

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND  
ENTREPRENEURIAL DEVELOPMENT**

**ADDIE INSTRUCTIONAL DESIGN IN PHYSICS TEACHING:  
INVESTIGATING ITS INFLUENCE TO IMPROVE THE CONCEPTUAL  
UNDERSTANDING OF STUDENTS IN ELECTRONICS CONCEPTS**

**DANIEL AMANKWAAH**

**FEBRUARY, 2024**

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**BY**

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**A thesis submitted to the School of Graduate Studies, Akenten Appiah-Menka  
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of the requirements for the award of a Master of Philosophy  
(Science Education)**

**FEBRUARY, 2023**

# DECLARATION

## Candidate's Declaration

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

**Daniel Amankwaah**

**Signature:** ..... **Date:**.....

## Supervisors' Declaration

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

**Dr. Eric Appiah Twumasi (Principal Supervisor)**

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**Signature:** ..... **Date:**.....

## ABSTRACT

The demonstration of misconceptions of students in Electronics concepts cannot be overlooked in the study of Physics. In an attempt to solve this problem, researchers have emphasized that, the employment of appropriate instructional method during Instructional delivery can contribute to enhancing conceptual change among students. This study therefore, sought to determine the efficacy of ADDIE Instructional Design Model in enhancing the conceptual change of SHS 3 Physics students in Tano-North Municipality in Electronics. A design-based research (DBR) methodology was adopted for the study using a sample of 101 participants. A 10-item Electronics Concepts Test (ECT) was used to collect data for the study. Data was analysed quantitatively and qualitatively. It was found that high percentages (ranging from 71.29% to 94.06%) of students demonstrated misconceptions in all the items before the intervention. However, after the intervention, the percentages of students who showed misconceptions in all the items reduced (ranging from 28.71% to 48.51%). Also, equivalent percentages of male (55.77% to 71.15%) and female (55.10% to 71.43%) students demonstrated conceptual change after the use of ADDIE model. To complement the quantitative findings, qualitatively, students expressed amongst that “temperature increases conductivity of conductors”, “conductivity remains constant”, “heat increases temperature of conductors”, and “temperature causes a change in shape of a conductor”. It was concluded that the use of ADDIE model enhanced students conceptual change in Electronics concepts in the Tano-North Municipality. It was therefore recommended amongst others that, SHS Physics teachers in the Tano-North Municipality should consider employing the ADDIE model in the teaching and learning of Electronics concept.

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## **DEDICATION**

This thesis is dedicated to the Almighty God who has made it possible for me to complete this work. To my sister, Mrs. Mary Boateng, and to my sons and daughters.

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## ABBREVIATIONS

A.D.D.I.E	Analyse, Design, Develop, Implement and Evaluation
A.C	Alternating Current
A.S.S.U.R.E	Analyse, State, Select, Utilize, Required Learner Participation and Evaluate
D.C	Direct Current
E. C. G	Electrocardiogram
I.C.T	Electronics Concepts Test
I.E.E.E	Institute of Electrical and Electronics Engineers
N.M.R	Nuclear Magnetic Resonance
P.C.B	Printed Circuit Board
U.S.A.I.D	United States Agency for International Development
S.H.S.	Senior High School
W.A.E.C.	West African Examination Council
WASSCE	West African Secondary School Certificate Examination
Z.P.D	Zone of Proximal Development

# **CHAPTER ONE**

## **INTRODUCTION**

### **1.0 Overview**

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

### **1.1 Background to the Study**

It has been suggested that science is the root of modern technology. Every nation is striving hard to progress its science and technology, especially developing nations like Ghana because education in science and technology has become the backbone of development in recent times. Coffie et al. (2020). Science cannot be entirely discussed without considering Physics because according to Akinbobola and Bada (2019), Physics is the foundation of science and technology since it directly produces many of the tools that are essential to their growth. As a result, Physics is a crucial subject for the advancement of science and technology due to the fact that it helps people comprehend a society that is fast advancing in terms of technology and because it encompasses the fundamentals of many ideas and phenomena. Physics is the study of matter, energy, and its interactions (Bada and Jita,

2021). Therefore, one can say that its study helps us to understand the world in which we thrive.

One of the major topics in Physics studied in the senior high school (SHS) in Ghana is Electronics (Ministry of Education, 2010). Electronics is a branch of Physics that deals with the theory and application of devices in which electrons move through a vacuum, gas, or semiconductor medium. This motion of these electrons takes place under the influence of applied electric and/or magnetic fields Atsumbe et al. (2018).

Various concepts studied under Electronics are passage of electricity in gases and evacuated tubes, induced electricity and their uses, cathode rays, positive rays and their properties, simple electronic devices, diodes and their characteristics, Oscilloscope T.V. tubes, band theory of solids, energy level diagrams for conductors, semi-conductors and insulators, doping, types of semiconductors, thus, P-types and N-types, P-N junctions, rectifying property of a p-n junction, forward and reverse biasing, simple transistors and oscillator circuits. Others include basic structures and terminologies and their applications, colour coding, and integrated circuits (Atsumbe et al., 2018b; Kola and Akintunde, 2014; Ministry of Education, 2010).

The study of Electronics has revolved over time, and today, engine management and in-car entertainment systems are two areas of heavy use for Electronics in the automotive industry. In the aerospace sector, Electronics is significant. One important sector that incorporates Electronics in all aspects of its operations is the health care industry. The

utilization of Electronics is used in a wide range of treatments, including Electrocardiogram (ECG), ultrasound, X-ray, Nuclear Magnetic Resonance (NMR), and many more. Air conditioners, elevators, lighting, laptops, printers, fax machines, and desktop computers are just a few of the electrical devices that apply the knowledge of Electronics in offices. Agriculture, which supports our nation, also depends on the idea of Electronics to water crops with motors and to remotely monitor crop growth and soil moisture. The internet is an idea that has completely changed the way we live today; it depends on the knowledge of Electronics to function. The application of Electronics aids data to be sent from servers to computers and from computers to servers. Hinojosa et al., (2020).

Students who study Electronics are better able to understand how everyday electronic gadgets function, which helps them appreciate the benefits and technological developments that the field of Electronics has produced. Therefore, Electronics, a well-known branch of engineering, can offer a variety of real-world situations for the development of engineering abilities and attitudes (Ministry of Education, Singapore, 2017). Nevertheless, many different levels of learners find it difficult to understand topics connected to Electronics Chen et al. (2013). It is widely acknowledged by the research community that many students present severe misconceptions about the essentials of Electronics (Trotskovsky et al., 2015). This is evidenced in the work of Nelson et al. (2017), who found that students had misconceptions about semi-conductor phenomena- diffusion, drift, and excitation. According to a study by Chen et al. (2013) on common misconceptions about learning about diodes, it was found that seven students had misconceptions about semi-conductor

concepts of a diode, four about bias features of a diode, seven about simplified models of a diode, and ten about fundamental circuits of a diode.

Also, students' recent performances in Electronics, especially in external examinations, have not been encouraging (WAEC, 2017, 2018, 2020, 2021). According to the chief examiners, "Candidates could not list the advantages of p-n junction diode over diode valves" (WAEC, 2017). They speculated that "it appeared semiconductors were not treated by most candidates". Also, few candidates gave the correct answer to questions relating to intrinsic semiconductor, as well as difference between p-type and n-type semiconductors (WAEC, 2018). Again, few candidates were able to use the band theory to explain why electrical resistance of a semiconductor decreases with increase in temperature (WAEC, 2020). According to WAEC (2021), "candidates could not state the function of (i) low voltage battery and (ii) high tension source, as a component of an X-ray tube". Further, "candidates were not able to state the reasons for the design features of an X-ray tube". A read-through of the chief examiners reports identified that, candidates could only answer questions about Electronics in 2019 (WAEC, 2019).

This situation is not different in Ghana, as Yuoni (2018) revealed that about 60% of students had misconceptions about basic Electronics concepts. Students' poor academic performance in physics is a result of both instructor's qualifications and students' misconceptions. Studies have indicated that low academic performance in electronics and physics is mostly caused by the attitudes of both teachers and students toward the subject. Naki (2018).

Nonetheless, these are Physics students who may staff the country's engineering, healthcare, and other economic sectors in the near future. As a result, it implies that deliberate and rigorous efforts should be taken to address this ongoing problem in Physics.

Researchers in the field of education are always looking for factors that could affect how students perform in the classroom due to the low levels of students' achievement. One of the main reasons why Physics students' academic performance has declined is that the subject's abstract nature makes its concepts difficult, which stems from inappropriate teaching strategies, poor use of teaching and learning resources and poor instructional design, as well as gender differences (Aina & Akintunde, 2013; Appiah-Twumasi et al., 2022; Gidena & Gebeyehu, 2017; Jugović, 2017; Ngussa, 2014).

Among other things, possible solutions to the aforementioned problem include the employment of appropriate instructional techniques that will clear up students' misunderstandings, enhance the learning environment, and promote students' positive attitudes about Physics (Ministry of Education, 2010). Also Ngussa (2014) suggests that classroom instructors can employ instructional design models that will help students plan their instructional activities in order to improve students' understanding of concepts.

Misconceptions, according to Qian and Lehman (2017), are false beliefs that students hold, frequently with great conviction, that run counter to the generally acknowledged body of scientific knowledge. That is, a misconception is a scenario that results from incorrect ideas that are believed by learners to be true (Karaarslan and Çetin, 2018). Misconceptions also

include such knowledge that is learned from unscientific recourses like beliefs and religious mythological precepts. Misconceptions can be detrimental to learning because they are resistant to change (Nelson et al., 2017). In other words, they serve as obstacles to learning and “cognitive bottlenecks” that must be surmounted for further learning to take place. Students may not be aware that they have created a misunderstanding when they think they grasp a phenomenon or concept because their limited prior knowledge of the physical world strengthens their sensory perceptions of the concept. Students must, therefore, engage in conceptual change to get past the misperception. Misconceptions impede students’ interpretation and application of scientific concepts. This means that teachers must therefore make conscious efforts to identify students’ wrong conceptions and use effective instructional design, experiments, models, and appropriate student-centered approaches to help students overcome their misconceptions of certain scientific ideas (Yuoni, 2018).

Any successful endeavour, including teaching, requires thoughtful design and planning. Because teachers who are also instructional designers are required to be familiar with the epistemological foundations of various theories and their effects on the process of instruction, the idea of instructional design continues to be of utmost relevance to educators. They must create learning strategies that will be successful. Instructional design, according to Basu (2018), is the methodical process of creating, developing, and delivering educational and training programs dependably and consistently. In other words, instructional design is the process of designing, developing, and delivering learning content. Thus, in instructional design, decisions are made and these decisions, according to

Swanwick (2019), are based on reliable educational theory. The focus of instructional design, as Swanwick (2019) explain, is on the pedagogical methodology, or the methods that a teacher might create to aid all students in learning, in greater depth. That is, it addresses the “how” of the teaching. Planning a learning intervention requires careful consideration of instructional design because it enables the designer or teacher to develop effective, efficient, and interesting learning experiences. Better learning is the result of well-designed instruction which is student-centered Swanwick et al., (2019).

One of the most fundamental instructional design models, according to Swanwick et (2019) is ADDIE which is the acronym for Analyse, Design, Develop, Implement, and Evaluate. The ADDIE model is commonly used in developing instruction Dwitiyanti et al., (2020). According to them, this model-based strategy can aid in the creation of learning systems, educational materials, and teaching methods by teachers. During the “Analysis” stage, the teacher analyses the problem or goal(s). It is at this stage the teacher gets information about learners’ prior knowledge, skills, and other areas prior to designing a lesson. The “Design” stage involves preparing a pre-lesson by outlining the goals of the lesson and precisely describing the delivery method. At the “Development” stage, the content and materials that the students will use in the lesson are created. This includes determining whether the lesson meets the learning objectives and whether the content is accurate and comprehensive. The lesson and its goals are then presented to the students during the “Implementation” phase. “Evaluating” mastery of the objectives through formative and summative assessments is the last phase. This is also the time for any necessary adjustments.

The goal of a product learning objective is to impart knowledge from a subject matter expert to one or more people. It can take the shape of online or offline training, coaching sessions, lectures, information brochures, or any other product. Therefore, the ADDIE model's main benefit is that it gives the classroom a structured framework to use as a guide while developing a learning product. The ADDIE model when successfully implemented in the classroom as an instructional method, can enhance conceptual change, thereby leading to improved students' academic performance in the classroom, since it focuses more on the learner, thus being an active learning technique or learner-centered instructional approach (Alnajdi, 2018; Asuncion, 2016; Vijayakumar & Srinivasan, 2015). However, it appears to be not much studies in the field of Physics, especially in Ghana on how the ADDIE instructional model affects the academic performance of Physics students has been done, hence the need for this study.

This study also looked into the effect of the ADDIE instructional approach on gender. Since a long time ago, there has been awareness of the problem of gender equity in science Kaur et al., (2020). Gender, according to Donovan et al. (2019), refers to perceptions of the attitudes, behaviours, and skills connected to the various sex groups, that is male and female. According to Chiquito et al., (2020), because every person learns differently, different learning strategies can never be accepted by everyone, which will result in varying degrees of performance. More research is, therefore, needed to ascertain whether there are gender biases in outcomes or learning. Researchers in the science field place a lot of importance on the gender accomplishment gap. Even though women are underrepresented in Physics, there is a performance difference between them and their male counterparts

Bichi et al., (2017). Chiquito et al., (2020) revealed higher female performance than their male counterparts in Physics. Also, Offordile et al., (2021) revealed no significant difference between male and female Physics students. As suggested by Kaur et al., (2020), teachers must first show that all students in the classroom are equally valuable and capable of success to foster gender sensitivity due to the lack of consensus in academic attainment concerning gender. Establishing a democratic, gender-neutral learning environment where everyone has unrestricted access to the opportunity to voice their opinions and pose and respond to questions makes this possible. This can be achieved by employing gender-friendly instructional approaches such as the ADDIE instructional model (Basu, 2018). In light of this, the researcher set out to determine how the ADDIE instructional approach can affect the conceptual development of SHS Physics students in Tano North Municipality, Ahafo Region, Ghana.

## **1.2 Statement of the Problem**

Electronics is one of the major concepts studied at the SHS level of the Ghanaian SHS system. It is a branch of science and technology that deals with the study of the flow and control of electrons in electrical circuits and their behaviours and effects in vacuums, gases, and semiconductors. (Ministry of Education, 2010 physics syllabus). The application of Electronics is prevalent and important domestically and industrially (Hinojosa et al., 2020). However, students exhibit various misconceptions and other difficulties with electronic concepts Abaniel, (2021). According to the authors, students had misconceptions about semiconductor phenomena, including diodes. This problem is also present in Ghana, where

Yuoni (2018) found that 60% of students had an incorrect understanding of fundamental technological concepts.

Also, the difficulty of Physics students in Electronics concepts is emphasised, more particularly in external examinations (WAEC, 2017, 2018, 2020, 2021). According to the West African Examination Council (WAEC) chief examiners for Physics, “candidates could not list the advantages of p-n junction diode over diode valves” (WAEC, 2017). The chief examiners speculated that “it appeared semiconductors were not treated by most candidates”. Few candidates gave the correct answer to questions relating to intrinsic semiconductors, as well as the difference between p-type and n-type semiconductors (WAEC, 2018). Again, few candidates were able to use the band theory to explain why the electrical resistance of a semiconductor decreases with an increase in temperature (WAEC, 2020). Again, according to WAEC (2021), “candidates could not state the function of (i) low voltage battery and (ii) high tension source, as a component of an X-ray tube”. Further, “candidates were not able to state the reasons for the design features of an X-ray tube”. A read-through of the chief examiners reports identified that, candidates could only answer questions pertaining to Electronics in 2019 (WAEC, 2019).

An observation by the researcher in the Tano North Municipality revealed that, 2021/2022 as well as 2022/2023 SHS 3 Physics students demonstrated difficulties in solving Electronics problems. This was revealed in their mock examinations, which students write to prepare for their final year external examinations. During this observation, it was revealed that out of about 300 SHS physics students from the three selected schools, about

60% of Physics students who sat for the mock exams in the 2021/2022 and 2022/2023 academic years answered the questions wrongly, while 35% did not attempt to answer questions under Electronics (Field Study, 2023). It can therefore be said that students studying Physics at SHS in the Tano North Municipality find Electronics to be a significant obstacle.

SHS students' misconception in Electronics cannot be glossed over because these Physics students may staff the country's engineering, healthcare, and other economic sectors in the near future. As a result, it implies that deliberate and rigorous efforts should be taken to address this ongoing problem in Physics, as highlighted in the background. The major cause of this challenge is that students constantly report that the concept is too abstract to comprehend its reality (Trotskovsky et al., 2015; Yuoni, 2018), which stems from inappropriate teaching methods, as well as poor instructional design (Aina & Akintunde, 2013; Appiah-Twumasi et al., 2022; Gidena & Gebeyehu, 2017; Jugović, 2017; Ngussa, 2014), as well as gender differences (Bichi et al., 2017). However, researchers have suggested using student-centered strategies, such as the ADDIE instructional teaching model to enhance conceptual change of Physics students, and the same time bridging the gender gap in performance between male and female students (Alnajdi, 2018; Asuncion, 2016; Vijayakumar and Srinivasan, 2015).

Various studies have been conducted on the ADDIE instructional design model. For instance, a Comparative Study of the ADDIE Instructional Design Model in Distance Education, University of Ioannina, Greece. (2022). Also, using the ADDIE Model in

instructional strategies to help teachers to improve their teaching competencies. Almelhi, (2021). In Ghana, a comparative Study of SAM and ADDIE Models in Simulating STEM Instruction for Science and Mathematics Teachers who offer distance education at the University of Education, Winneba, Ghana in the 2018/2019 academic year.

However, a paucity of research exists, especially, in Ghana on how the ADDIE instructional design model can enhance conceptual change among SHS Physics students in the concept of Electronics. Therefore, this study seeks to investigate the impact of the ADDIE instructional design model on the conceptual change of SHS Physics students in the Tano North Municipality in the Ahafo Region, Ghana.

### **1.3 Purpose of the Study**

The purpose of this study was to investigate the influence of ADDIE instructional design in Physics teaching to improve the conceptual understanding of students in electronics concepts” in the Tano North Municipality in the Ahafo Region, Ghana.

### **1.4 Objectives of the Study**

The objectives of the study were to determine the:

1. Misconceptions among SHS Physics students in Electronics concepts.
2. Effect of using ADDIE instructional design model in enhancing conceptual change among SHS Physics students in the studying of Electronics concepts.
3. Extent of male and female SHS Physics students’ conceptual understanding in Electronics before and after exposure to ADDIE instructional design model.

## **1.5 Research Questions**

The following are the research questions for the study:

1. What are the misconceptions among SHS Physics students in Electronics concepts?
2. What is the effect of the use of ADDIE instructional design model on SHS Physics students' conceptual change in Electronics concepts?
3. What is the extent of male and female SHS Physics students' conceptual understanding in Electronics before and after exposure to ADDIE instructional design model?

## **1.6 Significance of the Study**

This study seeks to help students identify their misconceptions about Electronics concepts and help students enhance their conceptual understanding of Electronics after employing ADDIE instructional design. As learning becomes student-orientated in ADDIE-instructed lessons, it allows students to change any misconceptions as they go through series of tasks on their own; this will assist them in learning new concepts and knowledge for themselves. Additionally, the application of ADDIE instructional design would allow the students to link Electronics concepts to the activities they engage in daily in their surroundings, ensuring that what they learn is retained. Also, the study's findings provide information to physics teachers on the need to employ instructional designs such as ADDIE to improve students' conceptual understanding of electronics. By the applications of such instructional designs, Physics teachers can tailor their lessons to their learners' needs and use appropriate and effective techniques to present content to students, which will improve their understanding.

### **1.7 Delimitations of the Study**

The study considered only seven concepts in Electronics, namely, conductors, insulators, semi-conductors, diodes, p-n junction, light-emitting diode, and transistors. These topics were taken into consideration because they appear almost yearly in the WASSCE because WAEC and other researchers have found that these are the concepts that students struggle with the most. Also, only SHS three elective Physics students within the Tano North Municipality could participate in the study, because Electronics is studied in SHS three according to the Ministry of Education (2010). Another delimitation was that a design-based research methodology was employed, therefore, not all schools in the Tano North Municipality could participate in this study. Only two schools from the municipality were selected to participate in this study. Again, there are various instructional design models that can help enhance students' conceptual change, nevertheless, for the purpose of this study, ADDIE instructional design was selected.

### **1.8 Limitations of the Study**

The results of this study cannot be generalised to all Physics students in the municipality because only two SHS 3 intact classes were used in the study and not all SHS 3 Physics classes in the Tano North Municipality since Design Base research was employed in this study did not allow for random selection of participants. Again, Students undergo conceptual transformation when they move from one misconception or an incorrect belief to one that is backed by scientific evidence. Heddy et al. (2018). Hence the researcher focused the study's objectives mostly on misconceptions.

## 1.9 Operational Definition of Terms

**Misconceptions** – incorrect, frequently firmly held ideas that students hold that are at odds with the general body of knowledge in science.

**Conceptual change** – the process of replacing a misconception with a scientifically acceptable concept.

**Conceptual understanding** - a thorough and practical understanding of mathematical, scientific, and other concepts of study. Conceptual understanding requires students to organize facts and ideas into meaningful concepts in science

**ADDIE instructional design model** – a learning model that educators and instructional designers employ to construct successful learning environments. It consists of five phases: Analyse, Design, Develop, Implement, and Evaluate.

**Electronics** – the area of Physics that studies how electrons behave and emit when they are in electronic devices.

**Gender** – the social and/or cultural disparities and distinctions that are a result of one's biological characteristics and are expressed as male or female.

**Instructional Design** – the process of creating, developing, and delivering learning content.

**Physics** – the area of natural science that investigates matter and energy, its basic components, as well as how they move and behave in space and time.

## 1.10 Organisation of the Study

The study is divided into five chapters, each of which focuses on a different area of the subject. The study's background, statement of the problem, purpose, objectives, research

questions, significance, delimitations, limitations, and definition of words were all covered in chapter one. In chapter two, the literature pertinent to this subject was reviewed. This included reviews of conceptual, theoretical, and empirical studies. Research design, population, sampling technique, data collecting tools, data collection methods, data processing and analysis were all covered in the third chapter. The presentation of the results and a discussion of them are included in chapter 4. The overview of the study, the findings, the recommendations, and the ideas for additional research were all included in chapter five.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.0 Overview**

This chapter discussed a review of literature that relates to this study. Specifically, the theoretical review, where the theory underpinning this study was discussed, the conceptual framework which served as the basis for conducting this study, as well as the conceptual review of the study's variables, which talked about the various concepts that were related to this study, thus, the concept of instructional design, and ADDIE Instructional design model. Also captured in this chapter were the concepts of gender, misconceptions, conceptual change, Electronics, as well as students' difficulties in Electronics. All these concepts were conceptualized in the conceptual framework of the study. Additionally, the empirical review of this study was also highlighted in this chapter. The chapter ends with summary of the reviewed literature.

#### **2.1 Theoretical Review of the Study**

By enhancing conceptual change, this study is anchored on the constructivism theory. The foundational ideas of the constructivist movement are those of Piaget and Vygotsky (Schunk, 2012). Constructivism, according to Schunk (2012), is an educational and philosophical viewpoint which holds that people create a large portion of the knowledge and concepts they acquire. That is, individuals are self-directed learners who generate knowledge. Thus, Learners need to grasp the fundamentals of the subject matter to fully comprehend the learning material, and teachers should not impart knowledge to pupils in

the conventional sense. Instead, teachers ought to set up scenarios so that students actively engage with the material through material manipulation and interpersonal communication. Another major principle of constructivism is that learners construct new knowledge on the basis of their prior information. The new or modified knowledge that a person constructs from fresh learning experiences is influenced by their prior knowledge. According to Appiah-Twumasi et al. (2021), students enter the classroom with some prior knowledge which can align or misalign with scientific truths. Some of these ideas that children have developed are well-rooted in their culture, traditions and religion, and this creates conflict in their minds as they encounter Science in the classroom. Therefore, according to constructivism, the learner should begin learning by engaging in activities that activate this previous knowledge by the learners. By so doing, the content will be well understood by the learner and learning will become meaningful to the learner and the child will be eager to know more (increased interest).

Thirdly, to constructivists, learning is not an abstract idea; rather, it is something we do in groups, through interactions with one another. For example, Vygotsky (1978) had the belief that community is essential to the act of “making meaning”. For Vygotsky, a child's upbringing has an impact on both the content and manner of their thinking. As a result, sharing and negotiating socially constructed information is the foundation of all teaching and learning.

The theory of constructivism is split into two major camps namely; cognitive constructivism, propounded by Piaget, and social constructivism, propounded by Vygotsky.

Cognitive constructivism emphasises how each person constructs their own internal knowledge. This viewpoint, which comes from Piaget (1976), stresses how each learner creates their own knowledge as they work to overcome "mental disequilibrium," which is sparked by internal cognitive conflict. "Mental disequilibrium" here is used to refer to the mental conflict created when an individual attempts to fit new knowledge into their cognitive structures, which Piaget called schemas, or change outrightly already existing knowledge. Practically, in the classroom, a child's schema refers to their prior knowledge they hold about the subject matter.

The stage of mental disequilibrium comes to play as a result of interrelatedness among three cognitive processes: organisation, adaptation (assimilation and accommodation), and equilibration. That is, every act an individual makes is cognitively organised and then adaptation provides the means for change (Khadidja, 2020). Accommodation refers to an individual's tendency to change their structures in light of new knowledge or stimuli. Assimilation on the other hand, is the recognition of functional identity. That is, assimilation is an intellectual process whereby the individual deals with the environment in terms of their present schemas. Thus, assimilation takes place as fresh experience is incorporated into the existing framework of knowledge.

Both accommodation and assimilation are necessary for adaptation to occur. Adaptation that involves accommodation and assimilation will be completed when the individual reaches equilibrium. In summary, Akpan et al. (2020) state that when students learn something new, they have to make sense of it in light of their prior knowledge and

experiences. This may require either accommodating the new information by changing completely prior knowledge or modifying existing beliefs (assimilation). Either way, they actively create the knowledge that we possess. In order to accomplish this, we need to investigate, evaluate, and pose questions. Thus, equilibrium is used to describe a balanced condition between an individual and their external environment. The principle of adaptation according to Piaget (1976), involves the active engagement of the learner because modification of structures can never be achieved when an individual remains passive in the learning environment.

On his part, Vygotsky also stressed on how the child's social and cultural environment play active role in the knowledge construction process. Vygotsky gave equal weight to the mental and physical processes involved in learning. He placed an emphasis on the social and cultural aspects of growth and saw students as active organisers of their experiences. His socio-cultural theory of development contrasted with Piaget's in that it rejected the emphasis on individual development. According to Vygotsky, a child's development is dependent on their social environment first, before transcending to the individual level. Thus, learning via social contact is inherently cooperative. Therefore, rather than isolating the student from their surroundings, educators should encourage them to interact with other students, themselves, and other knowledge-gathering resources like computers, books, and notebooks. As Topçiu and Myftiu (2015) iterated, every child experiences a different change of their brain structure depending on the role that their social environment plays. When the youngster actively participates in this factor interaction, modification is achieved.

The language needed to acquire communication is imparted to the student through these interactions. The primary role of the teacher is to facilitate or mediate the learning process and coordinate the learner's concepts. Khadidja (2020) explicates that Vygotsky distinguished between "scientific concepts or nonspontaneous" and "everyday concepts or spontaneous concepts". These ideas are clearly defined and are acquired through many situations. In contrast to "scientific concepts", which are acquired formally through formal education, "everyday concepts" are those that are spontaneously learned in daily life. Additionally, the formation of "everyday concepts" moves from concrete to abstract experiences, whereas "scientific concepts" move from abstract to concrete. For instance, the student adapts "everyday concept" while learning "scientific concepts" in school, and they also need to acquire "scientific concepts" based on those same "everyday concepts". Therefore, understanding and knowledge construction depend on both ways. The difference between the two categories of concepts, according to Cakir (2008) is the presence or absence of a system.

Additionally, the cultural elements of Vygotsky's theory shed light on the idea that context is an essential component of both learning and development. The way that students connect with the people, things, and institutions in their worlds alters how they think. Concepts' meanings evolve as they get intertwined with the outside world. Therefore, Schunk (2012) posits that "school" is more than just a noun or a building; it is also a type of organisation that aims to advance citizenship and learning. The "tools" of the social environment, such as its cultural artifacts (such as automobiles, machinery), as well as its language and social institutions (such as schools, churches), have an impact on cognition. Thus, social

interactions aid in coordinating development-related influences. Thus, the use of cultural tools in social interactions as well as the internalisation and mental transformation of these interactions lead to cognitive change.

In this process of learning, a key concept Vygotsky coined known as the Zone of Proximal Development (ZPD) is identified by teachers. The ZPD is defined by Vygotsky (1978) as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (p. 86). The ZPD is a measure of how much a learner can learn under ideal teaching circumstances. It demonstrates the relationship between learning and development and is primarily an assessment of a student's intellectual level or developmental preparedness in a particular subject (Schunk, 2012). The student and teacher collaborate on a task in the ZPD that is too difficult for the learner to do alone. Helping students reach their potential level of performance through the social environment can be accomplished in many ways. A common application according to Khadidja (2020) involves the concept of instructional scaffolding, which refers to regulating task components that are beyond the learners' understanding so they can concentrate and master those aspects of the concept they can grasp quickly.

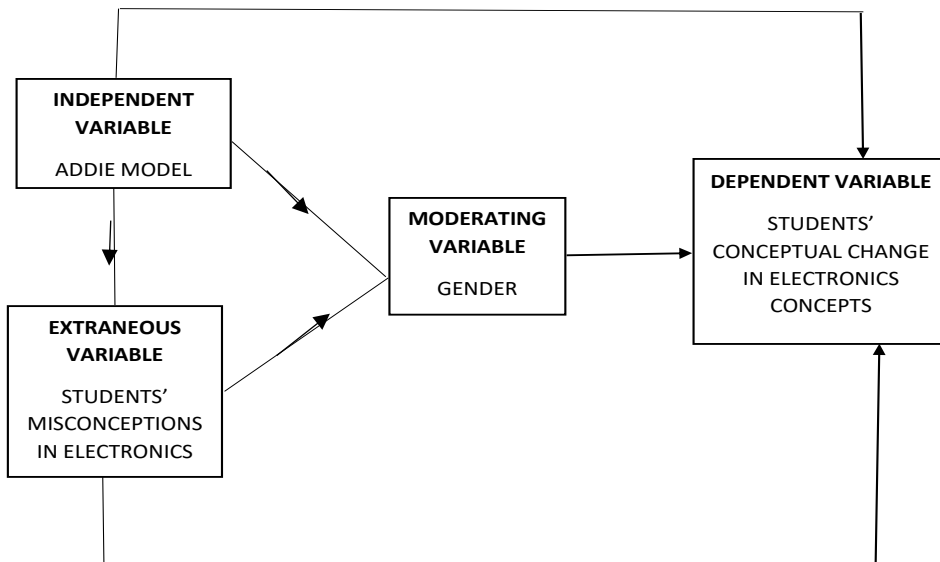
### **2.1.1 Implication of Constructivism Theory for the Study**

It is widely acknowledged that Piaget's theory of cognitive development heavily relies on past cognitive structures, as these structures dictate opportunities for disequilibrium and

subsequent accommodation or conceptual change (Cakir, 2008). For a student to effectively absorb new information or concepts, prior knowledge or preexisting schemata are crucial, which is part of the first stage (analyse) of the ADDIE model. When a learner encounters disparities with what they already know, cognitive conflict arises. Through this, the student by experiencing the material actively, will come to terms with any pre-existing knowledge which are not in alignment with the scientific fact being studied. By employing the ADDIE Instructional Design Model, students participate actively in classroom lessons. Learning is thus connected to students' actual environments and gives them the chance to participate actively in the learning process (Vijayakumar & Srinivasan, 2015). Additionally, the ADDIE Instructional design model emphasises that instructors employ cultural tools such as media and other locally-made materials that will help communicate the meaning of concepts to the learners. Cognitive change thus occurs in the ZPD as shared cultural tools between the instructor and students lead to cognitive transformation when the student internalises this culturally-mediated interaction.

## **2.2 Conceptual Framework of the Study**

The theoretical foundation of this study is constructivism, mainly propounded by Piaget and Vygotsky. Piaget (1976) and Vygotsky (1978) borrowed the theoretical framework from constructivism. As a result, the conception of the interaction of the study's variables in Figure 2.1 was built on this idea theory.



**Figure 2.1: Conceptual Framework of the Study (self - designed)**

From Figure 2.1, the employment of ADDIE Instructional Design model as a constructivist teaching method, which places the student at the center of the learning process, enhances students' academic conceptual change in the Electronics concept. During the process of conceptual change, the teacher, who is also an instructional designer in this model, plays the role as a facilitator of the instruction who only moderates and guides the students to make their own meaning of the instructional content through active participation, using appropriate teaching and learning materials. By so doing, prior knowledge is activated; and the activities they are made to undertake during Electronics lessons means that any misconception held before the entering the classroom will be changed. This is because, the scientific truth will be revealed to students through these activities under the proper guidance of the teacher.

From Figure 2.1, the independent variable therefore, is ADDIE Instructional Design Model, whereas the dependent variable is students' conceptual change in Electronics concepts. Also, gender differences in academic performances in Electronics concepts in this study was conceptualised as a moderating variable, since according to the literature, gender differences affect students' academic performances in Physics. In order to statistically account for its variance, the moderating variable of gender was added to this study, as seen in the conceptual framework. Therefore, mixed schools were selected on purpose to include both boys and girls. However, students' misconceptions were regarded as extraneous variable which could influence the teaching and learning process in enhancing conceptual change in Electronics concepts. This is because, in some cases, students' misconceptions are very difficult to modify, which may affect the tendency for conceptual change, according to Keeley (2012), Verkade et al. (2017) and Heddy et al. (2018). In view of this, students' misconceptions were therefore identified and measured.

## **2.3 Conceptual Review of the Study's Variables**

### **2.3.1 Instructional Design**

In order to promote effective and efficient learning, instructional design is a methodical and iterative process that involves creating and implementing learning experiences and resources. According to Molenda et al. (2006), instructional design is a systematic way of transforming learning and teaching principles into designs or specifications for instructional materials or activities. They see it as the systematic solution of instructional issues, followed by an examination of the conditions of learning and the creation of an engaging learning environment based on the results of this analysis. The IEEE, as stated in

Botturi (2003) defines instructional design as the process by which a teacher selects the best instructional strategies for certain pupils in a specific setting in an effort to attain a specific goal. The definition provided by the IEEE shows that there are various specialised components to design, including a teacher who is also an educational designer, students, the learning environment, and the learning objectives. Thus, instructional design refers to a collection of techniques and devices used to develop specific educational responses for specific contexts. The IEEE asserts that broad solutions are not offered through instructional design.

From the above definitions, one can say that the instructional design process typically includes several stages, such as needs assessment, analysis, design, development, implementation, and evaluation, as Brown and Green (2015 p.43) agree. The needs assessment, according to Brown and Green (2015) involves gathering information about the learners, the learning environment, and the learning goals in order to identify the gaps in knowledge and skills that need to be addressed; thus, determining the desired change that must happen, the people who want the change, and the setting in which the change should take place. Brown and Green (2015) assert that the information acquired during a requirements analysis will assist the instructional designer—in this case, the teacher—in being clear about what instruction needs to be designed or even if teaching is actually essential to help bring about the desired change. The analysis entails breaking down the learning goals into precise learning objectives as well as determining the instructional approaches and materials that will be applied to meet these goals. A blueprint or plan for the learning experience is created by the instructional designer during the design stage.

This blueprint or plan includes the order in which learning activities will be completed, the kinds of assessments that will be applied, and the instructional materials that will be created. To Brown and Green (2015), the creation of instructional materials, including handouts, videos, interactive media, and assessments, occurs during the development stage. The instructional resources are utilised to support learning during the implementation stage, and the success of the instructional design is evaluated during the assessment step. The process of instructional design requires consideration of a variety of factors. These factors are intricately connected to one another and influence one another to some extent. These components should be arranged according to the steps of instructional design. For instance, in the opinion of Işman (2011), if the purposes and objectives are not properly chosen, expressed, or written, the succeeding steps will have problems as a result of the inappropriate and lacking elements in the preceding step. The instructional design connects each of the steps to the others. The phases must be set up in a manner that makes sense and is connected to one another. To put it another way, a primary function of instructional design is to develop teaching and learning activities; as a result, each step must be carefully chosen and implemented in a logical sequence. During the implementation, every small detail could be crucial. Every choice must have a noble purpose behind it; it cannot be made only for the sake of it. Designing should take into account how the various processes interact with one another. During the teaching and learning process, the designer should gather trustworthy information on the students, their backgrounds, and their prior learning. Since they have a significant impact on the results of instruction, they should be carefully considered by designers as they work to develop a model that will enable them to maintain a balance between them (Işman, 2011).

Instructional design is systematic, employs a systems approach to knowledge and human learning, is focused on individual learning, has short-term and long-term stages, and is methodical (Branch, 2009, p.8), which means a planned sequence of external events ought to support internal circumstances predicated on a model of information processing. Planning performance objectives, choosing instructional strategies, media, and selecting or producing resources are all steps in the iterative process of instructional design. Evaluation is also a step in the process.

The goal of instructional design is to create a learning environment that is engaging, relevant, and effective for learners of all ages and abilities. Therefore, by following a systematic approach to design and development, instructional designers can ensure that their materials are relevant, effective, and engaging for learners. Thus, it becomes evident how important instructional design is to the learning process and how it addresses issues like the growing need for skilled workers, access to learning opportunities, outcomes-based teaching and learning, and the transferability of skills across academic disciplines. As a result, increasingly advanced learning tools and materials have been created, suggesting that instruction and learning materials ought to be prepared ahead of time, recorded beforehand, and packaged beforehand (Molenda et al., 2006).

Molenda et al. (2006) suggest that innovations brought forth by the instructional design method enable the translation of learning challenges into lesson plans, guaranteeing the quality of instruction. Since the goal of instructional design is to achieve predetermined learning outcomes, the instructional objectives serve as a roadmap for all parties involved,

including employers, educators, administrators, and parents, as well as learners and learning facilitators. It is possible to ascertain whether or not those outcomes have been fulfilled by using performance standards and assessment procedures. Since every factor that could affect the design is taken into account and the final learning materials have been reviewed and tested until the learning objectives are satisfied, both teachers and students can feel confident in the effectiveness of the instruction.

### **2.3.2 The ADDIE Instructional Design Model**

One of the most widely used instructional design models is the ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation.

#### **Analyse**

During the “Analysis” stage the teacher analyses the problem or goal(s). The Analysis phase of instructional design model, according to McGrif (2000) serves as the starting point for all other phases. At this stage, specific research techniques such as needs analysis, and task analysis are conducted in order to have better understanding of the problem (Misesani et al., 2020). During this phase, as an instructional designer, the instructor must define the issue, locate its origin, and come up with potential fixes. Thus, in order to identify the characteristics of the target learner (such as prior knowledge, interests, and attitudes), as well as to establish instructional goals and the learning context/environment, the learner, context, and instructional materials are reviewed during the “Analysis” phase (Khalil & Elkhider, 2016). That is, it is at this stage that before designing a lesson, the teacher gathers information on the students' past knowledge, needs, and other characteristics. Therefore, the "Analyse" phase guides a designer toward developing a thorough understanding of a

certain problem. This step often results in a list of tasks that need to be taught as well as the instructional objectives. These outputs will serve as the phase's input during design.

### **Design**

Using the “Analysis” phase's outputs, the “Design” phase plans an approach to creating the instruction (McGrif, 2000). According to Heaster-Ekholm (2020), the design phase involves organising the material to be learnt into topics, assignments, and performance objectives. Performance objectives specify the abilities a learner will possess after receiving instruction. By implication, the "Design" stage involves developing a pre-lesson and outlining precisely how the lesson will be presented. Some of the elements of the “Design” phase, McGrif (2000) stated, may include organising the learning objectives and techniques that were developed during the “Analysis” stage, choosing a method of delivery, and arranging the lessons. Shelton and Saltsman (2011) added that the “Design” stage is most comparable to the process of creating a blueprint, a guide for building that directs all parties involved toward the desired result. The outputs of the Design phase will be the inputs for the Develop phase.

### **Develop**

The “Development” stage involves the creation of content and any materials the learners will be using during the lesson (Heaster-Ekholm, 2020; Vijayakumar & Srinivasan, 2015). Thus, examining the course objectives, examining the textbook, developing learning objects, creating learning modules, churning material, developing content, and providing extra resources are all part of the “Development” stage. This stage's goal is to produce the

lesson plans and instructional materials. McGrif (2000) added that the teacher develops the instruction, together with any accompanying materials and every piece of media that will be utilized during the lesson. This could involve both software and hardware, like computer-based training and simulation tools. As emphasised by Shelton and Saltsman (2011), because of the expertly created educational resources, faculty members may be the most reliant on outside help at this point.

### **Implement**

The lesson is then presented to the students during the “Implementation” phase. Whether teaching is delivered in a classroom, laboratory, or on a computer, the “Implementation” phase relates to how it is really done. This stage's goal is to offer training in an effective and efficient manner. This stage must help the students grasp the subject matter, encourage their mastery of the objectives, and guarantee the transfer of information from the classroom to the workplace (McGrif, 2000). This is because, during this stage, the learner should be given maximum opportunity to manipulate the learning materials which are used to deliver the content. Therefore, Lu and Sides (2022) stated that there are three ways one can implement the design: through one-to-one teaching, in a small group, or through field trial.

### **Evaluate**

The last phase in the ADDIE model is assessing mastery of the objectives through formative and summative assessment techniques. The teacher gathers data about the lesson both during and after implementation in order to offer feedback on the design (Lu & Sides,

2022). As a result, this step evaluates how effective and efficient the lesson was. This means that, in actuality, evaluation ought to take place at every stage of the instructional design process—during each phase, in between phases, and after implementation. Any revisions that need to be made are also done at this time (McGrif, 2000). Therefore, McGrif (2000) concluded that with the ADDIE model, instructional designers can go back to any earlier phase based on the findings of the formative evaluation of that phase.

According to Branch (2009, p 20), “ADDIE is a product development paradigm and not a model per se”. Therefore, Heaster-Ekholm (2020), corroborated that the five phases of ADDIE move a designer through the process of creating an instructional product. However, researchers such as Vijayakumar and Srinivasan (2015), Lu and Sides (2022), and Sarkodie (2023) contend that the model can be adopted for use in the classroom by teachers. This will serve as a guide to help instructors plan and deliver lessons effectively.

#### **2.4 The Concept of Misconception**

There are instances when students from various fields come to class with a variety of incorrect preconceived notions or false assumptions. These could include ideas, interpretations, and convictions regarding the environment. Such children, in the opinion of Soeharto et al. (2019), acquire knowledge about their environment through official education at schools or informally based on their experiences, which are usually used to create an understanding using the views of the students. These beliefs are given different names by researchers which include conceptual difficulties (Doğru, 2021), flawed mental models (Dewi et al., 2023), alternative conceptions (Kruatong et al., 2006) and

misconceptions (Appiah-Twumasi et al., 2021). Though these are different terms used in teaching and learning, they all represent the same idea, as Keeley (2012) states that misconception is a term used to refer to students' ideas that are either completely false or partially true in terms of science.

According to Verkade et al. (2017), there are at least two circumstances in which conceptual learning can take place. In one scenario, a student may have some true prior knowledge of a topic, but their comprehension of the entire subject to be studied is imperfect. In this situation, Verkade et al. assert that learning is a process of using accurate knowledge to fill in the knowledge gaps in their understanding. In the second scenario, a student has prior information that contradicts the concept they need to learn. Learning in this situation involves analysing, updating, and replacing inaccurate past information with ideas that are consistent with the subject to be learnt. The incorrect prior information is a misconception in the second scenario. This means that misconceptions are errors in conceptual understanding.

Misconceptions are therefore defined by Qian and Lehman (2017) as erroneous beliefs that students hold, frequently with great conviction, and which run counter to the consensus of science. In other words, misconceptions are learners' crude perceptions that go counter to widely accepted theories and factual information. Thus, in the scientific domain, misconceptions, according to Ajayi V. Z. (2017) are prevailing opinions about science that are not supported by actual scientific data. Soeharto et al. (2019) and Appiah-Twumasi et al. (2021) also considered misconception in science as students' concepts from non-formal

education or life experience that are poorly organised and give the wrong interpretation when interpreted via a scientific lens.

Ajayi (2017) asserts that misconceptions are common; they are an expected aspect of learning. To him, not all concepts created are valid in light of the most recent research and scholarship in a certain area, but people naturally form ideas from their everyday experiences. Additionally, some ideas across a range of subject matters are just incredibly challenging to understand. They might be exceedingly ethereal, illogical, or extremely intricate. This leads to an incorrect understanding of them. This implies that anyone can demonstrate a misconception according to Ajayi (2017).

#### **2.4.1 Types of Misconceptions**

Misconceptions can be broken into five basic categories namely: Preconceived notions, nonscientific beliefs, conceptual misunderstandings, vernacular misconceptions and factual misconceptions (Ajayi, 2017; Soeharto et al., 2019; Verkade et al., 2017). These are briefly explained as follows.

**Preconceived Notions:** Preconceived concepts are prevalent beliefs that result from real-world and personal experience. For instance, despite evidence to the contrary, many individuals think that light must first reach our eyes in order for us to view an item. As a result, because students do not yet understand the concept of light, preconceived notions arise (Soeharto et al., 2019).

**Non-scientific Beliefs:** Views or information that students have learned from sources other than scientific ones are considered non-scientific beliefs. For instance, some individuals think that gender differences affect how well students learn mathematics, science, and languages, which makes men more powerful than women (Soeharto et al., 2019).

**Conceptual Misunderstanding:** When students build their own unclear and incorrect notions based on the proper scientific concepts, they are creating conceptual misunderstandings, according to scientific knowledge (Soeharto et al., 2019).

**Vernacular Misconception:** Mistakes resulting from the usage of words in common speech that have distinct meanings when viewed in the context of science are known as vernacular misunderstandings. Students, for instance, struggle to grasp the idea of heat because they do not realise that heat is caused by an increase in energy, not just by fire (Soeharto et al., 2019).

**Factual Misconceptions:** The term "factual misconceptions" refers to misunderstandings that develop early in life and persist into adulthood (Soeharto et al., 2019). These beliefs, according to Verkade et al. (2017), may be founded on false information that someone has learned from friends, family, the news, social media, or even in the classroom. Children, for example, believe that lightning would strike them if they were outside the home. Science misconceptions are persistent, resistant to change, and deeply rooted in some concepts (Soeharto et al., 2019). Therefore, Verkade et al. (2017) added that in order to

assist students in recognizing and assessing their own misconceptions, it is crucial to understand the process by which a misconception arises.

#### **2.4.2 Sources of Misconceptions**

Over the years, researchers have expressed an interest in assisting students in changing their misunderstandings, and they have ascribed these errors to some of the sources that are listed below.

**Everyday Experiences:** Students' interactions with the environment in daily life experiences confuse the students. According to Widiyatmoko and Shimizu (2018), the environment becomes familiar to the children, and they spend a lot of time outside of the classroom. They each have their own interpretations of the meanings of the items in their environment. In general, these explanations do not make sense in terms of science. Students' comprehension of scientific concepts is dependent on their interactions with their surroundings and is ingrained with their experience of daily life.

**Language Use:** When scientific terms are utilised in common vernacular, students have difficulty (Widiyatmoko & Shimizu, 2018). As a result, students' misunderstandings may result from the language used by certain people. For example, students commonly speak that light is something that makes vision possible. However, in science, the definition of light is electromagnetic radiation of any wavelength that travels in a vacuum with a speed of 299,792,458 meters per second; specifically: such radiation that is visible to the human eye. Also, students also have the misconceptions that colour is a property of the object

rather than light. In daily language saying “the table is red” instead of “the table is reflecting red light” may be considered as the source of misconceptions.

**Teachers:** On the part of teachers, some misconceptions held by teachers may be transferrable to the students during lesson delivery since they are the major source of information during the instructional process. When teachers acquire abstract topics throughout their training without having a good understanding of them, they end up passing on their misconceptions to their students. The science concepts used in each learning activity must therefore be clearly understood conceptually by science teachers (Qian & Lehman, 2017; Widiyatmoko & Shimizu, 2018). Additionally, Appiah-Twumasi et al. (2021) stated that some instructional strategies and methods used to communicate knowledge to students may result in students gaining a superficial understanding of the material, which could lead to students developing erroneous information.

**Textbooks:** Textbooks serve as a tool for the teaching-learning process as well as a manual for instructors and learners. The development of conceptual comprehension by students is significantly influenced by textbooks. However, textbooks could also contribute to misunderstandings. For example, Gudyanga and Madambi (2014) reported that some textbooks use the unclear figures and diagrams in explaining concepts. Similarly, some textbooks do not always provide complete and correct information or explanations.

### **2.4.3 Misconception as a Barrier**

When misconceptions among students are portrayed as barriers, their existence implies a hindrance to their learning and suggests that their absence would take them more directly to their desired learning objectives (Larkin, 2012). This means that misconceptions obstruct learning by stopping students from accessing key scientific ideas, keeping them from understanding concepts, and interfering with how they learn new information. Students frequently try to incorporate new knowledge into their pre-existing mental models, which are built on false assumptions. They might therefore have trouble adequately understanding and integrating new concepts. For example, if a student misunderstands the concept of the particles of the atom, it can hinder their ability to understand heat and temperature. Because of this, when presented with an issue, students could use their misconceptions to produce poor answers. They might find it difficult to recognise and correct their assumptions, which could result in recurring mistakes in how they approach solving problems. As a result, the student will develop a flawed foundation for future learning.

### **2.4.4 Misconceptions as Resources**

Resources is used in this case to emphasise the idea that the definition of resources goes beyond “conventional material resources to include personal, environmental, and social resources that are accessed during instruction, such as books, buildings, libraries, teachers’ formal qualifications, and more” suggested by (Cohen et al., 2003, p. 122). According to Larkin (2012), this viewpoint suggests that the manner that both teachers and students use these resources to facilitate learning mediates the relationship between resources and learning. Students’ preconceptions, thus, can be used as tools to encourage more in-depth

and worthwhile learning. Therefore, if the teacher uses them in any way, they serve to direct pedagogy and instruction. This, Heddy et al. (2018) assert, is due to the fact that students who display misconceptions need to be taught in order to improve their conceptual thinking.

According to Verkade et al. (2017) these preconceptions frequently coincide with the ideas and concepts that students will learn in a course and do not prevent them from learning more. Proper preconceptions, often referred to as anchoring conceptions, can improve a student's learning by serving as a framework for the development of higher-level conceptual knowledge by serving as anchor points for new information. Therefore, Larkin (2012) is of the opinion that in order to explicitly teach for conceptual change, the teaching activities and classroom methodology are guided by students' ideas that are both solicited and predicted. Formative assessment methods can be used to evaluate these concepts.

When properly identified, students' concepts may also play metacognitive functions in that they allow students to explicitly compare their conceptions with those of other students while giving justifications, arguments, and explanations (Larkin, 2012). Thus, ideas from students can be improved, changed, connected to, and built upon by teachers and students alike as the foundation of classroom learning. The utilisation of students' ideas is seen from this angle, much like the usage of any resource. In fact, Keeley (2012) borrowed the term "steppingstones" to refer to misconceptions, which means they play a crucial role in assisting students in gradually altering their mental models in order to comprehend the modern scientific perspective on the universe and the natural world.

Therefore, in order for pupils to acquire scientific knowledge in an efficient manner, misconceptions, which are cognitive structures that are subject to alteration, must be addressed. In the words of Keeley (2012), a learner will hold onto a misconception more tenaciously the longer it goes unanswered. However, this does not imply that simply correcting children would eliminate misconceptions. As was previously mentioned, misconceptions can be significant. It is crucial to create instructional experiences that will challenge students' thinking and lead them through a process of conceptual change that will enable them to voluntarily give up the misconception, rather than trying to "fix" learners by correcting their incorrect beliefs right away.

#### **2.4.5 Identifying Students' Misconceptions**

To measure and identify students' misconception in several science concepts, various diagnostic tests have been developed and used. These include interview, open-ended questions, multiple-choice questions, and multiple-tier tests, thus, two-tier, three-tier and four tier tests (Appiah-Twumasi et al., 2021; Soeharto et al., 2019; Verkade et al., 2017).

##### **Interview**

In order to fully comprehend students' cognitive knowledge frameworks, researchers often employ interviews as one of the numerous methods to spot misconceptions. According to Shin et al. (2016), interviews can be used to translate students' responses or answers so that they can be examined and categorised in accordance with pertinent scientific notions. It is possible to apply a variety of interviewing strategies, including interviews for remedial learning (Kusairi et al., 2017), individual and group interviews (Fontana & Prokos, 2016),

and interviews that serve as a complement to tests with multiple-tiered questions (Linenberger & Bretz, 2015; Mutlu & Sesen, 2015; Murti & Aminah, 2019).

Finding out what students believe, what is on their minds, and how they feel about a subject are the main goals of interviews rather than obtaining responses to specific questions (Seidman, 2006). Interviewing is the most efficient technique to uncover students' misconceptions when it is done correctly, as Gurel et al. (2015) explained. Additionally, they advise combining interviews with other examinations, such as multiple-choice examinations, to improve the research tool. Even while conducting an interview has several benefits for gathering information, it takes a lot of time and requires special skills for the researcher. Also, because data analysis will be a bit challenging and complex, interview bias may be present in research (Tongchai et al., 2009).

### **Open-Ended Tests**

The open-ended inquiry is a diagnostic technique that can be used to ascertain students' knowledge in the investigation of students' conceptual understanding (Soeharto et al., 2019). This approach provides students the flexibility to think and express themselves in writing, but it can be challenging to assess the outcomes or responses due to linguistic difficulties and the tendency of students to write incomplete sentences when expressing their understanding (Baranowski & Weir, 2015). Krosnick (2018), supported this idea by highlighting that the open-ended test provides a number of benefits, including allowing students' to express their thoughts and limiting the number of responses they provide. However, there are some limitations associated with it, including challenges in interpreting

and analysing student responses, the need for specialised knowledge to obtain meaningful responses, the possibility of some responses being unimportant, and the possibility of biased responses if students do not comprehend the question.

### **Simple Multiple-Choice Tests**

Multiple-choice tests can also be used to diagnose students' misconceptions concerning a topic. Soeharto et al. (2019) summarise some benefits of multiple-choice tests and are enumerated as follows:

1. Multiple-choice tests allow researchers to make coverage of various topics in a relatively short time.
2. Multiple-choice tests are versatile and can be used at different levels of instruction.
3. Multiple-choice tests are objective in assessing answers and being reliable.
4. They are simple and faster to score.
5. They are suitable for students who have a good understanding but inadequate to write.
6. They are ideal for item analysis where various variables can be determined for the analysis process.
7. They are valuable in assessing students' misconceptions and can be used on a large scale.

The fundamental challenge with multiple-choice tests is that it might be challenging to ascertain pupils' genuine knowledge if items are not thoughtfully prepared. Additionally, students could be inclined to guess, which can lead to errors on variances and undermine

reliability. Moreso, choices do not give students any insight into or knowledge of their concepts (Soeharto et al., 2019).

### **Two-Tier Multiple-Choice Test**

Two-tier tests are diagnostic tools that have a first tier of multiple-choice questions and a second layer of reasons that work with the first tier's multiple-choice questions (Appiah-Twumasi et al., 2021). If the answer options for the contents and justifications are accurate, the students' responses are considered to be correct. According to Soeharto et al. (2019), by employing two-tier tests, researchers can even find students' answers that have not been thought of before. They are also more practical to be used by researchers in various ways such as reducing guesses, large-scale use, ease of scoring, and giving explanations regarding students' reasoning. However, in the opinion of Gurel et al. (2017), two-tier examinations might offer a false alternative concept, although it is unclear if students' mistakes are the result of misinterpretations or extraneous words that make the questions difficult to read on the test. Also, Vitharana (2015) revealed that two-tier tests' choice of answers may help students determine which are the right ones. The answer options for misconceptions are logically related to the reason; for instance, students can select answers from the second tier because they must be related to answers to first-tier questions, or a portion of the two-tier test can offer interrelated and partially correct responses, making it simpler for them to select the correct response using this reasoning. Due to this, a number of recent studies have used a three-tier and four-tier test to identify misconceptions among students when learning science (Soeharto et al., 2019).

### **Three-Tier Multiple-Choice Test**

In three-tier multiple-choice test, the first tier is the simple multiple choice step, the second tier is the possible reasons of the given answer for the first tier, and the third tier is the confidence step for the first two tiers (Soeharto et al., 2019). Thus, students' answers to each question item are considered correct when if the answers of the first is accurate and equipped with reason with advanced confidence in the second and third tier respectively, and vice versa. According to Soeharto et al., the level of confidence is only used in answer options that are related to reasoning, therefore there is a chance that the proportions of knowledge in the student's answers will be overestimated. This is one of the downsides of three-tier assessments. Due to this, four-tier examinations that offer a level of confidence in the reasoning and content are now being developed and introduced.

### **Four-Tier Multiple-Choice Test and Multi-Tier Test**

The three-tier examinations still have certain drawbacks because of the limits in converting confidence ratings on the first and second tier, while being recognised legitimate and trustworthy in measuring students' misconceptions. Due to this condition, there are two issues that arise: First, the level of knowledge is too low; and, second, estimates of the number of students' misconceptions and accurate responses are overly generous (Soeharto et al., 2019). These restrictions were removed with the development of the four-tier multiple-choice tests. Nevertheless, they require quite a long time for the testing process and is quite difficult to use in achievement tests; also, the possible choice of students' answers at the first level can influence responses at the next tier questions (Ammase et al., 2019).

## 2.5 Conceptual Change

Once a misconception has been identified and the student made aware, the onus is now on the student to put in much effort for changing the misconception, as suggested by Verkade et al., (2017). However, through this learning process, the student can be helped and guided (Kalpana, 2014). The most commonly recognised model for assisting in the correction of misconceptions is described by conceptual change theory. It makes the argument that prior knowledge and previously held ideas must be critically analysed, changed, and replaced with new, accurate information in order for conceptual learning to be successful (Verkade et al., 2017). According to Heddy et al. (2018), students experience conceptual change when they go from a misconception to one that is supported by science. Leonard et al. (2014) also define conceptual change as learning that necessitates a learner's conceptual framework be fundamentally restructured in order to transition from nonscientific conceptions to conceptions that are congruent with scientific understanding. The concept of conceptual change was first applied in education as a means of considering how discipline subjects like Physics (Posner et al., 1982) and Biology (Carey, 2000) should be learned. To Posner et al. (1982), for a conceptual change to occur, these conditions must be met;

**There must be dissatisfaction with existing conception:** Before they are certain that less drastic alterations won't work, scientists are unwilling to make significant adjustments to their concepts. Therefore, it is logical to assume that a person must have accumulated a store of unsolved riddles or anomalies and lost faith in the ability of his current notions to

handle these difficulties before they may outright shift a preexisting concept for a new one (Strike & Posner, 1982).

**A new conception must be intelligible:** The person must be able to comprehend a new concept's ability to shape experience well enough to explore the possibilities it holds. According to Heddy et al. (2018), if students fail to understand a lesson, they could stop participating in the conceptual change process right away and stick to their original misconception.

**A new concept must appear initially plausible:** Heddy et al. (2018) explain plausibility as the subjective assessment of a person regarding the possible veracity of a message. In other words, the outcome of the concept's congruence with another piece of information. For instance, if a new theory in astronomy contradicts existing physical understanding or lacks a convincing physical explanation, it is less likely to be accepted.

**A new concept should suggest the possibility of a fruitful research programme:** This means that the new concept need to be better able to address issues or anticipate events than the current concept. Therefore, in an instruction, when the teacher aims to bring about conceptual change in the students, these four conditions must be met in order for conceptual change to occur. Learner engagement is one construct that has been demonstrated to be particularly significant in facilitating conceptual change (Heddy et al., 2018). As a result, it is the teacher's responsibility to engage the students in by employing teaching methods and strategies that might facilitate conceptual change to occur. According to Widiyatmoko

and Shimizu (2018), overcoming misconceptions require teaching strategies which provide chances for students to reveal their pre-concepts and dissatisfaction with their concepts. Nevertheless, Appiah-Twumasi et al. (2021) suggest that the instructor has an obligation to be cognizant of the ideas of the students and to provide instruction in a manner that will hopefully encourage students to modify their conceptions.

By identifying students' misconceptions held on some concepts, the teacher can adopt various formative assessment techniques. One major form of formative assessment is a diagnostic test (Keeley, 2012). When the teacher alters or adapts their course to help students develop conceptual knowledge, that is when diagnostic assessment transforms into formative assessment. This is the heart of formative assessment, where the emphasis is on instructional and conceptual transformation rather than simply pointing out misunderstandings.

## **2.6 The Concept of Gender**

Gender, according to Istratii (2017), was introduced within development discourse to differentiate the socially constructed status, roles, and responsibilities of male and female from their biologically sexed anatomies. Gender is a social construct that is culturally specific and subject to change. Gender and sex are frequently used interchangeably (Blackstone, 2003). However, according to Rolleri (2013), while gender and sex are related, gender itself is distinct from sex, which describes the biological and physiological differences among males, females, and intersex individuals, including variations in chromosomes, hormones, and reproductive organs.

Since gender is a social concept, it is therefore important to understand that male and female groups shoulder responsibilities which are expected of them by the society. However, these responsibilities or roles are learned and therefore modifiable (Istratii, 2017) . For example, in some societies, it is expected of the male gender to undertake all physically and mentally difficult tasks such as washing of car, farming, reading programmes like engineering, medicine, among others, while the female is expected to partake in activities that do not need enough physical and mental skills like washing, cooking, cleaning, as well as reading programmes such as English, nursing, and programmes related to the social sciences. But this notion is modifiable, which means that societies can lean towards a paradigm where males and females can have equal access to resources and also share equal outcomes.

According to the USAID (2008), equality of educational outcomes is when girls and boys have equal opportunity to succeed and their educational accomplishments are determined by their unique abilities and efforts. Thus, the duration of a person's school career, their academic credentials, and their certificates should not vary depending on being male or female, with the aim to provide equal opportunities for success. Procedures for assessing personal accomplishment must be impartial towards gender. The things that examinations, assessments, and tests evaluate and communicate to students what is important, and to the degree that these processes exhibit gender bias, they send messages to students that may deter them from being interested in learning or in specific subjects. Therefore, the outcomes of assessments conducted nationally and internationally, as well as classroom examinations, can have an impact on how confident boys and girls feel about themselves,

their talents, and what is expected of them. They may also have an effect on the curriculum and methods of instruction used in the classroom.

### **2.6.1 Gender and Students' Performances in Physics**

Studies have been reported in literature concerning students' gender and their academic performances in Physics. These studies report mixed evidence where in some instances males dominate, while females dominate other instances. For example, Acar et al. (2015) in their study found that Turkish 8<sup>th</sup> graders Physics students had significant difference between male and female students in their conceptual knowledge ( $F(1, 44) = 12.65, p = 0.00$ ), with females performing better (mean=8.20, SD=2.04) than males (mean=6.35, SD=1.50).

On the contrary, according to Barasa et al. (2015), who conducted a study in Tinderet Sub-County, in Kenya using students from three different school categories which included single-sex boys school, single-sex girls school, and coeducational schools. An Analysis of Variance revealed significant difference in the distribution of scores from a Physics Achievement test between male and female students. Barasa et al. discovered that male students had a higher mean score of 12.41(SD=3.938) than girls (mean=9.01, SD=1.696). This, to Barasa et al., implies that males performed better than females in the Physics Achievement test.

Similarly, Appiah-Twumasi et al. (2021) conducted research in Ghana where they used two-tier test instrument to assess students' misconceptions about heat and temperature. The

authors discovered a significant difference ( $F = 4.541$   $p = 0.038 < 0.05$ ) between males and females (Males,  $M = 8.75$ ,  $SD = 2.67$ ; Females,  $M = 8.00$ ,  $SD = 2.37$ ) on their misconceptions about heat and temperature concepts, implying that females showed major misconceptions about heat and temperature concepts than males did.

In another research conducted by Olufunke et al. (2022) in secondary schools in Ondo State, Nigeria, using students from three different school categories which were single-sex boys school, single-sex girls school, and coeducational schools, the researchers found no significant influence of gender on students' achievement in Physics. Olufunke et al. revealed that there was no significant difference in the pre-test and post-test achievement mean scores of male and female students exposed to Physics concepts among the three groups ( $F_{2, 131} = 2.495$ ,  $p = 0.086 > 0.05$ ). Similarly, the main effect of gender on students' achievement in Physics was not significant at 0.05 level of significance ( $F_{1, 131} = 0.248$ ,  $p = 0.619 > 0.05$ ). Therefore, Olufunke et al. concluded that gender had no significant influence on students' achievement in Physics.

## **2.7 The Concept of Electronics**

Electronics, according to Atsumbe et al. (2018), examines the movement and management of electrons as well as their behavior and impacts in semiconductors, gases, vacuums, and other environments where they are used in devices. Kola and Akintunde (2014) also added that, the study of Electronics involves the analysis of electrons and the application of their principles in different contexts. The concept of Electronics refers to what links to the electron, which is one of the essential particles of atoms. The controlling of the electrons

is done by devices, called electronic components, are responsible for resisting, carrying, selecting, steering, switching, storing, manipulating, and exploiting electrons. In addition, the fields of optoelectronics, quantum electronics, microelectronics, and nanoelectronics are included in the umbrella of electronics since they deal with the creation and use of electronic devices at optic, quantum, microscopic, and nanoscopic sizes (Ministry of Education, Singapore, 2017).

According to Chen et al. (2013), many facets of contemporary society and culture, including communication, entertainment, education, health care, business, and security are significantly impacted by Electronics. The semiconductor industry, which creates the fundamental materials and components for electronic devices and circuits, is the primary driver behind the growth of Electronics. Any part, whether active or passive, that is a part of an electronic system is called an electronic component. Capacitors, inductors, and resistors are examples of passive electronic components. On the other hand, semiconductor devices like transistors and thyristors, which regulate current flow at the electron level, are examples of active components. Some concepts studied under Electronics include direct current (DC), alternating current (AC), charge, voltage, diode, conductors, semi-conductors, insulators, resistance, capacitance, current, inductance, and impedance, p-n junction, and amplifiers (Chen et al., 2013).

### **2.7.1 Students' Difficulties in Electronics**

Students have been reported to demonstrate various difficulties in Electronics. For example, Karaarslan and Çetin (2018) explored students' misconceptions using open-

ended questionnaires, in electrical and Electronics engineering department in Turkey and discovered that students were unable to construct any semantic relations and had only memorized that semi-conductor materials—which are ordinarily non-conductors—become conductors when energy is supplied. According to Karaarslan and Çetin the misconception rate was 48% of 120 students.

Also, Nelson et al. (2017) found in Georgia that from three introductory circuits course sections taught in the electrical engineering department at a large university in the Southwestern United States, out of 41 students, students demonstrated misconceptions in some concepts related to semi-conductors namely; diffusion (87%), drift (75%), and excitation (80%). Furthermore, Pérez (2021) reported misconceptions exhibited by sophomore engineering students, as students conceived a capacitor as always operating as an open circuit.

In Ghana, Yuoni (2018) revealed that in junior high schools, some of the students had some misconceptions about basic Electronics. For instance, they mentioned that the voltages used at this level are low and are not likely to cause fire or any harm to the students. These challenges Physics students encounter is reflected in their external examinations. For example, according to the Physics chief examiners from WAEC, “candidates could not list the advantages of p-n junction diode over diode valves” (WAEC, 2017). They speculated that “it appeared semiconductors were not treated by most candidates”. Also, few candidates gave the correct answer to questions relating to intrinsic semiconductor, as well as difference between p-type and n-type semiconductors (WAEC, 2018). Again, few

candidates were able to use the band theory to explain why electrical resistance of a semiconductor decreases with increase in temperature (WAEC, 2020). In 2021, according to WAEC (2021), “candidates could not state the function of (i) low voltage battery and (ii) high tension source, as a component of an X-ray tube”. Further, “candidates were not able to state the reasons for the design features of an X-ray tube”. A read-through of the chief examiners' reports identified that candidates could only answer questions pertaining to Electronics in 2019 (WAEC, 2019).

## **2.8 Empirical Review of ADDIE Instructional Design Model on Students' Academic Performances**

In an attempt to mitigate the abysmal performance of Physics students in Physics, though limited, studies have been conducted to investigate the effect of employing ADDIE Instructional model as an instructional method, on students' academic performances in diverse learning environments. For instance, Vijayakumar and Srinivasan (2015), by employing a true experimental design, investigated the effect of the ADDIE model by integrating technology for teaching argumentative writing at the tertiary level in B.S. Abdur Rahman University, India, using 32 Mechanical Engineering-B section. Using paired sample t-test to analyse the scores of both experimental (exposed to ADDIE model) and control groups (exposed to conventional teaching method), Vijayakumar and Srinivasan (2015), found that the control group had a non-significant increase in mean ( $p=0.114>0.05$ ) from 4.12 (SD=1.02) of the pretest scores to 4.71 (SD=1.03) of the posttest scores. Also, the experimental group had a significant mean increase ( $p=0.001<0.05$ ) from

4.37(SD=0.97) to 7.03 (SD=0.88). Therefore, according to Vijayakumar and Srinivasan, ADDIE model enhanced students' argumentative writing.

Asuncion (2016) conducted a study in the Philippines using sophomore bachelor's degree students in elementary education. The study employed a quasi-experimental single group pretest/posttest design using 107 students. A paired sample t-test analysis revealed that the ADDIE when used in developing multimedia projects enhanced the performance of the respondents in Educational Technology. Specifically, before exposure to ADDIE model, students obtained a pretest mean score of 64.98, while after exposure to ADDIE model, students obtained a posttest mean score of 82.84. This difference, according to Asuncion was statistically significant a t-value of 23.28 at  $p=0.00$ .

In Ghana, Sarkodie (2023) also added reflection stage to both ASSURE and ADDIE models to highlight the importance of reflection processes in instructional processes, thereby transforming ASSURE to ASSURE-R and ADDIE to ADDIE-R. These models were comparatively studied to determine their relative efficacy on final-year Technical University hospitality students in Sunyani. The study employed a pretest/posttest experimental design using 40 students who were randomly sampled, and divided evenly to the two groups. In this study, both groups were taught at different times using the conventional teaching method, after which they were subjected respectively to ADDIE-R and ASSURE-R treatments. A paired sample t-test for the ADDIE-R group revealed a significant difference ( $t=-2.625$ ,  $p=0.017$ ) between the control class test scores (mean=65.50, SD=11.91) and experimental class test scores (mean=77.75, SD=12.08) of

students, with an effect size of 0.266 indicating a large effect size. The implication is that the ADDIE model with reflection aided in improving students' academic performances. With the gender perspective, no study has been reported in the literature on the effect of ADDIE model on male and female students.

## **2.9 Summary of Literature Review**

From the literature review, it could be summarised that the theoretical underpinning by employing ADDIE Instructional model as used in this study is constructivism. Teachers who adhere to this philosophy advocate that students learn best when they are given opportunities to practice through diverse activities, what they learn in the classroom. As a result, any misconception taken to the classroom are changed. Also, the literature review revealed that Physics students globally exhibit conceptual difficulties as well as misconceptions in Electronics. But research has shown that the ADDIE Instructional model, which is a student-centered instructional method, can enhance students' academic performances. This is due to the fact that students do not learn by memorizing concepts, but learn to apply them in order to discover the scientific truth and reasoning behind every principle.

Also, there were some gaps that were revealed from the literature. First, there are limited research studies that have been conducted by employing ADDIE model as a teaching method in the classroom to improve students' learning outcomes. Moreover, none has been reported to be in the field of Physics. Also, among these studies, only a single study has been reported to be conducted in Ghana which used technical university students. But none

exists in Ghana, which used senior high school students in the Ahafo Region of Ghana. Further, none of the literature reviewed statistically controlled for gender in an attempt to ascertain the effect of ADDIE instructional design model on male and female students' academic performances in Physics.

## **CHAPTER THREE**

### **METHODOLOGY**

#### **3.0 Overview**

This chapter outlines the research's study area. Additionally, it outlines the research paradigm and corresponding design employed to collect data. The chapter goes on to describe the population, sample and sampling methods that were utilized to determine the study's sample size. The research instruments for data collection, their validity and reliability are also thoroughly described in this chapter. The procedures of collecting data and subsequent analyses of the data collected wrap up the chapter.

#### **3.1 Study Area**

In Ghana's Ahafo Region, there are six districts/municipals, including Tano North Municipal District, where this study was conducted. Prior to the western part of the district being divided off to become Tano North District in December 2004, it was a part of the then-larger Tano District, which was first established in 1988, with the remaining part of the district being renamed Tano South District. In April 2018, Tano North District gained the rank of municipal assembly and was renamed Tano North Municipal. The municipality's capital town is Duayaw-Nkwanta, and it is situated in the eastern portion of the Ahafo Region in Ghana. (Tano North Municipal Assembly, 2019).

Major towns within the municipal include; Adrobaa, Bomaa, Duayaw Nkwanta, Subompong, Susuanso, Terchire, and Yamfo. The Tano North Municipal is divided into 4

school Circuits namely; Bomaa, Yamfo, Terchire and Duayaw-Nkwanta. Basic education is widespread in the municipality. The municipality has a total of three hundred public and private schools, 68 kindergartens, 69 primary schools, 67 junior high schools, 86 private basic schools, 5 senior high schools, 1 vocational school, 3 nursing training schools, , and 1 medical assistant training school at Yamfo (Tano North Municipal Assembly, 2019).

### **3.2 Research Paradigm**

According to the Merriam-Webster Dictionary (2023), a paradigm is “a philosophical and theoretical framework of a scientific school or discipline within which theories, laws, and generalizations and the experiments performed in support of them are formulated.”<sup>1</sup> As applied in the context of research, a research paradigm is a worldview or philosophical framework, including ideas, beliefs, and biases, that guides the research process. That is by choosing a particular paradigm in a given study, what should be studied, how research should be done, and how results should be interpreted, are all influenced (Siddiqui, 2019). A paradigm, according to Siddiqui, thus, denotes the philosophical stances of researchers on the nature of an object, what can be known, and how this knowledge may be obtained. In other words, a paradigm guides a researcher to know how an investigation ought to be conducted (methodology), as well as their definitions of truth and reality (ontology), and how the investigator ascertains that reality or truth (epistemology) (Boru, 2018). According to Creswell (2014), positivism, post-positivism, interpretivism, pragmatism, constructivism, and transformative paradigms are the paradigms that exist in educational research. This study however, was designed to operate in the realm of pragmatism.

The pragmatist school of thought, according to Kaushik and Walsh (2019), holds the unusual conviction that human interaction is the only means of experiencing reality, which has its roots in the environment and exists outside of human perception. Pragmatists question the possibility of establishing reality once and for all. They contend that knowledge claims cannot be entirely dissociated from contingent assumptions, routines, and experiences. Therefore, according to Migiro and Magangi (2011), pragmatism as a philosophy includes the use of induction (or identifying patterns or learning the meanings that people ascribe to events, getting a deeper comprehension of the context of the investigation, and gathering qualitative data), deduction (moving from theory to data, the collection of quantitative data, testing of theories and hypotheses, elucidating causal links between variables, and the selection of adequate sample sizes in order to extrapolate conclusions), and abduction (selecting and relying on the most plausible explanation from a range of options to help one comprehend their outcome). This means that operating from the pragmatism point of view suggests that it is possible to combine different approaches to research (quantitative and qualitative), and by so doing the researcher will gain a more thorough understanding of the research problem.

### **3.3 Research Design**

Research design is the conceptual blueprint within which research is conducted. A scholar for his research, prepares an action plan, which constitutes the outline of the collection, measurement, and analysis of data. Khanday (2019) The purpose of using a particular research design is to make sure that the data collected by the researcher allows them to answer the research topic as clearly and rationally as possible. Thus, according to Thakur

(2021), decisions regarding what, where, when, how much, and by what means concerning a research study constitute a research design. Thakur further explains that the design of a study defines the study type (descriptive, correlational, quasi-experimental, experimental, action research, systematic review, meta-analysis), data collection methods, and a statistical analyses plan. Therefore, the purpose of a research design is to guarantee that the data collected enables the researcher to approach the research problem as clearly and logically (Thakur, 2021). Connecting the ideas of pragmatism, this study employed the design-based research (DBR) methodology.

The goal of the DBR methodology, which was created by and for educators (Easterday et al., 2014), is to enhance practice by maximising the impact, transfer, and translation of education research (Anderson & Shattuck, 2012), while assisting in the creation of prototype solutions to address difficult, real-world problems that are context-specific, and also emphasising the necessity of developing and testing design ideas and theories that direct, enlighten, and enhance research and practice in educational settings (Alghamdi, 2013). Therefore, in relation to the context of this study, SHS Physics students' misconceptions in Electronics were identified, and an intervention, using ADDIE model, based on the constructivism theory of learning, was designed to address the challenge. In this way, DBR is centered on analysing a specific intervention through the cycle of design, implementation, analysis, and redesign (Zheng, 2015). The intervention, according to Zheng (2015), can be a technological one, such as evaluating the efficacy of a certain learning environment or tool, or it can be an instructional strategy, kind of assessment, learning activity, or combination of these. Through the design of innovations, educators

can establish productive learning situations that learning theory recommends, which are not widely used or poorly understood (Hoadley et al., 2003). Such is the case of the ADDIE model which has not been widely used as a pedagogical methodology during the teaching and learning activities.

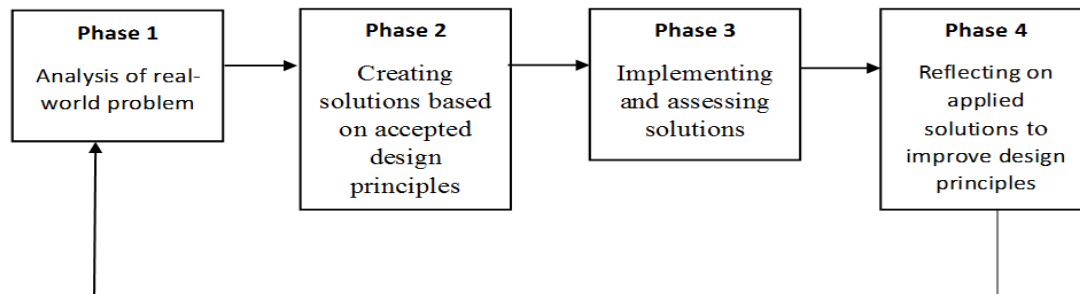
Within this DBR, quantitative and qualitative data were concurrently collected and analysed in order to understand a research question more completely. When used in combination in one study, Migiro and Magangi (2011) highlighted that quantitative and qualitative methods complement each other and allow for a more complete analysis of the research problem. That is, the “what” (quantitative) aspect, and the “how” or “why” (qualitative) aspects of research questions are answered (Siddiqui, 2019).

Therefore, research questions 1 and 2 were answered by collecting both quantitative and qualitative data. This combination allowed for a deeper exploration of the research questions that allowed for complementarity, and provided a holistic understanding regarding the challenges students encounter in the study of Electronics. The quantitative data for research questions 1 and 2 were collected using achievement test, while the qualitative data was collected using a semi-structured interview. However, research question 3 was answered using only quantitative data through an achievement test.

### **3.3.1 Overall Study Design**

The DBR process adopted from Felton et al. (2023) for this study involved four phases as shown in Figure 3.1, which are; analyzing the issue using the body of current knowledge

and the researcher's own practical experience; putting up a conceptual model for creating solutions based on accepted design principles; applying and assessing solutions in real-world situations; and thinking back or reflecting on execution to improve design principles.



**Figure 3.1: A framework of the DBR employed in the study (Adopted from Felton et al., 2023).**

The first stage in the DBR process employed in this study was to identify, understand and define the problem perceived as critical in an everyday teaching situation, which was SHS Physics students' misconceptions in Electronics. In collaboration with practitioners, every facet of the problem was carefully examined to determine the appropriate context for implementing a solution. Informed by the analysis and exploration of the identified problem, phase 2 which was aimed at designing and constructing the intervention began. This process, which followed the ADDIE model, included designing of tools and materials which were used during instructional sections, as well as instruments (achievement test and interview guide) for collecting data. After designing the intervention which aimed to provide solution to the problem under research, the tools and materials were implemented using intact classes during classroom lessons at Phase 3. At the same Phase (Phase 3), the

intervention was subsequently evaluated through conduction of the achievement test and an interview guide to provide a comprehensive understanding of the effectiveness of the intervention. At Phase 4, the whole process was reflected upon which helped to make connections between actions and results.

### **3.4 Population**

According to Martínez-Mesa et al. (2014), a population is the set of people who are limited to a given area (such as a neighbourhood, state, city, nation, or continent) or set of institutions (such as hospitals, schools, or businesses). That is, a group of people who share one or more characteristics. Within a population is found the target population, which refers to the subjects that one hopes to make conclusions about, and an accessible population which will actually be part of the study, be evaluated and will allow conclusions to be drawn about the target population, as long as it is characteristic of the target population (Creswell, 2014; Martínez-Mesa et al., 2014). In this study, the target population consisted of all SHS Physics students in the Tano North Municipality. However, the accessible population comprised of all SHS 3 Physics students in the Tano North Municipality. This is because, the “Electronics” concepts considered in this study is studied in SHS 3, according to the Ministry of Education (2010) syllabus.

### **3.5 Sample and Sampling Technique**

Creswell (2012) defines a sample as a subgroup of the target population that the researcher plans to study to make generalisations about the target population. However, according to Creswell, the sample must be an accurate representation of the target population and have

the same traits. In doing so, the researcher used a sampling technique method. According to Creswell (2012), sampling is the process of taking a representative sample from a population. To select a representative sample from a population, however, the researcher can either use probabilistic sampling or non-probabilistic sampling. In probabilistic sampling, every member of the population has an equal chance of being selected for the sample (Peers, 2006). This includes; simple random sampling, systematic sampling, stratified random sampling, and cluster sampling. However, in a non-probabilistic sampling, some sections of the population may not have some chance to be represented. Thus, the researcher selects the samples deliberately. Examples are snowball sampling, purposive sampling, quota sampling, and convenience sampling. According to Creswell (2012), if a researcher is to use a particular sampling procedure, that will depend on the sample size, statistical analysis to conduct on the sample, research design, population diversity, etc.

In this study, multi-stage sampling was used. That is, simple random sampling was used to select two (2) SHSs. Out of the two (2) selected SHSs, simple random sampling was employed to select one intact class from each school, since there was more than one Physics intact class in each school. There were two physics intact classes in the first participating school and three intact classes in the second school. Also, using an identical sample, that is, participants who were used in the quantitative phase, twelve (12) students were selected using stratified random sampling (six students from each group), consisting of three males and females each for the qualitative component of the study, as recommended by Onwuegbuzie and Collins (2007). The employment of stratified random sampling was to

ensure that the participants for the qualitative interview would consist of an equal number of males and females.

### **3.6 Research Instruments**

Research instruments are the tools that help a researcher to collect appropriate data that would answer the specific research questions in a study (Creswell, 2014). These include test, questionnaires, interview guides, observation checklists, etc. However, the choice of a particular research instrument depends on the type of research questions the researcher seeks to answer. In this study, by gathering qualitative and quantitative data, an Electronics Concept Test (ECT) and a semi-structured interview guide were used.

#### **3.6.1 Electronics Concepts Test (ECT)**

The ECT was prepared by the researcher and sought to determine the misconceptions and conceptual change of students in Electronics concept before and after exposure to ADDIE model. The ECT (see Appendix A) consisted of 10 essay-type items, where students provided in-depth explanations to each item. This therefore put strong emphasis on students' abilities to demonstrate conceptual change after the intervention. The following areas of Electronics were selected to test students' misconceptions and conceptual understanding of Electronics as presented in Table 3.1.

**Table 3.1: ECT and Content Selection**

Concept	Questions
Capacitors and Transistors	Explain why a transistor possesses a thin base.
Conductors, Insulators and semi-conductors	<p>Explain the effect of temperature on the conductivity of conductors.</p> <p>What is the effect of temperature on the resistivity of conductors?</p> <p>Why does conductivity increase with temperature in semi-conductors?</p> <p>Explain why there is a wider forbidden band in insulators.</p> <p>Explain what happens when a semiconductor is doped with impurities.</p> <p>Why is the conduction band described as the highest energy band in a solid?</p> <p>Explain why the valence band can be described as the lowest energy band in a solid.</p> <p>How can normal temperature affect the conductivity of an insulator such as polythene?</p>
P-N Junction diode and Rectification	What is the effect of forward-biasing a Light Emitting Diode?

ECT and content selection (Ministry of Education, physics syllabus; 2010)

### 3.6.2 Interview Guide

The interview guide prepared by the researcher aimed to determine qualitatively, the misconceptions students exhibit in the concept of Electronics. The interview guide contained five (5) open-ended items sampled from the ECT items (see Appendix B), where

students were given the freedom to express their opinions and reasons for those misconceptions and difficulties. The items selected for the interview were items 1, 3, 6 and 10 from the ECT representing the items where greatest, moderate, and least percentage of students demonstrated misconceptions.

### **3.7 Validity of Instruments**

The validity of an instrument determines that the tool accurately measures what it is intended to measure (Appiah-Twumasi et al., 2022). Therefore, to determine the validity of the research instruments, the interview guide, and ECT were given to experts in the field of Physics and Science Education to determine the appropriateness of each item on the instruments. The experts critiqued the items after which modifications were made for subsequent piloting.

### **3.8 Pilot Testing of Instruments**

The ECT was piloted in order to determine the reliability of the scores of the instruments. The pilot test of the instrument was therefore conducted in an SHS within the Tano South Municipality using third year Physics students, who shared similar characteristics with the research participants, but did not take part in the main study. Third year Physics students were used because they had studied Electronics and were therefore the appropriate participants to answer the questions on the instruments. According to Johanson and Brooks (2010), thirty (30) representative participants from the population of interest is a reasonable minimum recommendation for a pilot study where the purpose is preliminary survey or

scale development. As a result, the number of Physics students who took part in the pilot study were 45 out of which twenty-four (24) were males and twenty-one (21) were females.

### **3.9 Reliability of Research Instruments**

Reliability, according to Cohen et al. (2018), concerns the degree of confidence that can be placed in the results and the data. In other words, the extent to which a measure yields the same scores across different times, groups of people, or versions of the instrument. Reliability is therefore about consistency (VanderStoep & Johnston, 2009). To determine the reliability of the ECT, the scores from the pilot test were computed, and the internal consistency of scores, specifically, inter-rater reliability, using Cohen's kappa, was determined.

#### **3.9.1 Internal Consistency of ECT**

The internal consistency of the ECT was determined using Kappa's measure of agreement. Table 3.2 shows the interpretations of various ranges suggested by Mchugh (2012).

**Table 3.2: Interpretation of values of Internal Consistency of ECT**

<b>Range</b>	<b>Interpretation</b>
Less than 0	No agreement
0.01 – 0.2	None to slight
0.21 – 0.40	Fair
0.42 – 0.60	Moderate
0.61 – 0.80	Substantial
0.82 – 1.00	Agreement

In this study, the value of Kappa's measure of agreement as seen from Table 3.3 is 0.720, which is a substantial agreement, as per Mchugh. Therefore, the ECT was deemed reliable to be used.

**Table 3.3: Internal Consistency of CCT**

		<b>Value</b>	<b>P</b>
Measure of Agreement	Kappa	.720	.000
N of Valid Cases		45	

### **3.10 Data Collection Procedure**

In this study, both qualitative and quantitative data were gathered. The study entailed the collection of a wide range of data on students' conceptions at different stages to make inference on the change process. The data collection process was done in three stages. These are pre-intervention stage, intervention stage, and post-intervention stage.

#### **3.10.1 Pre-intervention Stage**

This is the first stage of the data collection process, and during this stage, official permissions were sought from heads of various schools that were selected for the study. The Physics teachers and various heads of departments were also informed, and their consent was sought. The benefits and uses of the results of this study were explained to school authorities, various Physics teachers, and students from sampled schools while assuring them of the confidentiality of the results and information provided by the students. The study was carried out when there were no significant activities taking place in the schools. The sampled schools were then visited for familiarisation with students and the conduction of the pretest to identify the misconceptions students hold about Electronics

before the intervention. After the conduction of the pretest, 12 students were sampled for a semi-structured interview to understand comprehensively the misconceptions students hold and the reasons for their misconceptions. Students' permissions were sought for their voices to be recorded for further transcription and analysis.

### 3.10.2 Intervention Stage

This is the second stage of the data collection process, and at this stage the implementation of ADDIE model occurred. The intervention stage lasted for a period of four (4) weeks. Table 3.4 provides a summary of the various contents that were covered during the research.

**Table 3.4: Content of Electronics Taught to Experimental and Control Groups**

Period	Content Taught
Week 1	Electronic components and circuit diagrams
Week 2	Capacitors and Transistors
Week 3	Conductors, Insulators and Semi-conductors
Week 4	P-N junction diode and rectification

#### 3.10.2.1 Intervention Activities

Students were exposed to ADDIE instructional model during the teaching and learning of Electronics concepts. Table 3.4 highlights how the ADDIE model was implemented.

**Table 3.5: Intervention Activities**

STAGE	ACTIVITIES
Stage 1 Analyse	Determining of students' strengths and weaknesses based on their previous knowledge of the lesson objectives.
Stage 2 Design	Designing and planning of instructional tasks and activities, as well as materials, to be given to the students.
Stage 3 Develop	Development of materials which were to be used by students during classroom activities. Example; transistors, capacitors, resistors, LED, and videos of how to construct some basic electronic components, and how these components work.
Stage 4 Implement	Presentation of the lesson to students characterised by active involvement of the students.
Stage 5 Evaluate	Using both formative and summative assessment techniques to determine the achievement of lesson objectives.

### *Analyse*

The analyse stage was characterised by examining students' previous knowledge based on the lesson objectives in order to determine the misconceptions students hold in the concepts of Electronics. This was done using a 10-item essay type test where students were required to answer on sheets of paper. After completing the test, the researcher collected the scripts of the students and marked them to determine students' misconceptions.

### *Design*

Based on students' responses in the essay type test during the analysis stage, the researcher designed and planned instructional tasks and activities, as well as materials, to be given to

the students. Lesson objectives were also identified including specific skills and knowledge the researcher wanted students to obtain based on the misconceptions exhibited by students during the analysis stage. For example, by the end of the lesson, students will be able to;

1. Explain the effect of temperature on the conductivity of conductors.
2. Explain what happens when a semiconductor is doped with impurities.
3. Explain how normal temperature affects the conductivity of an insulator such as polythene.

### ***Develop***

At this stage, the researcher gathered and developed the materials which were to be used by students during the classroom activities. Example; transistors, capacitors, resistors, LED, and videos of how these and other basic electronic components work.

### ***Implementation***

At this stage, the researcher presented the lesson to students. Students were sometimes allowed to watch videos such as how temperature and doping affect the conductivity and resistivity of conductors, insulators and semiconductors, as well as practical applications of some electronic components such as Light Emitting Diode (LED). After watching the videos, they were given the opportunities to practice hands-on using the available components. During the activities, worksheets were given to students which contained instructions of which activities students were to undertake based on the lesson objectives. The researcher was available in person to offer needed assistance and guidance where necessary.

### ***Evaluate***

In order to assess whether the lesson objectives were achieved, the researcher used both formative and summative assessments to evaluate students based on the objectives stated at the design stage. Formatively, students were given similar essay type test as exercises and assignments after every lesson. The essay type test helped to determine whether there had been enhancement of conceptual understanding of the lesson objectives. However, the researcher conducted a summative evaluation test after completing the intervention stage.

#### **3.10.3 Post-Intervention Stage**

After the intervention stage, students were given one week to revise their notes, after which the posttest was conducted. The conduction of the posttest was done by the researcher with the help of Physics teachers from the various schools. Students were given 40 minutes to answer the test items.

#### **3.11 Data Analysis Procedure**

The data were analysed quantitatively and qualitatively. Quantitative data analyses involved descriptive analysis, while qualitative data analysis was done using content analysis. Specifically, descriptive statistics employed were frequencies and percentages of students' misconceptions demonstrated from the ECT. This was used to partially answer research questions 1 and 2, and to fully answer research question 3. By employing frequencies and percentages helped to identify the number of students demonstrating misconceptions and scientific understanding before and after the intervention.

Also qualitatively, content analysis was used to understand the context and deeper meaning behind students' answers to the items in the ECT, offering rich qualitative insights. This helped to comprehensively understand students' misconceptions in Electronics concepts

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.0 Overview

This chapter presents the distribution of the participants, results of the study, as well as the discussion of the results. The presentation of the results was done according to the research questions and research hypotheses. The data were analysed in terms of descriptive, inferential statistics, and thematic analysis.

#### 4.1 Distribution of Participants

The study was DBR action research where 101 participants from two intact classes were used. Among the 101 participants were 52 males and 49 females.

**Table 4.1: Distribution of participants' schools**

Participant schools	Male (N=52)	Female (N=49) (Years)	Age Range
School A	28	25	16-19
School B	24	24	17-20

#### 4.2 Results for Research Question 1

*What are the misconceptions among SHS Physics students in Electronics concepts?*

This research question aimed to determine the misconceptions SHS Physics students exhibit in Electronics concepts. Thus, it was answered quantitatively and qualitatively. Using students' answers from the Electronics Concepts Test, students' answers to each item were classified as misconceptions and scientific explanations. Specially, a student was

deemed to possess misconception if their answer contained incorrect information, misused terminology, or demonstrated flawed reasoning that is inconsistent with scientific principles on the electronics concept, while a student was adjudged to possess scientific understanding if their answer was accurate, demonstrated clear understanding and used correct terminology and logical reasoning. In addition, students who did not attempt to respond to an item that provided irrelevant or off-topic responses, or lacked coherence or any indication of concept knowledge were considered to demonstrate 'no understanding' of the concept. However, in this study, it was found that no student demonstrated 'no understanding' of an item. All students attempted each item, and their responses were scientifically accurate or inaccurate. Quantitatively, descriptive statistics, specifically, frequencies and percentages were used to determine the number of students having misconceptions on each item, while the qualitative analyses employed thematic analyses of specific misconceptions of students in Electronics concepts. Descriptive statistics of students' misconceptions on each item are presented in Table 4.2.

**Table 4.2: Descriptive Statistics of Students Misconceptions and Scientific Understanding on Electronics Concepts before Intervention**

Item No.	Item	NSEM (N=101)	%	Rank	NSHSU (N=101)	%	Rank
1	Explain the effect of temperature on the conductivity of conductors.	95	94.06	1	6	5.94	9
2	What is the effect of temperature on the resistivity of conductors?	73	72.28	9	28	27.72	2
3	Why does conductivity increase with temperature in semi-conductors?	80	79.21	5	21	20.79	5
4	Explain why there is a wider forbidden band in insulators.	81	80.20	4	20	19.80	7
5	Explain what happens when a semiconductor is doped with impurities.	79	78.22	6	22	21.78	6
6	Explain why a transistor possesses a thin base.	75	74.26	8	26	25.74	3
7	What is the effect of forward-biasing a Light Emitting Diode?	83	82.18	3	18	17.82	8
8	Why is the conduction band described as the highest energy band in a solid?	72	71.29	10	29	28.71	1
9	Explain why the valence band can be described as the lowest energy band in a solid.	76	75.25	7	25	24.75	4
10	How can temperature affect a polythene?	95	94.06	1	6	5.94	9

NSEM - Number of Students Exhibiting Misconception

NSHSU – Number of Students Having Scientific Understanding

Table 4.2 reveals that high percentages of students generally had misconceptions about all the items in the Electronics Concepts Test. This is because the percentage of students exhibiting misconceptions on all the items in the Electronics Concept Test ranged from 71.29% to 94.06%. It can be seen from Table 4.1 that a greater percentage of students (94.06%) exhibited misconceptions on items 1 and 10, while the lowest percentage of

students (71.29%) exhibited misconceptions on item 8. On the contrary, Table 4.1 reveals that students generally demonstrated low percentages of scientific understanding of Electronics concepts, with the percentage of students having scientific understanding of Electronics concepts ranging from 5.94% to 28.71%. The highest percentage of students (28.71%) demonstrated scientific understanding on item 8 while the lowest percentage of students demonstrated scientific understanding on items 1 and 10.

Content analysis of some misconceptions of students were also presented. Six students (comprising three males and three females) who were randomly sampled from each intact class were engaged in a semi-structured interview to examine deeply the ideas obtained in Electronics Concepts Test. The items selected for the interview were items 1, 3, 6 and 10, representing the items where greatest, moderate, and least percentage of students demonstrated misconceptions. Representative explanations of students from the interview are presented as follows.

### **Students' Misconceptions on item 1**

**Teacher:** Explain the effect of temperature on the conductivity of conductors.

**Common students' response:** During the interview session, students demonstrated misconceptions concerning this particular item. For instance, student **A** stated that:

*“Increasing the temperature of a conductor will always increase its conductivity.*

*This is because heat activates the electrons in the conductor, making them move more freely” (student A's interview transcript).*

**Identified Misconception:** Temperature increases conductivity of conductors

From the quote above, it could be seen that Student **A** could not explain that when temperature of a conductor is increased, atoms within the conductor vibrate faster at greater amplitude. As a result, the number of collisions between the vibrating electrons and free electrons increases. This causes a greater number of free electrons to reduce. Accordingly, student **A** failed to acknowledge that the current flow also reduces, which increases the resistivity of the material, and the conductivity reduces.

Also, student **B** expressed that:

*“The conductivity of a conductor remains constant regardless of temperature changes. This is because conductors always conduct electrons so no matter the amount of heat, its conductivity will not change”* (student **B**'s interview transcript).

**Identified Misconception:** conductivity remains constant

Student **B** also failed to acknowledge that when temperature of a conductor is increased, atoms within the conductor vibrate faster at greater amplitude. As a result, the number of collisions between the vibrating electrons and free electrons increases. This causes a greater number of free electrons to reduce. Accordingly, student **B** also did not understand that the current flow also reduces, which increases the resistivity of the material.

Similarly, student **C** articulated that:

*“When heat flows through a conductor, the conductor always gets hotter”. This is because heat always increases the temperature of objects and this temperature will*

*cause the conductor to get hotter. This will increase the conductivity of the conductor” (student C’s interview transcript).*

**Identified Misconception:** Heat increases temperature of conductors.

From student C, it could be seen that there was lack of scientific understanding or explanation concerning the item. Student C specifically failed to acknowledge the difference between heat and temperature, and how temperature would affect the conductivity of conductors.

Moreover, student D expressed that:

*“Sir, what I know is that temperature always causes objects to change in shape or state. So, I think when a conductor, which is a type of solid, is exposed to temperature, the material will change its shape. And when the shape is changed, conductivity will not take place” (student D’s interview transcript).*

**Identified Misconception:** Temperature causes a change in shape of a conductor.

The answer from student D clearly reflected lack of scientific understanding in Electronics. Student D refused to consider the internal changes of atomic particles, which increases or decreases the conductivity of conductors.

### **Students’ misconceptions on item 3**

**Teacher:** Why does conductivity increase with temperature in semi-conductors?

**Common students’ response:** Students demonstrated common misconceptions concerning this particular item. For instance, student E stated that:

*“Sir, I know that it is the electron that causes an object to be conductive. So, I can say that when you increase the temperature of a semiconductor, it adds more electrons to the material, making it more conductive”* (Student **E**’s interview transcript).

**Identified misconception:** Addition of electrons with increase in temperature.

For this item, student **E** did not realise that the number of electrons in a semiconductor remains constant, and temperature does not add or remove electrons. Student **E**, thus, failed to explain that when the temperature of a semi-conductor is increased, some covalent bonds are broken and more free electrons and holes are produced. With the increased in electrons, the conductivity of the semiconductor increases.

Also, student **F**’s answer on this particular item was that:

*“I think higher temperatures cause electrons to move faster within the semiconductor, leading to increased conductivity”* (Student **F**’s interview transcript).

**Identified Misconception:** Faster movement of electrons

It could be deduced from the answer from student **F** that there was inaccurate explanation of why conductivity increases with increasing temperature. Student **F** did not acknowledge that while temperature affects the thermal motion of electrons, it is the change in the balance between electrons in the valence and conduction bands that primarily influences conductivity in semiconductors.

Furthermore, student **G** provided an answer which stated that:

*“As temperature increases, semiconductors eventually become conductors. This is because higher temperatures increase the number of charge carriers in the conduction band, thereby increasing the object’s conductivity”* (Student **G**’s interview transcript).

**Identified Misconception:** Semiconductors become metals at high temperatures

The answer from student **G** did not reveal that while higher temperatures increase the number of charge carriers in the conduction band, semiconductors do not transform into metals solely due to temperature changes. The distinction between semiconductors and metals is based on their intrinsic properties and band gap, not just temperature.

Student **H** in providing an answer to this item also stated that:

*“...temperature increases the number of electrons in the conduction band, which therefore increases the conductivity of the conductor”* (Student **H**’s interview transcript).

**Identified Misconception:** Addition of electrons

The quote from student **H** also failed to reveal that while temperature can promote some electrons to the conduction band through thermal excitation. It does not create new electrons. The total number of electrons remains constant.

### **Students’ Misconceptions on item 6**

Teacher: Explain why a transistor possesses a thin base.

**Common students' response:** Students, again, in the interview session revealed common misconceptions concerning this item. For instance, student **I** stated that:

*“The base of a transistor is thin in order to increase the amplification of the device. So, a thicker base would result in lower amplification”* (Student **I**'s interview transcript).

**Identified Misconception:** Base Thickness Affects Amplification

From the response of student, **I**, one could discern that the student did not know the function of the base of a transistor. Student **I** did not understand that the primary function of the thin base is to control the flow of current between the emitter and collector regions, not to enhance amplification.

Likewise, student **J** response to this item was that:

*“Sir, I can say that a thin base allows more electrons to pass through it. Therefore, reducing the thickness of the base leads to higher current flow”* (Student **J**'s interview transcript).

**Identified Misconception:** A thin base allows the flow of electrons

From student **J**'s response, it could be seen that the student wrongly attributed the nature of the base to current flow, instead of acknowledging the fact that the thinness of the base is related to the control of minority carriers (holes or electrons), not the overall current flow.

Furthermore, student **K**'s response to this item revealed a misconception to this item.

Student **K**'s response was that:

*“The type of transistor (NPN or PNP) is determined solely by the thickness of the base. That is, a thin base corresponds to an NPN transistor and a thick base to a PNP transistor”* (Student **K**'s interview transcript).

**Identified Misconception:** The thickness of the base determines the type of transistor. Student **K** also, from the quote above, wrongly gave the correct scientific explanation to item 6. In reality, the type of transistor is determined by the arrangement of the layers and the types of semiconductor materials used, not the base thickness.

### **Misconceptions of item 10**

Teacher: How can normal temperature affect the conductivity of an insulator such as polythene?

**Common students' response:** Students, in the interview session, revealed common misconceptions concerning this item. For instance, student **L** stated that:

*“Ordinary temperature can transform an insulator into a conductor of electricity. This is because at ordinary temperatures, insulators become hot and start conducting electricity just like metals”* (Student **L**'s interview transcript).

**Identified Misconception:** Heat changes an insulator into a conductor.

From the quote of student **L**, one could decipher that the student thinks it is heat that changes an insulator into a conductor, and therefore any amount of heat can change an insulator into a conductor. What student **L** failed to understand was that atomic changes take place within the heated substance, and therefore could not acknowledge that ordinary temperatures have no significant effect in changing insulators into a conductor. This is

because, at ordinary temperatures, an insulator has no free moving electrons and therefore has negligible electrical conductivity. However, at high temperatures, some electrons gain energy and break away from influence of the nucleus becoming free electrons, which can conduct electricity.

Student **M** also responded that:

*“At normal temperatures the conductivity of an insulator increases. This is because an insulator has some property of conductivity, but the extent to which it conducts heat or electricity increases under normal temperature. This is because the electrons within the material become free upon heating, which will cause the conductivity of the material to increase”* (Student **M**’s interview transcript).

**Identified Misconception:** Normal temperature increases the conductivity of insulators.

The answer from student **M** also revealed the inability to acknowledge that ordinary temperatures do not affect the conductivity of insulators, rather, the conductivity of an insulator increases with increasing temperature.

Student **N** also gave his answer to item 10 which stated that:

*“Sir, I think normal temperatures will cause an insulator to melt, which will turn into liquid, of which we all know that liquid can conduct heat and electricity. So, at normal temperature, the conductivity of an insulator increases”* (Student **N**’s interview transcript).

**Identified Misconception:** Normal temperature changes the state of an insulator.

The answer from student N also lacked the accurate scientific reasoning behind the effect of temperature on insulators. Student N failed to make reference to the internal atomic changes of the material under temperature. Rather student N referred to the change of state of an insulator under temperature, after which the student linked it to a property of the new state of the insulator after being heated. What student N did not recognise was the fact that insulators have small number of electrons which when exposed to high temperatures, could be free to conduct heat or electricity.

#### **4.3 Results for Research Question 2**

*What is the effect of the use of ADDIE instructional design model on SHS Physics students' conceptual change in Electronics concepts?*

This research question aimed to determine how the use of ADDIE model could help clear students' misconceptions after the intervention. Therefore, this research question was answered quantitatively. Using students' answers from the Electronics Concepts Test, students' answers to each item were classified as misconceptions and scientific explanations. Quantitatively, descriptive statistics, specifically, frequencies and percentages were used to determine the number of students who could demonstrate scientific explanations on each item. The results are presented in Table 4.3.

**Table 4.3: Descriptive Statistics of Students' Misconceptions and Scientific Understanding in Electronics Concepts after Intervention**

Item*	NSEM (N=101)	%	rank	NSHSU (N=101)	%	rank	$\chi^2$	df	p
1	40	39.60	5	61	60.40	6	54.529	2	0.001
2	39	38.61	6	62	61.39	5	55.824	2	0.001
3	29	28.71	10	72	71.29	1	75.235	2	0.001
4	41	40.59	4	60	59.41	7	53.353	2	0.001
5	49	48.51	1	52	51.49	10	48.176	2	0.001
6	46	45.54	2	55	54.46	9	49.235	2	0.001
7	38	37.62	7	63	62.38	4	57.235	2	0.001
8	42	41.58	3	59	58.42	8	52.294	2	0.001
9	37	36.63	8	64	63.37	3	58.765	2	0.001
10	35	34.65	9	66	65.35	2	62.176	2	0.001

NSEM - Number of Students Exhibiting Misconception

NSHSU – Number of Students Exhibiting Scientific Understanding

\*Refer to Appendix A for the questions.

As observed in Table 4.3, a chi-square test for independence indicated a significant association between each item and the level of understanding (misconception and scientific understanding). From Table 4.3, low percentages of students generally possessed misconceptions in Electronics after introducing ADDIE model. This is because the percentage of students who exhibited misconceptions on all the items in Electronics Concept Test after the intervention ranged from 28.71% to 48.51%. Table 4.2 also reveals that greater percentage of students (48.51%) exhibited misconceptions on item 5, while least percentage of students (28.71%) exhibited misconceptions on item 3. Contrarily, it can be seen from Table 4.2 that student generally demonstrated high percentages of scientific understanding in Electronics concepts after the intervention, with percentage of students having scientific understanding in Electronics concepts ranging from 51.49% to 71.29%. The highest percentage of students (71.29%) demonstrated scientific

understanding on item 3 while the least percentage of students demonstrated scientific understanding on item 5. The results in Tables 4.2 and 4.3 were compared to determine the effect of the ADDIE model on students' conceptual change in electronics concepts as shown in Table 4.4.

**Table 4.4: Comparison of Percentage of Students who Demonstrated Misconceptions and Scientific Understanding Before and After Intervention**

<b>*Item</b>	<b>NSEM before intervention</b>	<b>NSEM after intervention</b>	<b>% change</b>	<b>NSESU before intervention</b>	<b>NSESU after intervention</b>	<b>% change</b>
1	95	40	-57.89	6	61	916.67
2	73	39	-46.58	28	62	121.43
3	80	29	-63.75	21	72	242.86
4	81	41	-49.38	20	60	200.00
5	79	49	-37.97	22	52	136.36
6	75	46	-38.67	26	55	111.54
7	83	38	-54.22	18	63	250.00
8	72	42	-41.67	29	59	103.45
9	76	37	-51.32	25	64	156.00
10	95	35	-63.16	6	66	1000.00

NSEM - Number of Students Exhibiting Misconception

NSESU – Number of Students Exhibiting Scientific Understanding

\*Refer to Appendix A for the questions.

As seen from Table 4.4, on the ten items, there was a decrease in the percentage of students who exhibited misconceptions after the intervention, hence the negative percentage changes on the ten items. However, there was an increase in the percentage of students who exhibited scientific understanding in each item after the intervention, hence the positive percentage changes observed across the ten items. The highest percentage change (decrease) in the misconception category was observed in item 3 (-63.75%), while the least

decrease was observed in item 5 (-37.97%). Also, the highest percentage change (increase) in the scientific understanding category was observed in item 10 (1000.00%), while the lowest percentage increase was observed in item 8 (103.45%).

The effect of the ADDIE instructional design model in enhancing the conceptual change of students across the ten items after the intervention was tested using the Wilcoxon Signed Rank Test on the difference in the percentage of students who exhibited scientific understanding before and after the intervention. The results are presented in Table 4.5.

**Table 4.5: Results for Wilcoxin Signed Ranked Test**

	<b>Scientific understanding after – scientific understanding before</b>
Z	-2.805
Asymp. Sig. (2-tailed)	0.002

From Table 4.5, the Wilcoxon Signed Rank Test revealed a statistically significant increase in the percentage of students who exhibited scientific understanding after ADDIE implementation ( $z = -2.805$ ,  $p = 0.002$ ). The negative z-value means that, on average, the ranks (absolute values) of positive differences (indicating improvement) are higher than the ranks of negative differences (indicating worsening). This means that there were more significant decreases in the percentage of students with misconceptions after the intervention than there were increases. To determine the magnitude of the effect of the ADDIE implementation, which was considered in this study to constitute the conceptual change, an effect size statistic was calculated using the formula shown in (1) by substituting the respective values in eqn. 1 gives  $r = 0.89$ . This effect size of 0.89 obtained for scientific

understanding according to Pallant (2011) indicates a large effect and, for extrapolation, a large conceptual change.

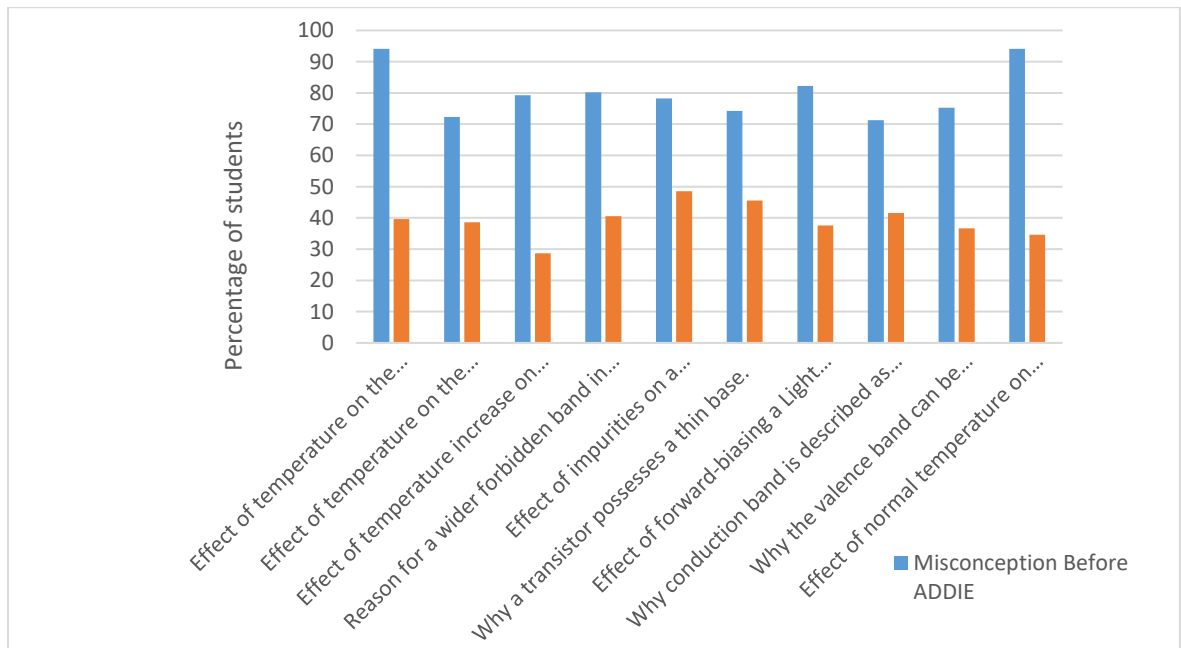
$$r = \frac{z}{\sqrt{N}} \dots\dots\dots \text{eqn. 1}$$

where  $r$  = effect size statistic;

$Z$  = absolute z-value from the Wilcoxon Signed Ranked Test = 2.805

$N$  = number of pairs of observations (items) = 10.

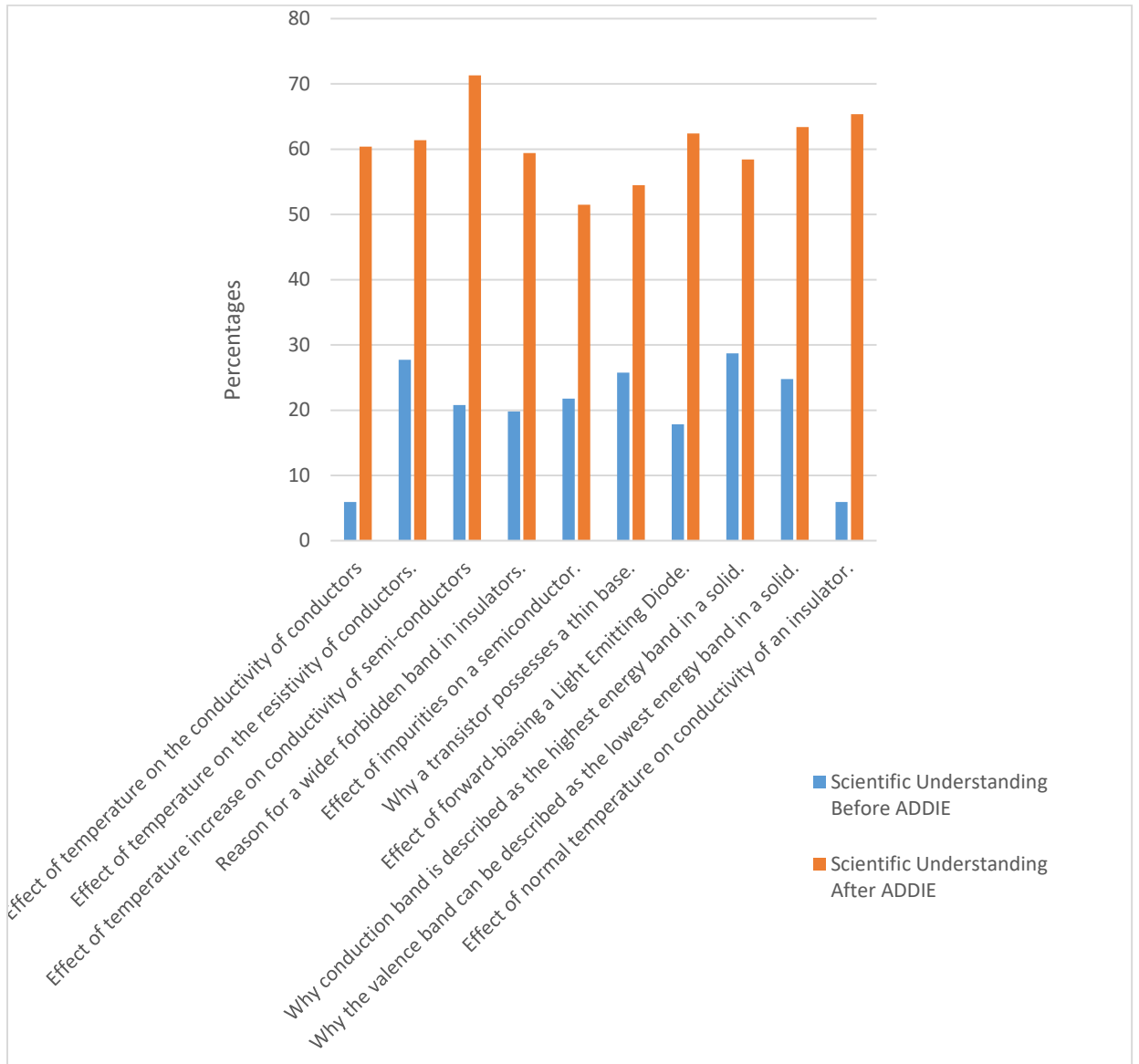
Graphical representation was also provided for a visual view of the change in percentage of students who demonstrated misconceptions across the ten items in the ECT before and after the use of ADDIE model as shown in Figure 4.1 and 4.2.



**Figure 4.1: A graph showing the percentage of students’ misconceptions of Electronics Concept Test items before exposure to ADDIE Model**

From Figure 4.1, it can be observed that higher percentage of students demonstrated misconceptions on all the items before the intervention. However, after introducing ADDIE

model, percentage of students who demonstrated misconceptions on all the items reduced, indicating that students exhibited conceptual change in Electronics concepts, as shown in Figures 4.2.



**Figure 4.2: A graph showing the percentage of students' scientific understanding of Electronics Concept Test items after exposure to ADDIE Model**

Again, as shown in Figure 4.2, there were lower percentages of students who had scientific understanding in all the items on the Electronics Concepts Test before the use of ADDIE model, but after introducing ADDIE model, percentages of students who demonstrated scientific understanding in Electronics concepts increased for all the items. Few representative statements from students after exposure to ADDIE model through a semi-structured interview are discussed as follows.

### **Students' Scientific Understanding on item 1**

**Teacher:** Explain the effect of temperature on the conductivity of conductors.

Student **A**, who answered this item wrongly before the intervention responded that:

*“At higher temperatures, the atoms within the conductor gain thermal energy, causing them to vibrate more strongly. These vibrations will now disturb the flow of electrons, leading to more regular collisions between electrons. As a result, the movement of electrons becomes limited, which makes it more difficult for them to move through the conductor. This then leads to reduction in conductivity”.*

Also, student **B** who also responded wrongly to this item before the intervention, now answered after the intervention that:

*“The vibration of conductor ions increases with rising temperature. As a result, the metal becomes more resistant, which reduces its conductivity”.*

### **Students' Scientific Understanding of item 6**

**Teacher:** Why does conductivity increase with temperature in semi-conductors?

For this item, student **C**, who responded wrongly before the intervention now responded that:

*“The conductivity of a semiconductor rises as a result of free mobility between the two bands created when electrons from the valence band are able to jump to the conduction band when the temperature rises”.*

Student D, who also answered this item wrongly before the intervention, answered after the intervention that:

*“Conduction in semi-conductors involves electrons moving from the valence band to the conduction band when heat energy allows them to overcome the band gap”.*

These few students’ responses on the sampled items could suggest that students demonstrated conceptual change after the intervention as presented in Table 4.2, as well as Figures 4.1 and 4.2.

#### **4.4 Results for Research Question 3**

*What is the extent of male and female SHS Physics students’ conceptual understanding in Electronics before and after exposure to ADDIE instructional design model?*

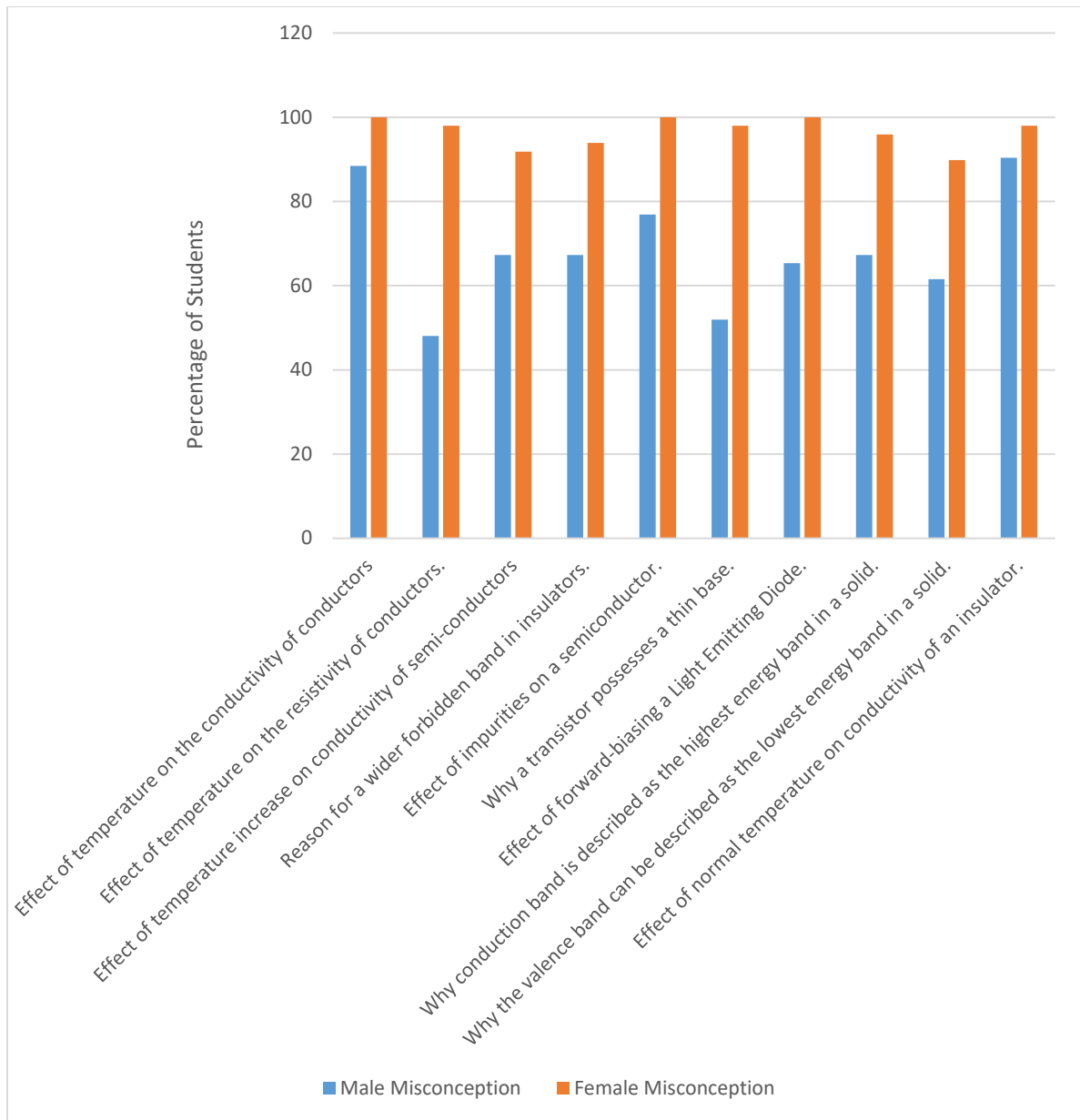
This research question sought to determine conceptual change between male and female SHS Physics students before and after the introduction of the ADDIE model. Thus, to answer this research question, descriptive statistics, specifically frequencies and percentages were used to determine the number of students having misconceptions and scientific understanding on each item in both gender groups before and after the intervention. The results are presented in Tables 4.3 and 4.4 respectively.

**Table 4.4: Descriptive Statistics of Male and Female Physics Students’ Misconceptions and Scientific Understanding on Electronics Concepts before Intervention**

Item	Male (N=52)				Female (N=49)			
	M Freq.	%	SU Freq.	%	M Freq.	%	SU Freq.	%
1	46	88.46	6	11.54	49	100	0	0
2	25	48.08	27	51.92	48	97.96	1	2.04
3	35	67.31	17	32.69	45	91.84	4	8.16
4	35	67.31	17	32.69	46	93.88	3	6.12
5	40	76.92	12	23.08	49	100	0	0
6	27	51.92	25	48.08	48	97.96	1	2.04
7	34	65.38	18	34.62	49	100	0	0
8	35	67.31	17	32.69	47	95.92	2	4.08
9	32	61.54	20	38.46	44	89.80	5	10.20
10	47	90.38	5	9.62	48	97.96	1	2.04

M – Misconception; SU – Scientific Understanding

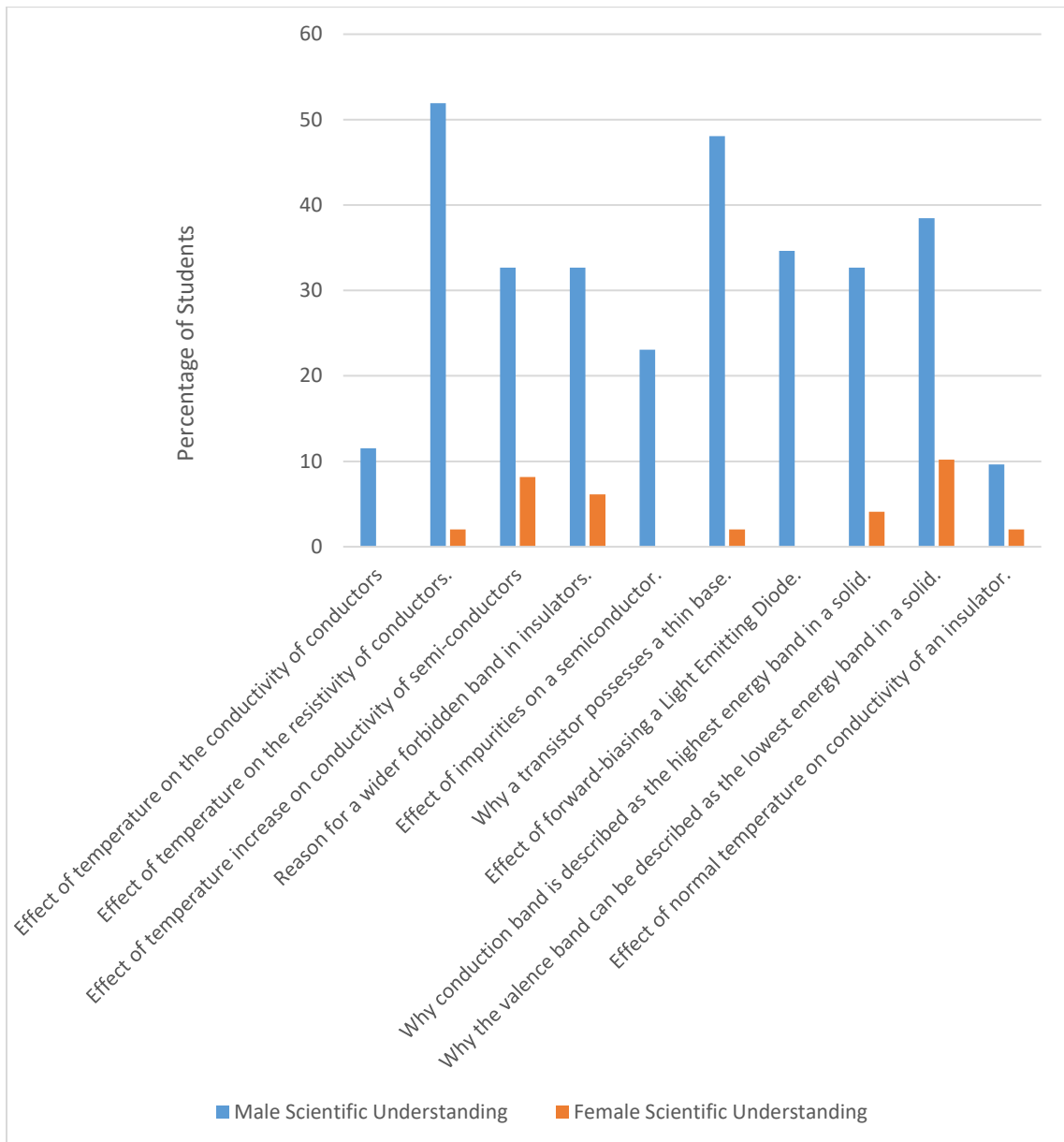
From Table 4.4, it can be seen that before the introduction of ADDIE model, greater percentages of female SHS Physics students (ranging from 91.84% to 100%) demonstrated more misconceptions (and less scientific understanding) in Electronics concepts than their male counterparts (ranging from 48.08% to 90.38%). For instance, considering item 1, while 46 males (88.46%) demonstrated misconceptions, all females (100%) demonstrated misconceptions. Also, for item 2, 25 males (48.08%) demonstrated misconceptions, while 48 females (97.96%) demonstrated misconceptions. Similarly for item 3, 35 males (67.31%) demonstrated misconceptions, while 45 females demonstrated misconceptions. This trend was observed for all items as shown in Table 4.3, and graphically represented in Figures 4.3 and 4.4.



**Figure 4.3: A graph showing the percentage of male and female students’ misconceptions of Electronics Concept Test items Before Exposure to ADDIE Model**

Figure 4.3 depicts that on all the items, higher percentage of female SHS Physics students demonstrated misconceptions than their male counterparts. This directly affected the

percentage of female SHS Physics students who had scientific understanding on all items as shown in Figure 4.4.



**Figure 4.4: A graph showing the percentage of male and female students' Scientific Understanding of Electronics Concept Test items before Exposure to ADDIE Model**

As portrayed in Figure 4.4, very low percentages of females demonstrated scientific understanding in Electronics concepts before the introduction of ADDIE model. For example, on item 1 (What is the effect of temperature on the conductivity of conductors?), item 5 (Explain what happens when a semiconductor is doped with impurities) and item 7 (What is the effect of forward-biasing a Light Emitting Diode?), no female (0%) demonstrated scientific understanding on the questions asked, while the number of males who showed scientific understanding on these items were 6 (11.54%), 12 (23.08%), and 18 (34.62%) respectively. On all the other items, females demonstrated scientific understanding, and they did so at very low percentages compared to their male counterparts, as depicted in Figure 4.3.

A chi-square test of independence was conducted to examine the association between gender and category of understanding of electronics concepts across the 10 items before the intervention.

**Table 4.5: Chi-Square Results Before Intervention**

	<b>Misconception</b>	<b>Scientific Understanding</b>	$\chi^2$	<b>df</b>	<b>p</b>
<b>Male</b>	691.4561	318.5439	273.64	1	0.001
<b>Female</b>	974.9732	35.0268			

The analysis as shown in Table 4.5 revealed a significant association between gender and category of understanding (misconception and scientific understanding) before intervention, ( $\chi^2 = 273.64$ ,  $df = 1$ ,  $p = 0.001$ ). This indicates that there were differences

between males and females in how they demonstrated misconception and scientific understanding across the 10 items.

Male and female misconceptions and scientific understanding on Electronics concepts were also compared after exposure to ADDIE model, as shown in Table 4.4.

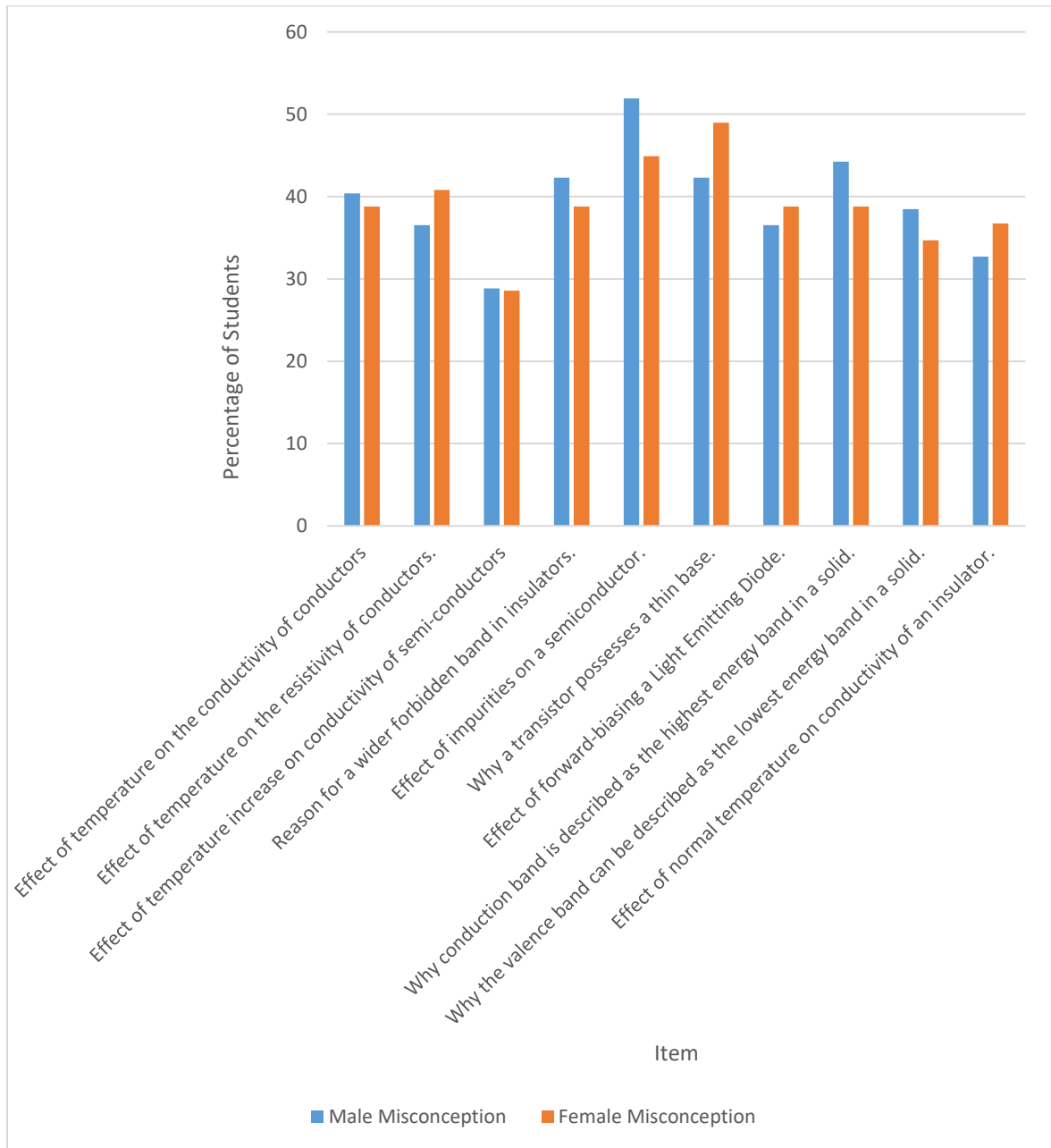
**Table 4.5: Descriptive Statistics of Male and Female Physics Students’ Misconceptions and Scientific Understanding in Electronics Concepts after Intervention**

Item	Male (N=52)				Female (N=49)			
	M Freq.	%	SU Freq.	%	M Freq.	%	SU Freq.	%
1	21	40.38	31	59.62	19	38.78	30	61.22
2	19	36.54	33	63.46	20	40.82	29	59.18
3	15	28.85	37	71.15	14	28.57	35	71.43
4	22	42.31	30	57.69	19	38.78	30	61.22
5	27	51.92	25	48.08	22	44.90	27	55.10
6	22	42.31	30	57.69	24	48.98	25	51.02
7	19	36.54	33	63.46	19	38.78	30	61.22
8	23	44.23	29	55.77	19	38.78	30	61.22
9	20	38.46	32	61.53	17	34.69	32	65.30
10	17	32.69	35	67.31	18	36.73	31	63.27

M – Misconception; SU – Scientific Understanding

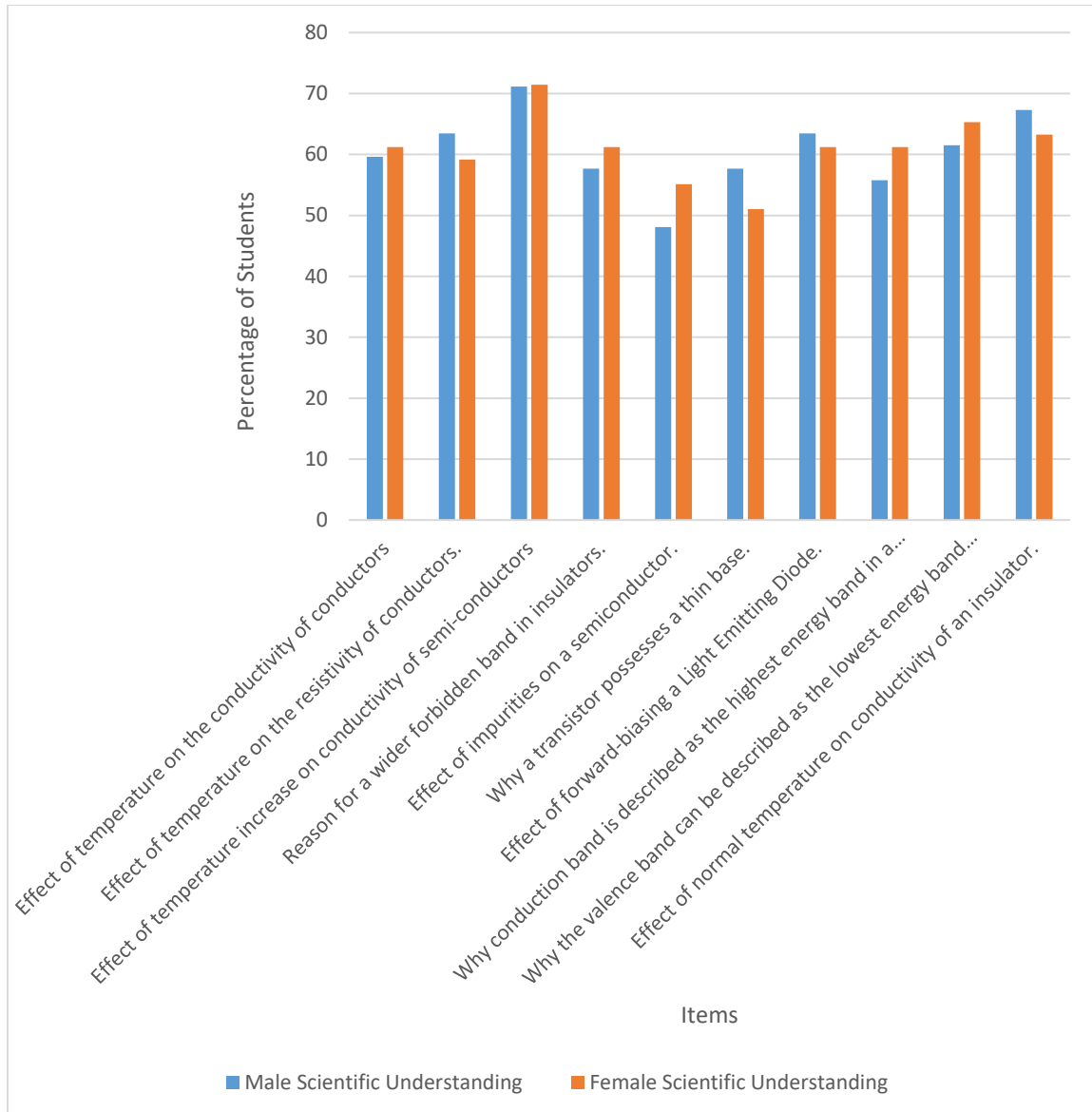
As revealed in Table 4.4, after the intervention, greater percentages of females (55.10% to 71.43%) demonstrated scientific understanding in Electronics concepts, and were apparently equivalent to males (55.77% to 71.15%) after exposure to ADDIE model. This means that after the intervention, percentage of male and female SHS Physics students who demonstrated conceptual change were equivalent. For instance, on item 1, whereas 31 males (59.62%) demonstrated scientific understanding, 30 females (61.22%) also demonstrated scientific understanding after the intervention. Also, on item 2, 33 males

(63.46) demonstrated scientific understanding while 29 females (59.18%) demonstrated scientific understanding. Similarly, on item 3, 37 males (71.15%) demonstrated scientific understanding while 35 females (71.43%) showed scientific understanding. This trend was observed for all items as represented in Figures 4.5 and 4.6.



**Figure 4.5: A graph showing the percentage of male and female students' Misconceptions in Electronics Concept Test items before exposure to ADDIE Model**

Figure 4.5 portrays that before exposure to ADDIE model, equivalent percentages of male and female SHS Physics students demonstrated misconceptions on all the items. This means that very low percentages of female SHS Physics students were recorded to demonstrate scientific understanding on the items in Electronics Concepts Test before the intervention was greatly increased as represented in Figure 4.6



**Figure 4.6: A graph showing the percentage of male and female students' Scientific Understanding in Electronics Concept Test items After Exposure to ADDIE Model**

From Figure 4.6, it can be seen that, similar percentages of male and female SHS Physics students demonstrated scientific understanding on all the items. Specifically on item 1 (What is the effect of temperature on the conductivity of conductors?), item 5 (Explain what happens when a semiconductor is doped with impurities) and item 7 (What is the effect of forward-biasing a Light Emitting Diode?), where no female (0%) demonstrated scientific understanding before the intervention, as portrayed in Figure 4.3, it was observed that after exposure to ADDIE model, on items 1, 5, and 7, the number of females who demonstrated scientific understanding increased to 30 (61.22%), 27 (55.10%) and 30 (61.22%) respectively, compared to their male counterparts where the number of males who demonstrated scientific understanding on items 1, 5, and 7 were 31 (59.62%), 25 (48.08%), and 33 (63.46%) respectively.

Moreover, a chi-square test of independence was conducted to examine the association between gender and category of understanding of electronics concepts across the 10 items after the intervention.

**Table 4.6: Chi-Square Results after Intervention**

	<b>Misconception</b>	<b>Scientific Understanding</b>	$\chi^2$	<b>df</b>	<b>p</b>
<b>Male</b>	398.1723	611.8176	0.025	1	0.875
<b>Female</b>	393.7081	616.2818			

As revealed Table 4.5, a no significant association between gender and category of understanding (misconception and scientific understanding) existed after intervention, ( $\chi^2$

= 0.025,  $df = 1$ ,  $p = 0.875$ ). This indicates that there were no differences between males and females in how they demonstrated misconception and scientific understanding across the 10 items.

## **4.5 Discussion of Results**

In this section, the main findings of this study are discussed, which are based on the specific research questions.

### **4.5.1 Discussion of Results for Research Question 1**

*What are the misconceptions among SHS Physics students in Electronics concepts?*

This research question aimed to determine the misconceptions of SHS Physics students in Tano North Municipality in Electronics concepts. Thus, the research question was answered quantitatively and qualitatively. The quantitative approach involved the use of descriptive statistics, notably, frequencies and percentages of SHS Physics students who demonstrated misconception or scientific understanding. It was found that high percentages of students generally had misconceptions on all the items in the Electronics Concepts Test. Specifically, the percentage of students who exhibited misconceptions on all the items in the Electronics Concept Test ranged from 71.29% to 94.06%. Also, greater percentage of students (94.06%) exhibited misconceptions in “explaining the effect of temperature on the conductivity of conductors” and also, “the effect of normal temperature on the conductivity of an insulator such as polythene”, while least percentage of students (71.29%) exhibited misconceptions on “why the conduction band is described as the highest energy band in a solid”.

Qualitatively, some misconceptions students expressed on the effect of temperature on the conductivity of conductors were “temperature increases conductivity of conductors”, “conductivity remains constant”, “heat increases temperature of conductors”, and “temperature causes a change in shape of a conductor”. Similarly, with regards to “the effect of normal temperature on the conductivity of an insulator such as polythene”, students’ expressed misconceptions such as “heat changes an insulator into a conductor”, “normal temperature increases the conductivity of insulators”, and “normal temperature changes the state of an insulator”.

The results of this study also support some of the findings obtained in earlier research related to students’ misconceptions in Electronics. For instance, Fayyaz et al. (2005) and Erceg et al. (2021) reported that students had the view that the conductivity of semiconductors increases with temperature mainly due to an increase in the number of one type of free charge carriers. Also, Fayyaz et al. (2005), reported that students thought increasing temperature increases the number of free electrons in a conductor, hence increasing the conductivity of a conductor. The misconceptions students portray may seem to indicate that some of them may arise because students have not grasped the concepts well enough (Soeharto et al., 2019), which partly stems from the teaching methods instructors employ in teaching some concepts (Appiah-Twumasi, 2020).

#### **4.5.2 Discussion of Results of Research Question 2**

*What is the effect of the use of ADDIE instructional design model on SHS Physics students’ conceptual change in Electronics concepts?*

The effect of the use of ADDIE Instructional Design Model on SHS Physics students' conceptual change in Electronics concepts were determined using descriptive statistics, mainly frequencies and percentages of students' responses from the Electronics Concepts Tests after the introduction of ADDIE model in the teaching and learning of Electronics concepts. It was found that low percentages of students generally exhibited misconceptions and high percentages of students demonstrated scientific understanding in Electronics after introducing ADDIE model.

This is because the percentage of students who exhibited misconceptions on all the items in Electronics Concept Test after the intervention ranged from 28.71% to 48.51%, while the percentage of students who demonstrated scientific understanding in Electronics concepts ranged from 51.49% to 71.29%. This was represented graphically as shown in Figure 4.0, where higher percentage of students demonstrated misconceptions on all the items before the intervention, while after introducing ADDIE model, percentages of students who demonstrated scientific understanding in Electronics concepts increased. The reduced percentage of students who demonstrated misconception after the intervention indicates that there was conceptual change after using ADDIE model to teach Electronics. This finding agrees with Vijayakumar and Srinivasan (2015), Asuncion (2016), and Sarkodie (2023) who found similar findings, that by employing ADDIE as a teaching method has positive effects on students performances. The positive effect on the use of ADDIE model on students' conceptual change was due to the fact that ADDIE model ensures that students had a "feel" of the material through concrete experiences, as well as

supplementing the teaching and learning with audio and visual resources such as videos and tutorials (Ngussa, 2014).

#### **4.5.3 Discussion of Results of Research Question 3**

*What is the extent of male and female SHS Physics students' conceptual change in Electronics before and after exposure to ADDIE instructional design model?*

This research question sought to determine the effect of ADDIE model on male and female SHS Physics students' conceptual change in Electronics concepts. The research question was answered using frequencies and percentages of male and female students' responses from the Electronics Concepts Test before and after the use of ADDIE model. The results revealed that before the introduction of ADDIE model, greater percentages of female SHS Physics students demonstrated more misconceptions (and less scientific understanding) in Electronics concepts than their male counterparts, while after exposure to ADDIE model, similar percentages of males and females demonstrated scientific understanding in Electronics concepts, as depicted by Figures 4.5 and 4.6. This means that after the intervention, the percentages of male and female SHS Physics students who demonstrated conceptual change were equivalent. The increase in percentage of female students exhibiting conceptual change after the use of ADDIE model in teaching Electronics concepts, which led to similar percentages of male and female students who showed conceptual change can be attributed to the fact that the ADDIE model gave all students equal opportunities to access the learning material, which helped them to equally understand the concepts taught. By doing so, both male and female students saw the relevance of the content, which increased their interests and attitudes towards the subject,

thereby leading them to seek further understanding where and when necessary (Appiah-Twumasi, 2020).

# **CHAPTER FIVE**

## **SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH**

### **5.0 Overview**

In this chapter the summaries of the findings of the study have been captured. Conclusions, recommendations and suggestions were noted based on the findings for further research work.

### **5.1 Summary of Findings**

This study aimed to investigate the effect of the ADDIE model on the conceptual change of senior high school Physics students in studying Electronics in the Tano North Municipality in the Ahafo Region, Ghana. Design-based research design was employed using 101 SHS Physics students from two intact classes, comprising of 52 males and 49 females. Research questions were answered quantitatively and qualitatively.

It was found that before the intervention, the percentage of students who demonstrated misconceptions in Electronics Concepts ranged from 71.29% to 94.06%, with percentage of students having scientific understanding in Electronics concepts ranging from 5.94% to 28.71%. Some of the misconceptions revealed in the qualitative analysis which were demonstrated by students included; temperature increases conductivity of conductors, conductivity remains constant with change in temperature, temperature causes a change in

shape of a conductor, semiconductors become metals at high temperatures, base thickness of a transistor affects amplification.

However, after the intervention, it was found that the use of ADDIE model had positive effect on the conceptual change due to the fact that low percentages of students (28.71% to 48.51%) generally possessed misconceptions in Electronics after introducing ADDIE model.

Also, this study revealed that before the intervention, greater percentages of SHS female students (91.84% to 100%) demonstrated misconceptions in Electronics concepts compared to their male counterparts who demonstrated misconceptions at relatively low percentages (48.08% to 90.38%) in Electronics concepts. However, after introducing the ADDIE model, equivalent percentages of females (55.10% to 71.43%) and males (55.77% to 71.15%) demonstrated scientific understanding in Electronics concepts.

## **5.2 Conclusions**

From the findings of this study, it can therefore be concluded that the employment of the ADDIE model is more effective in enhancing conceptual change of SHS Physics students in Tano North Municipality in the teaching and learning of Electronics concepts.

Also, the use of the ADDIE model is effective in helping male and female SHS Physics students in Tano North Municipality to understand Electronics concepts at equivalent levels.

### **5.3 Recommendations**

The following recommendations are therefore made from the findings of this study. It is recommended that:

1. SHS Physics teachers in the Tano North Municipality should turn their attention to identifying the various misconceptions SHS Physics students hold in Electronics.
2. After identifying those misconceptions, SHS Physics teachers should consider the use of ADDIE model to enhance conceptual change among Physics students, as well as helping male and female Physics students to understand Electronics concepts at equal levels.

### **5.4 Suggestions for Further Research**

The following suggestions were therefore made for further research.

1. Further studies should be conducted on the other cognitive effect of ADDIE model in different other areas, and other fields of study.
2. The affective outcomes of using of ADDIE model in the teaching and learning of Electronics and other fields of study should be investigated.
3. ADDIE model should be compared with different learner-centered teaching methods to inform Physics teachers about the appropriate learner centered teaching methods for teaching SHS Physics students.
4. Further investigations should be made into the use of ADDIE model in higher institutions of learning such as colleges of education, and other tertiary institutions.

## REFERENCES

- Abaniel, A. (2021). Enhanced conceptual understanding, 21st century skills and learning attitudes through an open inquiry learning model in physics. *Journal of Technology and Science Education*, 11(1), 30–43. <https://doi.org/10.3926.11004>
- Adamantia G. Laboratory of New Technologies and Distance Learning, School of Education, University of Ioannina, 45110 Ioannina, Greece
- Almelhi, A. M. (2021). Effectiveness of the ADDIE Model within an E-Learning Environment in Developing Creative Writing in EFL Students. *English Language Teaching*, 14(2), 20-36.
- Acar, Ö., Büber, A., & Tola, Z. (2015). The effect of gender and socio-economic status of students on their Physics conceptual knowledge , scientific reasoning , and nature of science understanding. *Procedia - Social and Behavioral Sciences*, 174, 2753–2756. <https://doi.org/10.1016/j.sbspro.2015.01.962>
- Aina, J. K., & Akintunde, Z. T. (2013). Analysis of Gender Performance in Physics in Colleges of education, Nigeria. *Journal of Education and Practice*, 4(6), 1–6.
- Ajayi, V. O. (2017). *Miconceptions*. Benue State University, Makurdi.
- Akinbobola, A. O., & Bada, A. A. (2019). Assessment of Resources for Physics Teaching in Nigerian Senior Secondary Schools. *International Journal of Humanities, Social Sciences and Education*, 6(8), 1–13. <https://doi.org/10.20431/2349-0381.0608001>

- Alnajdi, S. M. (2018). The Effectiveness of Designing and Using a Practical Interactive Lesson based on ADDIE Model to Enhance Students' Learning Performances in University of Tabuk. *Journal of Education and Learning*, 7(6), 212. <https://doi.org/10.5539/jel.v7n6p212>
- Ammase, A., Siahaan, P., & Fitriani, A. (2019, February). Identification of Junior High School Students' Misconceptions on Solid Matter and Pressure Liquid Substances with Four Tier Test. In *Journal of Physics: Conference Series* (Vol. 1157, No. 2, p. 022034). IOP Publishing.
- Anderson, T., & Shattuck, J. (2012). Design-Based Research: A Decade of Progress in Education Research? *Educational Researcher*, 41(1), 16–25. <https://doi.org/10.3102/0013189X11428813>
- Appiah-Twumasi, E. (2020). An Investigation into the Selection of Teaching Methods and Factors Influencing the Selection: A Case of Science Teachers of Berekum Municipality, Ghana. *International Journal of Innovative Research and Development*, 9(12), 67–74. <https://doi.org/10.24940/ijird/2020/v9/i12/dec20050>
- Appiah-Twumasi, E., Ameyaw, Y., & Kwasi Anderson, I. (2022). Development and Validation of Questionnaire for Physics Learning Self-Efficacy among Ghanaian Senior High Schools. *East African Journal of Management and Business Studies*, 2(1), 8–18. <https://doi.org/10.46606/eajess2022v03i01.0141>
- Appiah-Twumasi, E., Nti, D., Acheampong, R., & Ameyaw, F. (2021). Diagnostic Assessment of Students' Misconceptions about Heat and Temperature Through the Use of Two-Tier Test Instrument. *British Journal of Education, Learning and Development Psychology*, 4(1), 90–104. <https://doi.org/10.52589/bjeldp-o22b5epk>

- Asuncion, R. J. R. (2016). Effects of ADDIE Model on the Performance of B.E.E.D. Sophomore Students in the Project-Based Multimedia Learning Environment Raphael. *International Journal of Multidisciplinary Approach and Studies*, 3(4), 64–77.
- Atsumbe, B., Owodunni, S., Raymond, E., & Uduafemhe, M. (2018a). Students' achievement in basic Electronics: Effects of scaffolding and collaborative instructional approaches. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(8), 1–17. <https://doi.org/10.29333/ejmste/91898>
- Atsumbe, B., Owodunni, S., Raymond, E., & Uduafemhe, M. (2018b). Students' achievement in basic Electronics: Effects of scaffolding and collaborative instructional approaches. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(8). <https://doi.org/10.29333/ejmste/91898>
- Bada, A., & Jita, L. (2021). Rating of Physics Laboratory Resources Management in Tertiary Institutions: Implications for Teaching and Learning STEM Subjects. *International Journal on Research in STEM Education*, 3(2), 64–75. <https://doi.org/10.31098/ijrse.v3i2.515>
- Barasa, J. O., Changeiywo, J., & Okere, M. I. O. (2015). Influence of Gender on Student' Achievement in Secondary School Physics in Tinderet Sub-County, Kenya. *The International Journal Of Science & Technoledge*, 3(5), 166–180.
- Baranowski, M. K., & Weir, K. A. (2015). Political Simulations: What We Know, What We Think We Know, and What We Still Need to Know. *Journal of Political Science Education*, 11(4), 391-403.

- Basu, R. (2018). Instructional Design Models : Benefits and Challenges. *UGC Approved Journal, Vol.-41 N(June)*, 31–36.
- Bichi, A. A., Hafiz, H., & Abdullahi, S. (2017). Evaluating Secondary School Students' Science Achievement: Implication for Curriculum Implementation. *International Journal for Social Studies, 3(1)*, 113–121.
- Blackstone, A. M. (2003). Gender Roles and Society. In *An Encyclopedia of Children, Families, Communities, and Environments* (pp. 335–338).  
[https://digitalcommons.library.umaine.edu/soc\\_facpub/1/%0Ahttps://digitalcommons.library.umaine.edu/soc\\_facpub](https://digitalcommons.library.umaine.edu/soc_facpub/1/%0Ahttps://digitalcommons.library.umaine.edu/soc_facpub)
- Boru, T. (2018). Research Design And Methodology [University Of South Africa]. In *Chapter Five Research Design And Methodology 5.1. Introduction*.  
<https://doi.org/10.13140/RG.2.2.21467.62242>
- Botturi, L. (2003). Instructional Design & Learning Technology. *Quaderni Dell'Istituto, 9*, 1–69.
- Branch, R. M. (2009). Approach, Instructional Design: The ADDIE. In *Department of Educational Psychology and Instructional Technology University of Georgia* (Vol. 53, Issue 9). <https://doi.org/10.1007/978-0-387-09506-6>
- Brown, A. H., & Green, T. D. (2015). The Essentials of Instructional Design. In *The Essentials of Instructional Design* (3rd editio). Routledge.  
<https://doi.org/10.4324/9781315757438>
- Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. *International Journal of Environmental and Science Education, 3(4)*, 193–206.

- Carey, S. (2000). Science Education as Conceptual Change. *Journal of Applied Developmental Psychology*, 21(1), 13–19. [https://doi.org/10.1016/S0193-3973\(99\)00046-5](https://doi.org/10.1016/S0193-3973(99)00046-5)
- Chen, Y.-L., Pan, P.-R., Sung, Y.-T., & Chang, K.-E. (2013). Correcting Misconceptions on Electronics: Effects of a simulation-based learning environment backed by a conceptual change model. *Educational Technology and Society*, 16(2), 212–227.
- Chiquito, M., Castedo, R., Santos, A. P., López, L. M., & Alarcón, C. (2020). Flipped classroom in engineering: The influence of gender. *Computer Applications in Engineering Education*, 28(1), 80–89. <https://doi.org/10.1002/cae.22176>
- Coffie, I. S., Frempong, B. B., & Appiah, E. (2020). Teaching and Learning Physics in Senior High Schools in Ghana: The Challenges and the Way Forward. *Advances in Research*, 21(3), 35–42. <https://doi.org/10.9734/air/2020/v21i330192>
- Cohen, D. K., Raudenbush, S. W., & Ball, D. L. (2003). Resources , Instruction , and Research. *Educational Evaluation and Policy Analysis*, 25(2), 119–142.
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed). Routledge.
- Creswell, J. W. (2012). Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research. In *Pearson Education, Inc.* (4th ed.). Pearson Education, Inc.
- Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (4th ed.). SAGE Publications, Inc.

- Dewi, F. H., Samsudin, A., Chandra, D. T., Aminudin, A. H., Kunaedi, J., Rona, I., Astuti, W., Umar, F. A., & Mufida, S. N. (2023). How is students' mental model in the post-pandemic era? Work and Energy Concept Analysis using the Wright Map. *Journal of Research in Science Education*, 9(3), 1260–1268. <https://doi.org/10.29303/jppipa.v9i3.2773>
- Dođru, S. M. (2021). Conceptual Difficulties Encountered By Science Teacher Candidates In Static Electricity. *European Journal of Science and Technology*, 31(31), 957–967. <https://doi.org/10.31590/ejosat.913290>
- Donovan, B. M., Stuhlsatz, M. A. M., Edelson, D. C., & Buck Bracey, Z. E. (2019). Gendered genetics: How reading about the genetic basis of sex differences in biology textbooks could affect beliefs associated with science gender disparities. *Science Education*, 103(4), 719–749. <https://doi.org/10.1002/sce.21502>
- Easterday, M. W., Lewis, D. R., & Gerber, E. M. (2014). Design-Based Research Process : Problems, Phases, and Applications. *11th International Conference of Learning Sciences*, 317–324.
- Erceg, N., Jelovica, L., Hrepić, Z., Mešić, V., Karuza, M., & Aviani, I. (2021). University students' conceptual understanding of microscopic models of electrical and thermal conduction in solids. *European Journal of Physics*, 42(4), 1–30. <https://doi.org/10.1088/1361-6404/abf5eb>
- Fayyaz, F., Ashraf Iqbal, M., & Hashmi, Y. (2005). Problems of Learning Fundamentals of Semiconductor Electronics. *International Journal of Pedagogies and Learning*, 1(2), 3–17. <https://doi.org/10.5172/ijpl.1.2.3>

- Felton, M., Middaugh, E., & Fan, H. (2023). Civic Action on Social Media: Fostering Digital Media Literacy and Epistemic Cognition in the Classroom. *International Journal of Social Pedagogy*, 12(1), 1–14.  
<https://doi.org/10.14324/111.444.ijsp.2023.v12.x.010>
- Fontana, A., & Prokos, A. H. (2016). *The Interview: From Formal to Postmodern*. Routledge.
- Gidena, A., & Gebeyehu, D. (2017). The effectiveness of advance organiser model on students' academic achievement in learning work and energy. *International Journal of Science Education*, 39(16), 2226–2242.  
<https://doi.org/10.1080/09500693.2017.1369600>
- Gudyanga, E., & Madambi, T. (2014). Pedagogics of Chemical Bonding in Chemistry; Perspectives and Potential for Progress: The Case of Zimbabwe Secondary Education. *International Journal of Secondary Education*, 2(1), 11.  
<https://doi.org/10.11648/j.ijssedu.20140201.13>
- Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). A Review and Comparison of Diagnostic Instruments to Identify Students' Misconceptions in Science. *Eurasia Journal of Mathematics, Science & Technology Education*, 11(5).
- Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2017). Development and Application of a Four-Tier Test to Assess Pre-Service Physics Teachers' Misconceptions about Geometrical Optics. *Research in science & Technological Education*, 35(2), 238-260.

- Heaster-Ekholm, K. L. (2020). Popular Instructional Design Models: Their Theoretical Roots and Cultural Considerations. *International Journal of Education and Development Using Information and Communication Technology (IJEDICT)*, 16(3), 50–65.
- Heddy, B. C., Taasobshirazi, G., Chancey, J. B., & Danielson, R. W. (2018). Developing and Validating a Conceptual Change Cognitive Engagement Instrument. *Frontiers in Education*, 3(43), 1–9. <https://doi.org/10.3389/educ.2018.00043>
- Hinojosa, J., Martínez-viviente, F. L., Garcerán-hernández, V., & Ruiz-Merino, R. (2020). Teaching-Learning Model For The Science Of Electronics. *Journal of Technology and Science Education*, 10(1), 87–100.
- Hoadley, C., Baumgartner, E., Bell, P., Hsi, S., Joseph, D., Orrill, C., Puntambekar, S., Sandoval, W., & Tabak, I. (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher*, 32(1), 5–8.
- Işman, A. (2011). Instructional design in education: New model. *Turkish Online Journal of Educational Technology*, 10(1), 136–142.
- Istratii, R. (2017). Mainstream Gender and Development Concepts and Theories at the Interface with Local Knowledge Systems: Some Theoretical Reflections. *The Journal of Development Practice*, 3(June), 1–13.
- Johanson, G. A., & Brooks, G. P. (2010). Initial scale development: Sample size for pilot studies. *Educational and Psychological Measurement*, 70(3), 394–400. <https://doi.org/10.1177/0013164409355692>

- Jugović, I. (2017). Students' Gender-Related Choices and Achievement in Physics. *Center for Educational Policy Studies Journal*, 7(2), 71–95.  
<https://doi.org/10.26529/cepsj.170>
- Kalpana, T. (2014). A Constructivist Perspective on Teaching and Learning: A Conceptual Framework. *International Research Journal of Social Sciences*, 3(1), 27–29.  
<http://www.isca.in/IJSS/Archive/v3/i1/6.ISCA-IRJSS-2013-186.pdf>
- Karaarslan, A., & Çetin, Ş. (2018). An Exploration of Student Misconceptions in Electrical and Electronics Engineering Department. *International Scientific and Vocational Journal (Isvos Journal)*, 2(2), 12–19.
- Kaur, T., Blair, D., Choudhary, R. K., Dua, Y. S., Foppoli, A., Treagust, D., & Zadnik, M. (2020). Gender response to Einsteinian Physics interventions in school. *Physics Education*, 55(3). <https://doi.org/10.1088/1361-6552/ab764d>
- Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a Research Paradigm and Its Implications for Social Work Research. *Social Sciences*, 8(9), 1–17.  
<https://doi.org/10.3390/socsci8090255>
- Keeley, P. (2012). Misunderstanding misconceptions. *Science Scope*, 1–4.
- Khadidja, K. (2020). Constructivist Theories of Piaget and Vygotsky : Implications for Pedagogical Practices. *Psychological & Educational Studies*, 13(3), 359–372.
- Khalil, M. K., & Elkhider, I. A. (2016). Applying learning theories and instructional design models for effective instruction. *Advances in Physiology Education*, 40, 147–156.  
<https://doi.org/10.1152/advan.00138.2015>
- Khanday S. A.. *Research design*, Research Scholar Department of Sociology, A.M.U-aligarh Email: [sumbl.amu.k@gmail.com](mailto:sumbl.amu.k@gmail.com)

- Kola, A. J., & Akintunde, Z. T. (2014). Course Contents Analysis of Students' Academic Performance in Basic Electronics. *International Journal of Learning, Teaching and Educational Research*, 1(1), 25–34.
- Krosnick, J. A. (2018). Questionnaire Design. In *The Palgrave Handbook of Survey Research* (pp. 439-455). Palgrave Macmillan, Cham. Retrieved from [https://link.springer.com/chapter/10.1007/978-3-319-54395-6\\_53](https://link.springer.com/chapter/10.1007/978-3-319-54395-6_53).
- Kruatong, T., Sung-Ong, S., Singh, P., & Jones, A. (2006). Thai high school students' understanding of heat and thermodynamics. *Kasetsart Journal - Social Sciences*, 27(2), 321–330.
- Küçüközer, H., & Kocakulah, S. (2007). Secondary School Students' Misconceptions about Simple Electric Circuits. *Journal of Turkish Science Education*, 4(1), 101–115.
- Kusairi, S., Alfad, H., & Zulaikah, S. (2017). Development of Web-Based Intelligent Tutoring (iTutor) to Help Students Learn Fluid Statics. *Journal of Turkish Science Education*, 14(2), 1-11.
- Larkin, D. (2012). Misconceptions about “misconceptions”: Preservice secondary science teachers' views on the value and role of student ideas. *Science Education*, 96(5), 927–959. <https://doi.org/10.1002/sce.21022>
- Leonard, M. J., Kalinowski, S. T., & Andrews, T. C. (2014). Misconceptions Yesterday, Today, and Tomorrow. *CBE—Life Sciences Education*, 13, 179–186. <https://doi.org/10.1187/cbe.13-12-0244>

- Linenberger, K. J., & Bretz, S. L. (2015). Biochemistry Students' Ideas About How an Enzyme Interacts with a Substrate. *Biochemistry and Molecular Biology Education*, 43(4), 213-222.
- Lu, L., & Sides, M. L. C. (2022). Instructional Design for Effective Teaching: The Application of ADDIE Model in College Reading Lesson. *NOSS Practitioner to Practitioner*, 4–12.
- Martínez-Mesa, J., Bonamigo, R. R., Bastos, J. L., González-chica, D. A., & Duquia, R. P. (2014). Sample size : How Many Participants Do I need in My Research ? *Epidemiology and Biostatistics Applied to Dermatology*, 89(4), 609–615. <https://doi.org/10.1590/abd1806-4841.20143705>
- McGrif, S. J. (2000). Instructional System Design (ISD): Using the ADDIE Model. *Dermatology in a Week*. [https://doi.org/10.5005/jp/books/10200\\_4](https://doi.org/10.5005/jp/books/10200_4)
- Mchugh, M. L. (2012). Lessons in biostatistics Interrater reliability : the kappa statistic. *Biochemia Medica*, 22(3), 276–282.
- Merriam-Webster Dictionary. <https://www.merriam-webstwe.com/dictionary/paradigm> [Accessed March 10, 2023]
- Migiro, S. O., & Magangi, B. A. (2011). Mixed methods : A review of the literature and the future of the new research paradigm. *African Journal of Business Management*, 5(10), 3757–3764. <https://doi.org/10.5897/AJBM09.082>
- Ministry of Education, Ghana. (2010). *Teaching Syllabus for Senior High Schools, Elective Physics.36*. <https://mingycomputersgh.wordpress.com/wp-content/uploads/2015/03/elective-physics-syllabus-14-10-pdf>.

- Ministry of Education, Singapore. (2017). *Electronics Syllabus: Upper Secondary Express Course*. 1–43.
- Misesani, D., Janggo, W. O., & Wuwur, M. S. N. (2020). Need Analysis in ADDIE Model to Develop Academic Speaking Materials. *Ethical Lingua: Journal of Language Teaching and Literature*, 7(2), 438–446. <https://doi.org/10.30605/25409190.226>
- Molenda, M., Reigeluth, C. M., & Nelson, L. M. (2006). Instructional Design. *Encyclopedia of Cognitive Science*, 71–82. <https://doi.org/10.1002/0470018860.s00683>
- Murti, P. R., & Aminah, N. S. (2019). The Identification of High School Students' Knowledge of Newton's Law of Science Literacy Using a Test Based on Nature of Science (NOS). In *Journal of Physics: Conference Series* (Vol. 1153, No. 1, p. 012122). IOP Publishing.
- Mutlu, A., & Sesen, B. A. (2015). Development of a Two-Tier Diagnostic Test to Assess Undergraduates' Understanding of Some Chemistry Concepts. *Procedia-Social and Behavioral Sciences*, 174(2015), 629-635.
- Naki, E. (2018) Determining the effect of reducing procrastination tendency on the academic achievement in physics course. *International Journal of Educational Administration and Policy Studies*, 11(1), 1–11.
- Nelson, K. G., McKenna, A. F., Brem, S. K., Hilpert, J., Husman, J., & Pettinato, E. (2017). Students' Misconceptions about Semiconductors and Use of Knowledge in Simulations. *Journal of Engineering Education*, 106(2), 218–244. <https://doi.org/10.1002/jee.20163>

- Ngussa, B. M. (2014). Application of ADDIE Model in instruction in teaching-learning transaction among teachers of Mara Conference Adventist secondary school, Tanzania. *Journal of Education and Practice*, 5(25), 99–105.
- Offordile, E. E., Umeano, E. C., Adene, F. M., & ... (2021). Improving the academic achievement of low achieving secondary school students in Physics using peer tutoring learning strategy: Implications for Engineering .... *International Journal of Mechanical and Production Engineering Research and Development*, 11(3), 201–212.
- Olufunke, A. O., Education, F. O. F., & State, E. (2022). Influence Of Gender On Students' Achievement And Attitude Towards Physics In Secondary Schools In Ondo Stat, Nigeria. *Journal* 2(6), 1–9.
- Onwuegbuzie, A. J., & Collins, K. M. T. (2007). A Typology of Mixed Methods Sampling Designs in Social Science Research. *The Qualitative Report*, 12(4), 281–316. <http://www.nova.edu/ssss/QR/QR12-2/onwuegbuzie2.pdf>
- Peers, I. S. (2006). *Statistical Analysis for Education and Psychology Researchers* (2nd ed.). The Falmer Press.
- Pérez, S. R. A. (2021). *Undergraduate engineering student misconception regarding complex circuits: The case with solid-state device circuits* [West Lafayette, Indiana]./articles/thesis/Undergraduate\_engineering\_student\_misconception\_regarding\_complex\_circuits\_The\_case\_with\_solid-state\_device\_circuits/15082686/1
- Piaget, J. (1976). Piaget and His School: A Reader in Developmental Psychology. *Physical Therapy*, 58(3), 375–375. <https://doi.org/10.1093/ptj/58.3.375a>

- Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accomodation of Scientific Conception: Toward a Theory of Conceptual Change. *Science Education*, 66(2), 211–227.
- Qian, Y., & Lehman, J. (2017). Students’ misconceptions and other difficulties in introductory programming: A literature review. *ACM Transactions on Computing Education*, 18(1), 1–24. <https://doi.org/10.1145/3077618>
- Rolleri, L. A. (2013). Understanding Gender and Gender Equality Gender & Sexual Health Part One. In *ACT for Youth Center of Excellence* (p. 7).
- Sarkodie, N. A. (2023). Do Teaching Models Affect Students ’ Academic Performance ? *Journal of Engineering Applied Science and Humanities*, 08(01). <https://doi.org/10.53075/Ijmsirq/6345344555>
- Seidman, I. (2006). *Interviewing as Qualitative Research: A Guide for Researchers in Education and the Social Sciences*. Teachers College Press.
- Schunk, D. H. (2012). *Learning Theories: An Educational Perspective* (6th edition). Pearson Education, Inc.
- Shelton, K., & Saltsman, G. (2011). Applying the ADDIE Model to Online Instruction. *Adapting Information and Communication Technologies for Effective Education*, 566–582. <https://doi.org/DOI: 10.4018/978-1-60960-503-2.ch305>
- Shin, S. H., Park, H. J., & Yang, K. (2016). Types of Middle School Students’ Conceptual Change on the Concept of Electrolyte and Ion. *Journal of the Korean Chemical Society*, 60(1), 48-58.
- Siddiqui, S. (2019). Research Paradigms: Their Assumptions and Relevance. *International Journal of Research in Social Sciences*, 9(5), 254–265.

- Soeharto, Csapó, B., Sarimanah, E., Dewi, F. I., & Sabri, T. (2019). A review of students' common misconceptions in science and their diagnostic assessment tools. *Jurnal Pendidikan IPA Indonesia*, 8(2), 247–266. <https://doi.org/10.15294/jpii.v8i2.18649>
- Strike, K. A., & Posner, G. J. (1982). Conceptual change and science teaching. *European Journal of Science Education*, 4(3), 231–240. <https://doi.org/10.1080/0140528820040302>
- Swanwick, T., Forrest, K., & O'Brien, B. C. (2019). *Understanding Medical Education: Evidence, Theory, And Practice* (T. Swanwick, K. Forrest, & B. C. O'Brien (eds.); 3rd editio). The Association for the Study of Medical Education.
- Tano North Municipal Assembly. (2019). *Composite Budget (2022-2025)*.
- Thakur, H. K. (2021). *Research Methodology in Social Sciences (A Short Manual)*. 53–60. [file:///E:/Documents/dosen/bukuMetodologi/\[John\\_W.\\_Creswell\]\\_Research\\_Design\\_Qualitative\\_Q\(Bookos.org\).pdf](file:///E:/Documents/dosen/bukuMetodologi/[John_W._Creswell]_Research_Design_Qualitative_Q(Bookos.org).pdf)
- Tongchai, A., Sharma, M. D., Johnston, I. D., Arayathanitkul, K., & Soankwan, C. (2009). Developing, Evaluating and Demonstrating the Use of a Conceptual Survey in Mechanical Waves. *International Journal of Science Education*, 31(18), 2437-2457.
- Topçiu, M., & Myftiu, J. (2015). Vygotsky Theory on Social Interaction and its Influence on the Development of Pre-School Children. *European Journal of Social Sciences Education and Research*, 4(1), 172. <https://doi.org/10.26417/ejser.v4i1.p172-179>

- Trotskovsky, E., Sabag, N., & Waks, S. (2015). Students' achievements and misunderstandings when solving problems using Electronics models-a case study. *IEEE Transactions on Education*, 58(2), 104–109.  
\*<https://doi.org/10.1109/TE.2014.2331918>
- USAID. (2008). *Education From A Gender Equality Perspective*.
- VanderStoep, S. W., & Johnston, D. D. (2009). *Research methods for everyday life: blending qualitative and quantitative approaches* (1st ed.). Jossey-Bass A Wiley Imprint.
- Verkade, H., Mulhern, T. D., Lodge, J. M., Elliott, K., Cropper, S., Rubinstein, B. I. P., Espiñosa, A., Livett, M., Dooley, L., Frankland, S., & Mulder, R. (2017). *Misconceptions as a trigger for enhancing student learning in higher education: A Handbook for Educators*. In The University of Melbourne.
- Vijayakumar, S., & Srinivasan, M. P. (2015). Efficacy Of Addie Model In The Digital Classroom: An Evidence-Based Study. *An International Peer-Reviewed Open Access Journal*, 2(1), 347–353.
- Vitharana, P. R. K. A. (2015). Student Misconceptions about Plant Transport--A Sri Lankan Example. *European Journal of Science and Mathematics Education*, 3(3), 275-288.
- Vygotsky, L. (1978). *Mind in Society: The Development of Higher Psychological Processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (eds.); 1st editio). Harvard University Press.
- WAEC. (2017). *Chief examiners' Reports: Science Subjects*. <https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482>

- WAEC. (2018). *Chief examiners' Reports: Science Subjects*. <https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482>
- WAEC. (2019). *Chief Examiners' Report*. <http://waeconline.org/e-learning/physics/phys229cw.html>.
- WAEC. (2020). *Chief examiners' Reports: Science Subjects*. <https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482>
- WAEC. (2021). *Chief Examiners' Report*. <https://waecgh.org/chief-examiners-report/#1679644696468-0aa0c1d6-0482>
- Widiyatmoko, A., & Shimizu, K. (2018). Literature Review of Factors Contributing to Students' Misconceptions in Light and Optical Instruments. *International Journal of Environmental & Science Education*, 13(10), 853–863. <http://www.ijese.com>
- Yuoni, A. B. (2018). *Investigating The Teaching Of Basic Electronics In Basic Schools In The Jirapa Municipality Upper westr Region*, Ghana. University of Education, Winneba.
- Zheng, L. (2015). A Systematic Literature Review of Design-Based Research From 2004 to 2013. *Journal of Computers in Education*, 2(4), 399–420. <https://doi.org/10.1007/s40692-015-0036-z>

# APPENDICES

## Appendix A

### Electronics Concepts Test

1. Explain the effect of temperature on the conductivity of conductors.
2. What is the effect of temperature on the resistivity of conductors?
3. Why does conductivity increase with temperature in semi-conductors?
4. Explain why there is a wider forbidden band in insulators.
5. Explain what happens when a semiconductor is doped with impurities.
6. Explain why a transistor possesses a thin base.
7. What is the effect of forward-biasing a Light Emitting Diode?
8. Why is the conduction band described as the highest energy band in a solid?
9. Explain why the valence band can be described as the lowest energy band in a solid.
10. How can normal temperature affect the conductivity of an insulator such as polythene?

## **Appendix B**

### **Interview Guide**

1. Explain the effect of temperature on the conductivity of conductors.
2. Why does conductivity increase with temperature in semi-conductors?
3. Explain why a transistor possesses a thin base.
4. How can normal temperature affect the conductivity of an insulator such as polythene?



## Appendix D

Sample of Students Marked Mock Paper in Electronics, Physics.

Do not write in either margin	Question No. 11 Write On Both Sides Of The Paper	
	(i) Forbidden band is a band of the valency band of semi-conductor. ✗	0
	(ii) How a forbidden band may be used to distinguish between a semi-conductor and a conductor is that insulators have wide forbidden band and semi-conductor's have small forbidden band. ✓	1/2
	(iii) ✗	0
		0
	(b) The mechanism responsible for the change in electrical conductivity of intrinsic semi-conductor is that if it is doped with a group V-elements eg germanium it will have its five outermost electrons shared with remaining of the electrons. ✗	0
	(bii) Intrinsic semi-conductors are semi-conductors that are doped with impurities of foreign materials. ✓	0
	(ci) Chain reaction is the neutron produced as a results of fission of a nucleus to cause further fission. ✓	0
	(cii) ✗	0
		0 1/2

# BOMAA SENIOR HIGH SCHOOL

## WEST AFRICAN SENIOR SCHOOL CERTIFICATE EXAMINATION



# G

28/6

Candidate's Name: OWUSU JESSICA Full Index Number: 00602504  
 Candidate's Signature: [Signature] Date: 07-02-2022  
 Subject Title: Physics Paper: 2

For Examiner's  
Use Only

Question	Mark
Q1	06
Q4	07
Q6	05
Q8	03½
Q9	02
Q11	04½
<div style="font-size: 4em; font-family: cursive; margin: 0 auto;">Z</div>	
<b>TOTAL</b>	28

### DIRECTIONS TO CANDIDATES

1. Insert your Full Index number, Your Name, the Title of the paper and the Date of Examination in the spaces provided above.
2. Write on both sides of the paper unless otherwise instructed on the question paper.
3. Begin each answer to a question on a fresh page. Leave two lines between answers where these are sub-sections to the same question.
4. Write the number of each question at the top of each page.
5. You are warned that when marking the scripts, Examiners attach importance to accuracy and clearness of expression.
6. Any rough work should be done in your answer booklet and should be crossed out but not in such a way that it cannot be read.
7. If supplementary answer sheets are used, you must tie them to the back of this book, with string. The fastening should be done in the form of a loop so that the page can be opened freely. Do not write on any supplementary sheets unless all the leaves in this book are used up. On no account may you tear up any part of this book.
8. You are not allowed under any circumstances, to remove answer booklets or supplementary answer sheets, used or unused, from the Examination Hall.
9. Write in the space provided below, the NUMBER OF THE QUESTIONS YOU HAVE ANSWERED in the order in which you have written them.

## Appendix E

### Male\_Misconception \* Female\_Misconception Crosstabulation Before Intervention

Count

		Female_Misconception						Total
		89.80	91.84	93.88	95.92	97.96	100.00	
Male_	48.08	0	0	0	0	48	0	48
Misconception	51.92	0	0	0	0	52	0	52
	61.54	62	0	0	0	0	0	62
	65.38	0	0	0	0	0	65	65
	67.31	0	67	67	67	0	0	201
	76.92	0	0	0	0	0	77	77
	88.46	0	0	0	0	0	88	88
	90.38	0	0	0	0	90	0	90
Total		62	67	67	67	190	230	683

## Appendix F

### Male Scientific Understanding \* Female Scientific Understanding Crosstabulation

#### Before Intervention

Count

		Female_SU						Total
		.00	2.04	4.08	6.12	8.16	10.20	
Male_SU	9.62	0	90	0	0	0	0	90
	11.54	88	0	0	0	0	0	88
	23.08	77	0	0	0	0	0	77
	32.69	0	0	67	67	67	0	201
	34.62	65	0	0	0	0	0	65
	38.46	0	0	0	0	0	62	62
	48.08	0	52	0	0	0	0	52
	51.92	0	48	0	0	0	0	48
Total	230	190	67	67	67	62	683	

## Appendix G

### Male\_Misconception \* Female\_Misconception Crosstabulation After Intervention

Count

		Female_Misconception							Total
		28.57	34.69	36.73	38.78	40.82	44.90	48.98	
Male_ Misconception	28.85	1	0	0	0	0	0	0	1
	32.69	0	0	1	0	0	0	0	1
	36.54	0	0	0	1	1	0	0	2
	38.46	0	1	0	0	0	0	0	1
	40.38	0	0	0	1	0	0	0	1
	42.31	0	0	0	1	0	0	1	2
	44.23	0	0	0	1	0	0	0	1
	51.92	0	0	0	0	0	1	0	1
<b>Total</b>		1	1	1	4	1	1	1	10

## Appendix H

### Male Scientific Understanding \* Female Scientific Understanding Cross tabulation

#### After Intervention

Count

		Female_SU							Total
		51.02	55.10	59.18	61.22	63.27	65.30	71.43	
Male_SU	48.08	0	1	0	0	0	0	0	1
	55.77	0	0	0	1	0	0	0	1
	57.69	1	0	0	1	0	0	0	2
	59.62	0	0	0	1	0	0	0	1
	61.53	0	0	0	0	0	1	0	1
	63.46	0	0	1	1	0	0	0	2
	67.31	0	0	0	0	1	0	0	1
	71.15	0	0	0	0	0	0	1	1
Total	1	1	1	4	1	1	1	10	