be

A. amorphous

B. covalent

C. ionic

D. metallic

21. Noble gas molecules are held together by

A. covalent bonds

B. dative bonds

C. hydrogen bonds

D. van der waal's forces

22. Which of the following compounds is most ionic?

A. $AlBr_3$

B. AlI_3

C. BeI_2

D. CsF

23. Which of the following substances has a giant network structure?

A. benzoic acid

B. iodine

C. naphthalene

D. silicon dioxide

24. Both the thermal and electrical conductivity of metal could be explained in terms of the metal's

A. high densities

B. delocalized valence electrons

C. malleability

D. ductility

25. Solid iodine kept in an open jar gradually sublimed. This is because iodine

A. has strong interatomic forces

B. molecules are held together by van der waal's forces

C. is a non-polar molecule

D. has a low melting point

Section B
Fill in the spaces with the correct answer

26. The energy required to break one mole of an ionic crystal into its isolated gaseous ions iscalled the…………………………………………..………………………

27. …………………………………………..is a chemical bonding in which both shared pairs of electrons is provided by only one of the atoms.

28. Sodium chloride dissolves in water because…………………………………………………

29. Metals can be stretched into wires because they are………………………………

30. ………………………………………is the type of bond in which there is a complete transfer of electrons.

31. Water boils at a relatively high temperature because of the presence of ………… ……………………………………………………………………………………………

32. Silicon dioxide is a substance that contains a giant network of…………………

33. Covalent compounds have relatively low melting points because they possess weak……………………………………………………………………………..……………

………………… forces.

34. An ionic compound formed between calcium and fluorine can be represented as…………………………………………………………………………………...……

35. Electrical conductivity of metals could be explained in terms of the ……………………………………………………………………………………..of the metals.

SECTION C
Answer all questions

1. What is a covalent bond?

……………………………………………………………………………………………

……………………………………………………………………………………………

2. What is lattice energy?

……………………………………………………………………………………………

……………………………………………………………………………………………

3. Mention two factors that affect the lattice energy of an ionic compound.

……………………………………………………………………………………………

4. Which of NaCl and $MgCl_2$ has a higher lattice energy? Explain your answer

……………………………………………………………………………………………

……………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

5. Explain briefly what happens when sodium chloride dissolves in water.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

APPENDIX C

POST-INTERVENTION TEST

This test has sections A, B, and C, and answers all questions in each section.
SECTION A
Choose from the options lettered A – D the correct answer
GENDER: *MALE* [ ] *FEMALE* [ ] *Thick where which is appropriate* (√)

1. Ionic bonds are between

A. metals and semi-metals

B. semi-metal and non-metal

C. metals and non-metals

D. metals, semi-metals, and non-metals

2. In which of the following elements is the metallic bond strongest?

A. $_{11}Na$

B. $_{12}Mg$

C. $_{13}Al$

D. $_{19}K$

3. Covalent compounds have relatively low melting points because they

A. are organic compounds

B. possess weak intermolecular forces

C. are non-polar compounds

D. are volatile liquids

4. Which of the following compounds is covalent?

A. sugar

B. sodium hydroxide

C. ammonium chloride

D. silver nitrate

5. Which of the following compounds has the strongest Van der Waal forces?

A. Cl_2

B. O_2

C. CH_4

D. CO_2

6. The types of bonds found in ammonium ions (NH_4^+) are

A. covalent and ionic

B. covalent and dative

C. ionic and dative

D. ionic and metallic

7. Solid iodine kept in an open jar gradually sublimed. This is because iodine

A. has strong interatomic forces

B. molecules are held together by van der waal's forces

C. is a non-polar molecule

D. has a low melting point

8. Which of the following statements about metallic bonding is/are true?

I. it is formed by electrostatic attraction between the delocalized electrons and fixed positive metal ions

II. the strength of the metallic bond depends on the atomic radius

III. the metallic bond strength depends on the number of valence electrons

A. I only

B. II only

C. I and II only

D. I, II, and III only

9. In which of the following chlorides is the bonding covalent?

A. CCl_4

B. NaCl

C. $MgCl_2$

D. $ZnCl_2$

10. The most polar of the following bonds is

A. H – Cl

B. H – F

C. H – Br

D. H – I

11. Which of the following substances contain metallic bonding?

A. silicon

B. diamond

C. vanadium

D. alumina

12. Which of the following compounds does not exhibit hydrogen bonding?

A. H_2O

B. HF

C. C_2H_5OH

D. C_2H_4

13. Van der Waal's forces are the dominant attractive forces in

A. water

B. sodium chloride

C. chlorine

D. hydrogen chloride

14. A metal Z forms two chlorides, ZCl_2 and ZCl_3. What type of bond exists between Z and chlorine?

A. covalent

B. dative

C. ionic

D. metallic

15. The basis of a metallic bond is

A. the attraction of neutral metal atoms

B. the attraction between protons and neutrons

C. the attraction between positive metal ions and interlocking electrons

D. the attraction between positive metal ions and free-floating electrons

16. The polarizing power of a cation is enhanced by its

A. high charge and large size

B. high charge and small size

C. high ionization energy

D. small charge and small size

17. Sodium forms an ionic bond with chlorine because

A. sodium has low first ionization energy and chlorine has a high electron affinity

B. sodium accepts an electron from chlorine

C. sodium has a high first ionization energy and chlorine has a low electron affinity

D. an electron pair is shared between sodium and chlorine

18. The metallic bond in potassium is weaker than that in sodium because potassium has a

A. larger atomic size

B. smaller atomic size

C. greater number of valence electrons

D. higher melting point

19. Which of the following does not have covalent bonding?

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III. covalent bond

IV. metallic bond

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B. II and III only

C. II, III, and IV only

D. I, II, III, and IV only

21. A substance has high vapor pressure, soluble in tetrachloromethane, and does not conduct electricity. The substance could be

A. amorphous

B. covalent

C. ionic

D. metallic

22. Noble gas molecules are held together by

A. covalent bonds

B. dative bonds

C. hydrogen bonds

D. van der waal's forces

23. Both thermal and electrical conductivity of metal could be explained in terms of the metal's

A. high densities

B. delocalized valence electrons

C. malleability

D. ductility

24. At ordinary temperatures, H_2O is a liquid whereas H_2S is a gas. This is because H_2O has

A. weak intermolecular forces holding its molecules together

B. strong hydrogen bonds holding its molecules together

C. induced dipole-induced dipole forces between its molecules

D. ionic forces between its molecules

25. The number of electrons shared in the covalent bonds of methane is

A. 1

B. 4

C. 6

D. 8

Section B

Fill in the spaces with the correct answer

26. An ionic compound formed between magnesium and chlorine can be represented as………

27. ………………..………………..is a kind of bond that forms when atoms exchange electrons.

28. Metals can be bent into shapes because they are……………………………………………..

29 …………..…………………………………………is the force that holds two atoms together.

30. Sodium chloride dissolves in water because………………………………………………………………………………

31. Water boils at a relatively high temperature because of the presence of……………………...……………………………………………………………

32. The energy required to break one mole of an ionic crystal into its isolated gaseous ions is the ……………………………..…………………………………………

33. Silicon dioxide is a substance that contains a giant network of………………………………..

34. Covalent compounds have relatively low melting points because they possess weak……………………………………………………………………………………… ……… forces.

35. Electrical conductivity of metals could be explained in terms of the……………………….………………………………………………………………… ………………………..of the metals.

SECTION C

Answer all questions

1. What is meant by a polar covalent bond?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

2. State the type of bond in the compound CCl_4.

…………………………………………………………………………………………

3. Arrange the following compounds in the order of their increasing boiling points; HF, H_2O, and NH_3.

…………………………………………………………………………………………

4. Mention two factors that affect the lattice energy of an ionic compound.

…………………………………………………………………………………………

5. Explain the reason why wax dissolves in paraffin oil.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

APPENDIX D

PRE-INTERVENTION TEST MARKING SCHEME

SECTION A

1. A
2. B
3. B
4. A
5. A
6. B
7. D
8. B
9. C
10. D
11. C
12. C
13. C
14. B
15. B
16. A
17. A
18. C
19. C
20. B
21. D
22. D
23. D
24. B
25. B

[1 mark each × 25= 25 marks]

Fill In

26. lattice energy [1 mark]
27. dative bonding [1 mark]
28. lattice energy is less than hydration energy [1 mark]
29. ductile [1 mark]
30. ionic bond [1 mark]
31. hydrogen bonding [1 mark]
32. covalent bonds [1 mark]
33. intermolecular Van der Waal's [1 mark]
34. CaF_2 [1 mark]
35. delocalized valence electrons

SECTION B

1. Covalent bond is the type of bond that involves the equal sharing of electron pairs between two atoms in which each atom contributes an electron. [1 mark]

2. Lattice energy is the energy released to form one mole of ionic crystal from its gaseous ions [1 mark]

3. i. size of the ions

ii. the magnitude of the charge on the ions [0.5 mark each ×2= 1 mark]

4. i. $MgCl_2$

ii. This is because Mg^{2+} has a higher charge and a smaller size than Na^{+}

[0.5 mark each ×2= 1 mark]

5. Water and sodium chloride are both polar compounds. The sodium chloride ions interact with the water molecules through electrostatic forces. The process releases hydration energy that overcomes the lattice energy of the sodium chloride crystals. This breaks the crystal down and dissolves it. [1 mark]

APPENDIX E

POST-INTERVENTION TEST MARKING SCHEME

SECTION A

1. C
2. C
3. B
4. A
5. A
6. B
7. B
8. D
9. A
10. B
11. C
12. D
13. C
14. C
15. D
16. B
17. A
18. A
19. C
20. C
21. B
22. D
23. B
24. B
25. D

[1 marks × 25 = 25 marks]

Fill In

26. $MgCl_2$

27. ionic bond

28. malleable

29. inter-atomic bond

30. lattice energy is less than hydration energy

31. hydrogen bonding

32. lattice energy

33. covalent bonds

34. intermolecular Van der Waal's

35. delocalized valence electrons [1 mark × 10= 10 marks]

SECTION B

1. polar covalent bond is a bond formed between two atoms in which there is unequal sharing of electron pair between the atoms [1 mark]

2. covalent bond [1 mark]

3. $H_2O < NH_3 < HF$ [1 mark]

4. i. size of the ions [0.5 mark]

ii. the magnitude of the charge on the ions [0.5 mark]

5. Wax and paraffin oil are both non-polar substances. The wax molecules interact with the molecules of the paraffin oil through weak Van der Waal forces. This process causes the wax to dissolve in the paraffin oil. [2 marks]

APPENDIX F

Excerpts from the interview section with the first student (male, 18 years)

Interviewer: Have you treated or been taught the topic "chemical bonding."

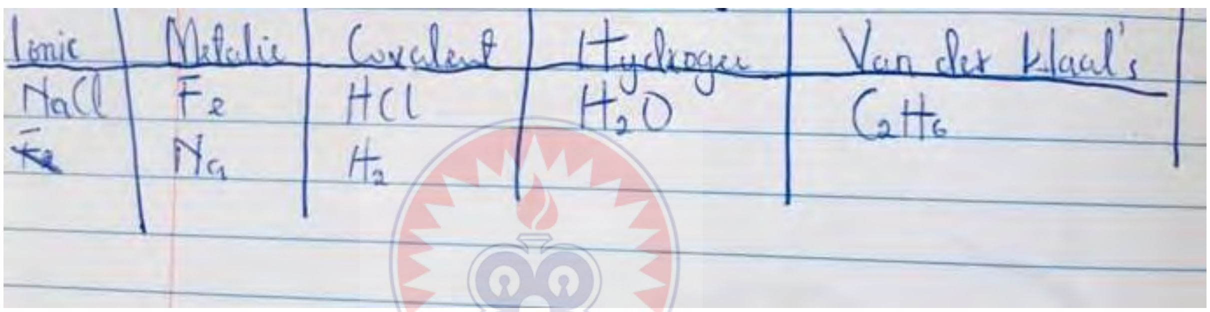
Student: Yes, please.

Interviewer: Tell me what you know about it.

Student: Forces that bring particles together.

Interviewer: Group the following under the type of bonds.

Student grouping:



Ionic	Metalic	Covalent	Hydrogen	Van der Waal's
NaCl	Fe	HCl	H_2O	C_2H_6
~~Fe~~	Na	H_2		

Interviewer: How were you able to group them?

Student: When compounds begin with a metal followed by a non-metal then it is ionic.

Interviewer: Do ionic bonds always exist only between metals and non-metals?

Student: Yes, ionic bond always exists between metals and some of the non-metals only except the noble gases.

Interviewer: Is there any bond existing in Na?

Student: No, because Na has no isotope, and its only one.

Interviewer: Is there equal sharing of electrons in a covalent bond?

Student: *Student waited for about 30 seconds, smiled.*

Hmmmmm No.

Interviewer: Why?

Student: I do not know the reason.

Interviewer: Which bond is the majority of all compounds and why?

Student: Ionic, because most elements are not stable so they lose or gain to be stable.

Interviewer: What form of NaCl will conduct electricity, solid or molten or both?

Student: The solid form.

Interviewer: Why?

Student: It is because in solid NaCl there is a transfer of electrons and electricity is the flow of electrons.

Interviewer: Do you understand the topic?

Student: Not very well, *smiled*, somehow.

Interviewer: What do you think is the cause of your partial understanding of the concept?

Student: The way the teacher taught the topic.

Interviewer: Which method did he use?

Student: Normal teaching.

Interviewer: Do you mean lecturing?

Student: Yes Sir.

Interviewer: Thank you.

Interviewer: Welcome sir.

Excerpts from the interview section with the third student (female, 17 years)

Interviewer: Have you treated chemical bonding?

Student: Yes, Sir.

Interviewer: What do you know about it?

Student: It is the interaction between atoms.

Interviewer: Put these elements or compounds under their respective place.

Student groupings:

Ionic	Covalent	Metallic	Hydrogen	Vander Waal
Na	HCl		Fe	
NaCl	H_2			
	C_2H_6			
	H_2O			

Interviewer: Why did you put Na at ionic bond?

Student: Because it is a metal.

Interviewer: So, metals undergo ionic bonding?

Student: Yes Sir.

Interviewer: Why is it that metals are ionic?

Student: Because of lattice energy and ionization.

Interviewer: Does ionic bond always occur between metals and non-metals?

Student: Yes please.

Interviewer: Why?

Student: Because the metals always attract the non-metals.

Interviewer: Which form of NaCl conducts electricity, solid, molten, or both?

Student: Solid form, please.

Interviewer: Why?

Student: NaCl is solid like metals hence it will conduct electricity.

Interviewer: What is a covalent bond?

Student: It is the mutual sharing of electrons of atoms.

Interviewer: Are there equal sharing of electrons in all covalent bond?.

Student: Yes.

Researcher: Why?

Student: Because they share the electrons equally and the electrons are in the middle.

Interviewer: Is the bond in H_2O molecule the same as the bond in H2O molecules?

Student: Yes.

Interviewer: Why?

Student: Because they are all covalent.

Interviewer: Which bonds occur in the majority of all compounds?

Student: Covalent bond.

Interviewer: Justify your answer.

Student: Sir please I do not understand.

Interviewer: I mean what makes your answer right.

Student: Because most of the elements are covalent.

Interviewer: Do you understand the topic?

Student: Not all/

Interviewer: What is the cause of your not understanding the topic?

Student: I do not get why some are dipole-dipole and some induce dipole-induced dipole. Also, I do not get why a giant covalent network does not fall under intermolecular.

Interviewer: Is the topic abstract, abstract means you can’t see it in nature?

Student: Yes.

Researcher: Do you want your teacher to use another method in his teaching apart from lecturing?

Student: Yes, he should involve in practicals.

Interviewer: Thank you.

Student: You are welcome, Sir.

Excerpts from the interview section with the fourth interviewee (male, 18 years)

Interviewer: Have you been taught the topic of chemical bonding?

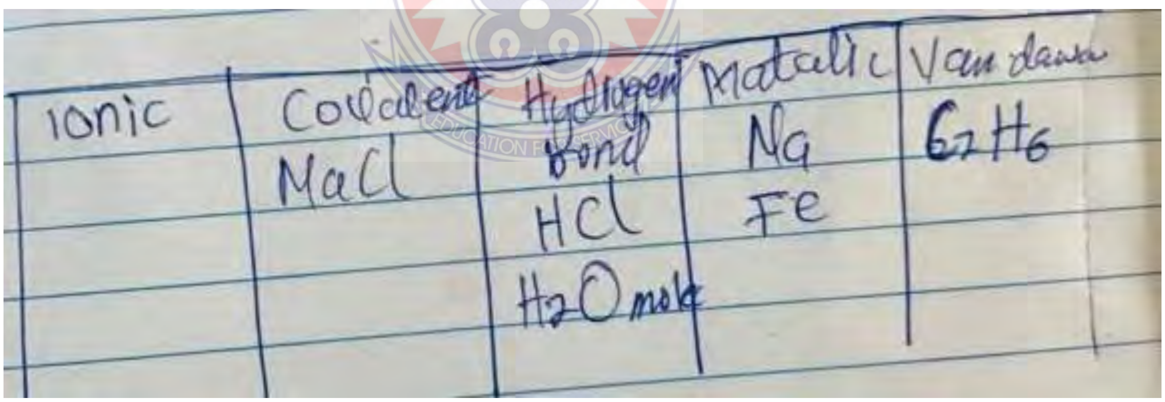
Student: Yes Sir.

Interviewer: What do you know about it?

Student: It is the bond between two or more atoms or the electrostatic force of attraction between two or more atoms.

Interviewer: Group the following under the type of bonding.

Student groupings:



Interviewer: Why did you put NaCl under a covalent bond?

Student: Sir please because both of them donate an electron to share.

Interviewer: Is there equal sharing of electrons in covalent bonds?

Student: Yes, please.

Interviewer: Why?

Student: Because in water the hydrogen and oxygen share the electrons equally.

Interviewer: Which form of NaCl conducts electricity, solid, molten, or both?

Student: Solid NaCl.

Interviewer: Why?

Student: Because their particles are packed together.

Interviewer: This makes it conducts electricity?

Student: Yes please, and NaCl is a metallic bond therefore it is a metal.

Interviewer: Always ionic bond is formed between metals and non-metals. True/False?

Student: True.

Interviewer: Why are you saying that?

Student: Because ionic bonds are supposed to have opposite always, Sir wait student, *student laughed.*

Interviewer: All right, what are saying?

Student: The bond between the ionic should be opposite charges and only metals and non-metals have those charges.

Interviewer: Is the bond in atoms of H_2O and H_2O molecules the same?

Student: Sir please it is the same.

Interviewer: What is your reason?

Student: They both have the same electrostatic force of attraction.

Interviewer: Do you understand chemical bonding?

Student: Not that much.

Interviewer: What is the cause of your not understanding the topic?

Student: During the lesson sometimes when sir comes to class he mixes the concept.

Interviewer: How do you want your teachers to teach the class?

Student: He should find another way to teach the topic again.

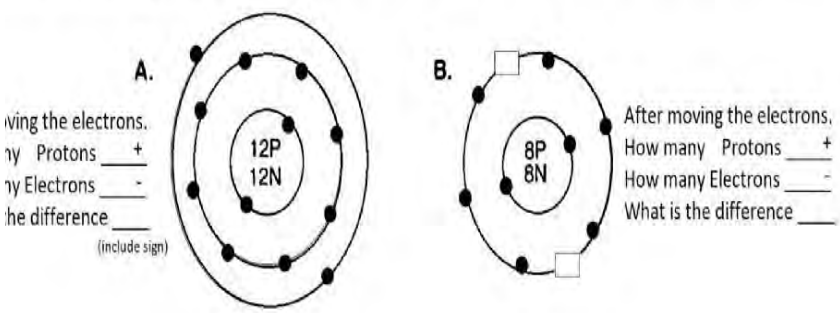
Interviewer: Thank you.

Student: You are welcome Sir.

APPENDIX G

WORKSHEET ON IONIC BONDING

Look at the Bohr Models below, move the eletrons from one model to the other as they would if these two atoms formed a bond.



. If atom A loses electrons to atom B,

a. how many electrons will atom A lose? ______________________

b. how many electrons will atom B gain? ______________________

c. what will be the oxidation number of atom A? (include sign) ______________________

d. what will be the oxidation number of atom B? (include sign) ______________________

e. what will be the total charge of the compound formed? Number format.

____

f. what type of bond will form?

____

g. State three characteristics of the type of bond formed.

h. Which form will the compound formed will conduct electricity, molten or solid, or both?

I. Sodium forms ionic bonds with chlorine because…………………..

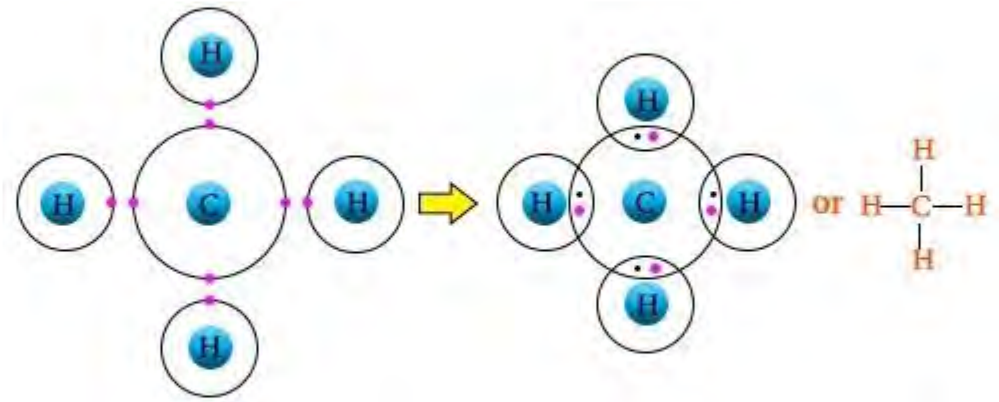
J. An ionic compound formed between magnesium and chlorine can be represented as………………….

K. Mention two factors that affect the lattice energy of an ionic compound.

L. Explain the reason why sodium chloride dissolves in water.

APPENDIX H

WORKSHEET ON FORMATION ON CH_4



Using the beads and thread given model the middle structure and answer the questions that follow.

(1) i. What type of bonding exists between the four hydrogens and the carbon atom in CH4?

ii. Use your beads and thread to model NH4, HCl, and H2 and state the type of covalent bonds in them.

(2) State four characteristics of the type of compounds formed this way.

(3) Apart from the compounds mentioned state four examples of compounds formed this way.

APPENDIX I

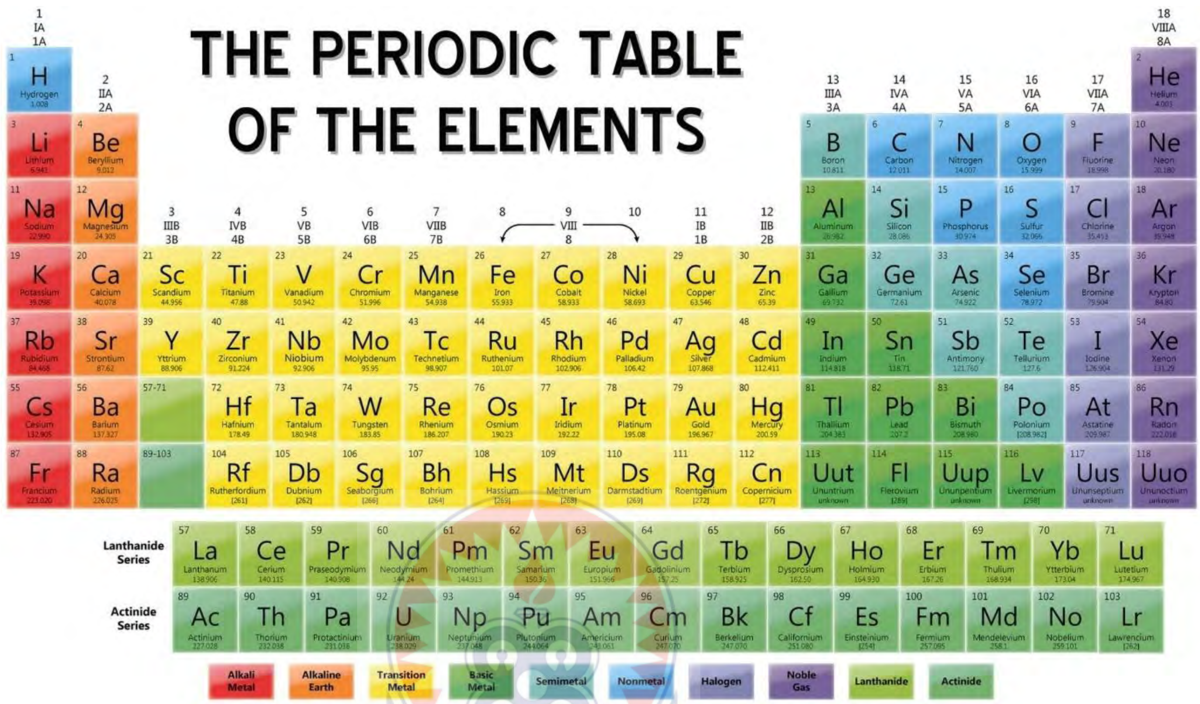
QUESTIONS ON METALLIC BONDING

Solve the following questions in your respective groups

1. Explain metallic bonding.
2. How does a metallic bond differ from an ionic bond.
3. Elements that undergo metallic bonding are called ………………….
4. State five elements that undergo metallic bonding.
5. State and explain three characteristics of metals.

APPENDIX J

GROUPWORK ON HYDROGEN BONDING



Use the periodic table above to answer the questions below:

(1) From the periodic table state the three elements which are very electronegative but have a small size (each group is to discuss the question and present their answers on the board).

(2) i. Explain hydrogen bonding.

ii. State three compounds or molecules that associate themselves with hydrogen bonding.

APPENDIX K

GROUPWORK VAN DER WAAL'S FORCES

From the video you watched:

(1) Explain Van Der Waal's forces.

(2) Group the following molecules under dipole-dipole interaction and induced dipole-induced dipole interactions. (H_2, H_2S, Cl_2 and O_2).

APPENDIX L

GROUPWORK ON INTER-ATOMIC BOND AND INTER-MOLECULAR BOND

I.

δ^- δ^+ δ^- δ^+

Cl------Cl………. Cl------Cl

↑ ↑

A B

II.

δ^+ δ^- δ^+ δ^-

H------Br……….H-------Br

↑ ↑

C D

1. From the diagrams above what type of bonds are found in A and C; and B and D?

2. Name the specific type of bond found in A, B, C, and D.

APPENDIX M

SAMPLES OF SOME MARKED STUDENTS' GROUP WORKS

Group 3

GROUP WORK

Look at the Bohr Models below, move the electrons from one model to the other as they would if these two atoms formed a bond.

A. 12P 12N

B. 8P 8N

After moving the electrons:
How many Protons: 8
How many Electrons: 10
What is the difference: 2−

a. How many electrons will atom A lose? 2 electrons

b. How many electrons will atom B gain? 2 electrons

c. What will be the oxidation number of atom A? 2+

d. What will be the oxidation number of atom B? 2−

e. What will be the total charge of the compound formed? Number format.
2+(−2) = 0

f. What type of bond will form?
Ionic Bond

g. State three characteristics of the type of bond formed.

h. Which form will the compound formed will conduct electricity, molten or solid or both?

I. Sodium forms ionic bond with chlorine because……………………

J. An ionic compound formed between magnesium and chlorine can be represented as……………………

K. Mention two factors that affect the lattice energy of an ionic compound.

L. Explain the reason why sodium chloride dissolves in water.

18/20

Group 8 Sunday, 17th March, 2025

g.i. They are crystalline solids at room temperature due to the strong electrostatic force of attraction holding the individual atoms together.

ii. They have high melting and boiling points due to the strong electrostatic force of attraction

iii. They conduct electricity at molten state or in aqueous solution.

h. Molten state.

i. Because it donates one electron to chlorine to obtain a more stable electron configuration.

j. $Mg^{2+} + Cl^{-} \longrightarrow MgCl_2$

k. i. Temperature

ii. Polarity

l. Sodium chloride dissolves in water ~~is gr~~ because the hydration energy (in the water) is greater than the lattice energy in the salt. Hence, sodium chloride dissolves in water.

Group 5

Group Work

g i. It is formed between a positively and negatively charged electrons.

ii. It dissolves in polar solvent.

iii. It is crystaline in nature

h. Molten

i. Sodium forms ionic bond with chlorine because there is a complete transfer of the electrons from the Sodium atom to the chlorine atom.

j. $Mg^{+2} + Cl^{-} \longrightarrow MgCl_2$

k. i. Atomic size

ii. First ionization energy

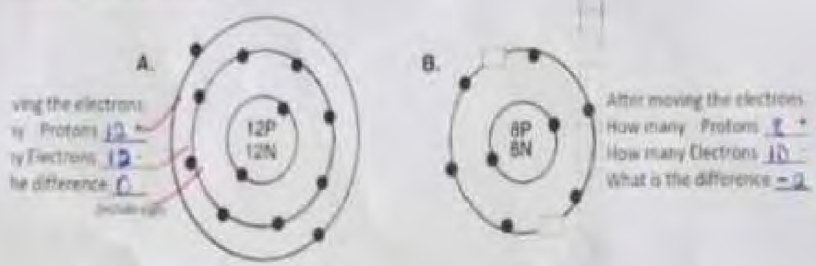
L. Water is polar and sodium chloride (NaCl) is ionic. The water molecules a the Sodium chloride ions are attracted to each other by the electrostatic force of attraction. The process releases hydration energy which overcomes the lattice energy of the sodium chloride crystals. This process breaks the crystals and dissolves it in the water.

20/35

Group 5

GROUP WORK

Look at the Bohr Models below, move the eletrons from one model to the other as they would if these two atoms formed a bond.



If atom A loses electrons to atom B,

a. how many electrons will atom A lose? Two (2)

b. how many electrons will atom B gain? Two (2)

c. what will be the oxidation number of atom A? +2

d. what will be the oxidation number of atom B? -2

e. what will be the total charge of the compound formed? Number format.

0

f. what type of bond will form?

Ionic bond

g. State three characteristics of the type of bond formed.

h. Which form will the compound formed will conduct electricity, molten or solid or both?

I. Sodium forms ionic bond with chlorine because……………………

J. An ionic compound formed between magnesium and chlorine can be represented as……………………

K. Mention two factors that affect the lattice energy of an ionic compound.

L. Explain the reason why sodium chloride dissolves in water.

GROUP: 4

1. Polar covalent bond

ii) NH_4^+ → dative covalent bond
HCl → Polar covalent bond.
H_2 → Non-polar covalent bond.

2) (i) The have low melting point.

ii). They are crystalline in nature.

iii) They are soluble in non-polar solvents such as ~~water~~ ether.

iv)

3). H_2O
CO_2
C_2H_6
Cl_2

09
12

Group 2.

(1) i. Covalent bond.

ii. NH_4^+ - hydrogen bond.

HCl - dipole - dipole interaction.

H_2 - Induced dipole - induced dipole interaction.

(2) - Most have relatively low melting and boiling point.

- They tend to be soft and flexible.

- Many do not dissolve well in water.

- When dissolved in water, they do not conduct electricity.

(3) Cl_2, N_2

H_2O

H_2SO_4

14½
15

Group 1

Metallic Bonding

① Metallic bonding is a type of bond formed between a fixed positively charge ~~ato~~ metal and delocalise atom

② Metallic bond involves metals but Ionic bond involves two elements which is metals and non-metals.

③ Metals.

④ ① Al.
② Na.
③ Fe.
④ Mg
⑤ K

⑤ ① Metals are malleable, which means they can be beaten into shape
② Metals are ductile, which means they can be drawn into wire.
③ Metals have high boiling point.

GROUP 6

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Group6 Metallic bonding

(1) it is the type of bond formed when a delocalized electron are floated around a fix positive charge metal.

(2) There is complete transfer of electrons in metallic bond but there is no transfer of electrons.

(3) Metals

(4) Na, Mg, K, Al, Ca

Sodium

Magnesium

Pottasium

Aluminium

Calcium.

(5) - They are malleable. Which means they can be beaten into different forms.

- They are good conductors of heat and electricity.
- They are have high boiling and melting point.

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Group 5

HYDROGEN BONDING

1 Flourine, Oxygen and Nitrogen.

2(i) It is the type of bond formed between hydrogen and a very electronegative but small size atom.

2

ii) HF, H_2O, NPK.

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Group 3 Hydrogen Bonding

(i) ~~N O F~~ F, N, O

(i) F, O, N

2. It is the type of bond form betwe[en] hydrogen and an atom which is very electro nagative but has more size.

ii) HF, H_2O, HN_3

5/5

Group 2

Van der Waal forces

(1) Is the weakest intermolecular force of attraction between molecules.

(2)

Dipole-Dipole interaction	Induce-dipole-induce-dipole interaction
H_2S	H_2
	Cl_2
	O_2

5/5

GROUP: 1.

Van der waal's forces.

① Van der waal's forces -> Is the weakest intermolecular force of attraction between atoms in a molecule.

② dipole-dipole interaction	Induced dipole-Induced dipole interaction
H_2S	H_2
	Cl_2
	O_2

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GROUP ONE (1)

INTERATOMIC AND INTERMOLECULAR BOND

1. A and C – Interatomic bond.

2 B and D – intermolecular bond.

2. A – Non-polar covalent bond.
B – Dipole – Dipole interaction.
C – Polar covalent bond.
D – Induced Dipole – Induced Dipole interaction

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GROUP SIX (6)

INTERATOMIC AND INTERMOLECULAR BOND

Q1. A and C - Interatomic bond.

B and D - Intermolecular bond.

Q2. A - Non Polar covalent bond

B - Induced dipole - Induced dipole interaction

C - Polar covalent bond.

D - Induced dipole - Induced dipole interaction.