UNIVERSITY OF CAPE COAST

EFFECTS OF STUDENT TEAMS ACHIEVEMENT DIVISIONS AND JIGSAW COOPERATIVE LEARNING STRATEGIES ON STUDENTS' LEARNING OUTCOMES IN ELECTRONICS

LINDA GYAWU

2024

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BY

LINDA GYAWU

Thesis submitted to the Department of Science Education of the Faculty of Science and Technology Education, College of Education Studies, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Science Education

JULY 2024

DECLARATION

Candidate's Declaration

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

Candidate's Signature: …………………………………… Date:……………......

Name: Linda Gyawu

Supervisor's Declaration

I 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 University of Cape Coast.

Supervisor's Signature: ……………………… Date:………………...

Name: Godwin Kwame Aboagye (Ph.D.)

ABSTRACT

This study was based on the premise that students have difficulties and alternative conceptions regarding electronics concepts and that cooperative learning methods could solve these issues. Therefore, this study compared the effects of Student Teams Achievement Divisions (STAD) and Jigsaw cooperative learning models on senior high school students' learning outcomes in electronics concepts. A total of 103 Form 2 senior high schools in the Cape Coast Metropolis students offering the general science programmes were randomly selected using computer-generated random numbers. The study used a quasi-experimental, pretest-posttest non-equivalent group design, with 41 students from one intact class at one school allocated to the STAD group and 62 students from another school assigned to the Jigsaw group. Both quantitative and qualitative research methodologies were used for data collection. The results showed that students in the Jigsaw group significantly performed better than their STAD counterparts in terms of achievement and conceptual understanding. Moreover, while addressing students' alternative conceptions in electronics, the Jigsaw cooperative learning technique helped students change their conceptions than the STAD method. After using both strategies, students' motivation and attitudes toward studying electronic concepts improved. It was suggested that senior high school teachers adopt STAD and Jigsaw cooperative learning models into their teaching tactics, particularly for complicated areas such as electronics, to improve students' achievement and understanding.

KEY WORDS

Conceptual change

Conceptual understanding

Cooperative learning

Electronic concepts

Jigsaw cooperative learning model

Learning outcomes

Student Teams Achievement Divisions (STAD) cooperative learning model

ACKNOWLEDGEMENTS

I am deeply grateful to my supervisor, Dr Godwin Kwame Aboagye of the Department of Science Education at the University of Cape Coast, for his invaluable guidance and dedication to my studies, despite his busy schedule with other important assignments. His supervisory role demonstrated his unwavering commitment to this research.

I also want to express my heartfelt gratitude to the University of Cape Coast, particularly the lecturers in the Department of Science Education, for their instruction and guidance during my studies. My profound thanks go to Emeritus Professor Paul Kingsley Buah-Bassuah of the Department of Physics at the University of Cape Coast for his relentless encouragement and assistance in ensuring the timely completion of my studies. I also appreciate the assistance of my colleagues at Jukwa Catholic Basic School.

My master's degree was made possible because of the encouragement and assistance of three great people: Rev. Fr. David Obeng Paintsil, Madam Joyce Agyemang, and my former headmaster, Mr. Patrick Debrah. Their invaluable assistance, counsel, and inspiration were critical for finishing my studies. A special thanks to my current headmaster, Mr. Joseph Asante, for the ideal conditions he created during the data gathering time.

I am particularly thankful to Mr. Edmund Owusu-Ansah for his technical assistance. My gratitude also goes to my colleagues, Mr William Amoako and Miss Jemima Owusua Frimpong, for their encouragement and the fun collaborative talks we had over these years of studies. Finally, I would like to thank the physics teachers who allowed me to use their classrooms for my studies.

DEDICATION

To my loving parents, Mr. and Mrs. Gyawu, and my siblings.

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CHAPTER ONE

INTRODUCTION

The growing global population has resulted in greater class sizes, making it difficult to engage students in academic conversations successfully. Teachers strive to meet the different requirements of their students, which include variances in gender, ethnicity, skill levels, learning styles, and motivation. This variability hampers teaching technical disciplines, such as electronics, which many students find difficult. Students struggle with concepts like semiconductors, p-n junctions, and diodes, prompting proposals for more effective teaching approaches. Critics argue that teacher-centred strategies fail to create 21st century abilities. In contrast, student-centred approaches, particularly cooperative learning models such as Student Teams Achievement Divisions (STAD) and Jigsaw, have demonstrated promise. These strategies promote cooperation and peer learning, leading to better academic, social, and psychological results. STAD requires students to work in diverse teams, with high-ability kids coaching their counterparts, encouraging both individual and team accountability. Jigsaw encourages students to become experts in specialised areas and then teach their friends, creating deep understanding and collaborative abilities. According to research, cooperative learning improves students' academic success, conceptual comprehension, motivation, and attitudes. Despite several comparison studies on the efficacy of STAD and Jigsaw, there is a noticeable paucity of studies on using these approaches to teach electronic topics. Addressing this gap is critical, as emotional characteristics like attitude and motivation have a substantial impact on academic performance. Given the demonstrated usefulness of cooperative learning models in enhancing learning outcomes, more research into their usage in scientific education, particularly in teaching electronics, is required.

Background to the Study

With the growing global population, the number of school-age students has increased, providing substantial obstacles to successful classroom education. Larger class numbers demand a rethinking of teaching and learning activities to promote active student participation and engagement rather than passive information intake (Berlyana & Purwaningsih, 2019; Rocca, 2010). Teachers confront challenges in such settings owing to student diversity in terms of gender, ethnicity, ability levels, learning styles, career pathways, and numerous motivating variables (Berlyana & Purwaningsih, 2019; Jamaludin & Mokhtar, 2018). Researchers and educators continue to face substantial challenges in managing and engaging students in deep learning to gain a complete comprehension of complicated subjects (Simamora, 2017; Tiantong & Teemuangsai, 2013). Surprisingly, most classroom interactions remain teacher-centered, which has been strongly criticised for failing to develop the 21st century skills required to accommodate students from all backgrounds, achievement levels, and learning styles. This weakness impairs students' capacity to learn knowledge successfully (Tiantong & Teemuangsai, 2013; Trilling & Fadel, 2009). There is an urgent need for teaching and learning methodologies that capture student attention, address diverse student needs, stress skill development, and promote critical thinking and situational management. Researchers and instructors (Simamora, 2017; Tiantong & Teemuangsai, 2013).

Several physics concepts, including electronics, have been described in the literature to pose obstacles to students (Husain, Misran, Arshad, Zaki & Sahuri, 2012; Trotskovsky, Sabag & Waks, 2015). Electronics has been incorporated into the natural and integrated science curricula from primary to senior high school to familiarize students with its sub-concepts. However, physics instructors and researchers universally admit that many students fail to grasp electronics and harbour serious misunderstandings about its principles (Leniz, Zuza, & Guisasola, 2017; Valiente et al., 2019). The West African Examinations Council (WAEC) (2011, 2013, 2017, and 2019) has raised concern over students' problems in using electronic ideas and principles to solve questions.

Students struggle with electronics topics like semiconductors, p-n junctions, diodes, and operational amplifiers, prompting suggestions for better teaching approaches to address these concerns. Although some studies have looked at students' knowledge of simple electronic circuits and their reasoning in general-purpose electric and electronic circuits (Valiente et al., 2019), there is still a gap in the research about the most effective teaching approaches for improving learning outcomes. In this study, learning outcomes are defined as student accomplishment, changes in concepts, motivation, and attitudes toward studying electronics. A study reveals that students' learning results frequently fall short of expectations (Animasahun, 2014), with the continued use of teacher-centred techniques playing a role (Ogundola, Abiodun, & Jonathan, 2010). Teachers of abstract ideas such as electronics confront obstacles in developing classroom activities that stimulate conceptual development, improve knowledge, and accommodate student variances (Atsumbe et al., 2018). According to Atsumbe et al., constructivist-based instructional techniques including cooperative learning, learning cycles, and concept maps are ideal for meeting these demands.

In response to the shortcomings of teacher-centred, competitive, individualistic techniques, student-centred educational approaches have evolved during the last 20 years (Baeten et al., 2010). Research has demonstrated that the popular student-centred strategy of cooperative learning can lead to beneficial modifications in instructional strategies (Zakaria et al., 2010). While the concepts of cooperative learning have been extensively embraced in North America at all educational levels (Johnson, Johnson & Smith, 2007; Mohammed & Kinyó, 2020; Vijayakumar Bharathi & Pande, 2024; Yang, 2023), there are still many sub-Saharan African classrooms where their application is still restricted.

Students who participate in cooperative learning work in groups to achieve shared objectives, offering an organised and methodical approach to teaching (Adeowu & Bakare, 2024; Iraola Romero & Millera, 2024). Students gain from better interactions and a nurturing atmosphere in cooperative learning groups, which improves their conceptual comprehension and fosters academic, social, and psychological growth (Johnson & Johnson, 2005; Ramos-Vallecillo, Murillo-Ligorred & Lozano-Blasco, 2024). Improved learning results arise from each member taking personal responsibility for the group's advancement. It has been demonstrated that cooperative learning enhances social skills, work satisfaction, critical thinking, motivation, accomplishment, and metacognition (Johnson & Johnson, 2004). Cooper and Mueck (1990) state that cooperative learning activities include the following: (i) establishing shared objectives with team members; (ii) taking accountability for individual and group learning; (iii) delegating particular roles and responsibilities within the group; and (iv) cultivating social skills for productive teamwork. Fun, group activities encourage motivation and participation in the learning process (Berlyana & Purwaningsih, 2019). In summary, cooperative learning provides a strong foundation for improving classroom education. It differs from previous peer learning approaches in that it emphasises positive interdependence, individual and group accountability, promotional engagement, and effective use of social skills and resources (Johnson & Johnson, 2004; John et al., 2023). These qualities are critical to developing successful collaboration and increasing educational achievement.

In addition to helping students meet academic objectives, cooperative learning methods help them build social and teamwork skills (Berlyana & Purwaningsih, 2019). These models are useful for improving critical thinking, teamwork, and problem-solving skills as well as for helping students grasp difficult topics (Cooper & Mueck, 1990). Student Teams Achievement Divisions (STAD), Jigsaw, Group Investigation (GI), Academic Controversy, Cooperative Integrated Reading and Composition, and the Structural Approach are a few well-known cooperative learning strategies (Johnson & Johnson, 2009). Of them, Jigsaw and STAD have shown especially good results in raising academic achievement and motivation (Adams, 2013; Millis, 2023; Yusuf, Gambari, & Olumorin, 2012).

Fostering student engagement, mutual respect, and the development of intrapersonal skills are only a few advantages of the STAD learning approach (Berlyana & Purwaningsih, 2019). Students are placed in diverse teams (four or five people with a range of skills, genders, and ethnicities) that work together to accomplish shared learning goals (Tiantong & Teemuangsai, 2013). High-ability students frequently act as peer tutors for less-achievement kids in this paradigm (Khan & Inamullah, 2011). After the teacher explains the ideas, the students collaborate in groups to make sure everyone is aware of them. Students take individual quizzes, and the results are averaged against past performance. Improvements are worth points, and these points go toward the team's final score. Many disciplines and educational levels have successfully adopted STAD (Tiantong & Teemuangsai, 2013). The STAD approach works especially effectively when teaching clearly defined objectives with correct responses. However, by adding open-ended evaluations like essays or performances, it may also be modified for less regimented goals (Adesoji & Ibraheem, 2009). Studies have indicated that positive attitudes, increased motivation, and improved learning outcomes are all brought about by STAD (Jamaludin & Mokhtar, 2018; Nugraha, Siahaan & Chandra, 2019; Simamora, 2017; Tiantong & Teemuangsai, 2013; Wyk, 2012). Through active student participation in the learning process, STAD contributes to a more dynamic and meaningful educational experience.

The Jigsaw technique is another cooperative learning strategy that divides students into small, diverse groups of 4-6 people. This strategy involves students becoming "experts" on certain ideas and then sharing their expertise with their peers

(Berlyana & Purwaningsih, 2019). Each student in a group is allocated distinct aspects of a topic to learn. After completing their allocated parts, students meet with others who have studied the same topic (expert group) to discuss and expand their comprehension. They then return to their original groupings (home group) to teach their peers about their specific portions. The procedure comprises group presentations, class discussions, and a thorough assessment (Muslimin & Ramadan, 2017).

The Jigsaw approach requires students to completely comprehend the topic and participate in conversations, problem-solving, and collaborative learning. It also encourages students to teach one another as well as themselves. Research has demonstrated that Jigsaw can improve student learning outcomes. Jigsaw improves the quality of relationships and communication while also increasing student engagement and learning results (Sulastri & Rochintaniawati, 2009). Scholars have examined the relative efficacy of Jigsaw and STAD learning models in improving students' learning results in a range of subject areas. Comparative research examining the effects of both strategies on students' learning outcomes is scarce, nevertheless. There aren't many comparison studies, but some have been done. For instance, while comparing the STAD and Jigsaw models for student learning success and motivation in economics, Berlyana and Purwaningsih (2019) made this comparison. According to their research, students with more motivation who used the STAD model outperformed those who used the Jigsaw approach in terms of learning results. They concluded that STAD was superior to Jigsaw in raising students' economics success levels. In separate research, Nugraha et al. (2019)

examined STAD and Jigsaw cooperative learning approaches for junior high school science students. Their findings revealed that pupils in the more structured Jigsaw groups outperformed those in the less structured STAD groups in terms of achievement. However, the relative efficiency of these models in teaching scientific ideas, particularly electronics, is questionable. This shows a vacuum in scientific education research, emphasising the need for more studies to address the issue.

Despite data demonstrating the benefits of cooperative learning for heterogeneous groups (Aboagye, Ossei-Anto, & Ampiah, 2018), its specific application to teaching electronic concepts remain unexplored. Students in classes frequently demonstrate a variety of reasoning abilities, including high-ability [hypothetical-deductive (HD], moderate-ability (MA), and low-ability [empirical-inductive (EI)]. Although Piaget's theory says students should be in the formal operational stage for abstract thinking (Abdullah & Shariff, 2008), actual classroom skills differ. High-ability students can help lower-ability friends improve their hypothetical-deductive reasoning and comprehension (Lou et al., 1996). Vygotsky's zone of proximal development theory supports this by demonstrating that peer contact increases learning. Hooper and Hannafin (1991) found that heterogeneous grouping increases performance in low-ability students. To completely comprehend and maximize their influence on student learning outcomes, further study is still required on the particular application of cooperative learning models to the teaching of difficult topics in electronics.

Again, affective elements such as students' attitudes, motivation, and contentment are strongly connected to accomplishment (Amedu & Gudi 2017).

Gungor, Eryhmaz, and Fakioglu (2007) argue that research on cognitive achievement must also address these affective elements. A good attitude toward studying supports student motivation (Omotayo, 2002). Motivated and satisfied students are more likely to have a positive attitude about the subject (Tran, 2019). Cooperative learning, which encourages cooperation and common goals, may be more successful than standard lecture-based techniques (Johnson & Johnson, 2009; Magnesio & Davis, 2010; Mehra & Thakur, 2008). Tran (2019) discovered that students in cooperative learning groups were more motivated than those taught through standard lectures. Hancock (2004) asserts that motivation is necessary to inspire, lead, and sustain a positive outlook on reaching objectives. Since emotional variables eventually affect cognitive results, Gungor et al. (2007) contend that regulating affective factors is more important than controlling cognitive factors. Cooperative learning makes use of peer support, learning attitudes, and self-belief to cultivate strong social networks and positive attitudes. In terms of academic and personal collaboration, research (Bertucci et al., 2010; Johnson & Johnson, 2006; Johnson, 2009; Slavin, 2011) demonstrates that students in cooperative learning situations do better than those in individualistic ones. The purpose of this study is to compare how students' success, conceptual understanding, attitude, and motivation in electronics are affected by the STAD and Jigsaw cooperative learning methods.

Statement of the Problem

Students frequently struggle with electronic concepts, resulting in low performance on associated class and test topics (Husain et al., 2012; Trotskovsky et al., 2015; WAEC, 2011, 2013, 2017, and 2019). This intricacy causes misunderstandings and alternate conceptions (Leniz et al., 2014; Valiente et al., 2019), which may contribute to poor performance, particularly in multiple-choice and essay parts of physics examinations. Despite its applicability to common technological gadgets, students continue to grapple with these ideas. Researchers are continuously looking for strategies to overcome these issues and increase comprehension of electronics. Could students' troubles with electronics be attributed to an over-reliance on instructors and insufficient active engagement in their learning? Could bad attitudes and lack of motivation be contributory factors? To address these challenges, teachers must use active engagement and motivation techniques. Cooperative learning has proven to be successful in a variety of areas and outcomes (Berlyana & Purwaningsih, 2019). As noted by Johnson and Johnson (1999), "collaborating towards a shared objective leads to higher achievement and increased productivity compared to working independently" (p. 72).

Studies indicate that conversation and group work improve students' understanding and learning (Slavin, 2011). However, many educators throughout the world find it difficult to make the switch from traditional teacher-led classrooms to team-based learning settings. There has been little or no research on the use of cooperative learning models like STAD and Jigsaw to teach electronics concepts, even though they are successful in raising motivation and accomplishment in a variety of subject areas (Berlyana & Purwaningsih, 2019; Nugraha et al., 2019). There is not enough data, despite several comparison research, to say which model - STAD or Jigsaw - is more useful in this situation.

Again, research shows that both STAD and Jigsaw cooperative learning models can significantly enhance positive attitudes among students. However, empirical evidence is lacking on which model is more effective at changing students' alternative conceptions of electronics. This is the reason for the current study's attempt to compare the impact of jigsaw cooperative learning approaches and STAD on students' learning outcomes in electronics.

Purpose of the Study

This study sought to compare the effects of STAD and Jigsaw cooperative learning models on senior high school students' learning outcomes of concepts in electronics. The study, specifically, investigated the extent to which STAD and jigsaw models can improve students' achievement in electronics, and changes in students' alternative conceptions, attitudes, and motivation towards learning.

Research questions

The following research questions guided the study:

1. What is the level of senior high school students' achievement of concepts in electronics taught with STAD and Jigsaw cooperative learning models?
2. What is the level of senior high school students' conceptual understanding of concepts in electronics taught with STAD and Jigsaw cooperative learning models?
3. To what extent does the implementation of STAD and Jigsaw cooperative learning models improve senior high school students' motivation, and attitude towards learning concepts in electronics?

Hypotheses

This study tested the following two hypotheses at a 0.05 level of significance.

1. **H_{01}**: There is no statistically significant difference in students' achievement in electronics concepts between senior high school students taught using the STAD cooperative learning model and those taught using the Jigsaw cooperative learning model.
2. **H_{02}**: There is no statistically significant difference in the extent of changes in students' alternative conceptions of electronics concepts between senior high school students taught using the STAD cooperative learning model and those taught using the Jigsaw cooperative learning model.

Significance of the Study

To begin, the lessons on STAD and Jigsaw models, as well as the numerous instruments produced in this study, have the potential to improve the teaching and learning of electronics concepts. Second, the findings of this study might help physics teachers understand how to use the STAD and Jigsaw models in the classroom for certain electronic concepts. Third, the findings may reveal students' alternate conceptions of electronic concepts that are specific to students, and this might be useful in the creation of lessons and curricula for teachers, and curriculum designers. Lastly, by adding to the corpus of knowledge and existing literature, the study's findings will support future studies in science education.

Delimitation

The focus of this study was mostly on electronics concepts included in the Form 2 physics syllabus for senior high school (SHS). Furthermore, it was limited to

Form 2 SHS students in the Cape Coast Metropolis pursuing elective courses in physics, chemistry, biology, and mathematics. Classification of Semiconductors, Biasing and Rectification, P-N Junction/ Semiconductor Diode, Electronics and Band Theory of Solids, and Transistors (Bipolar or Junction Transistors) are the specific topics covered.

Limitations

The study was unable to manage outside factors like age, maturity, experience, and prior knowledge, which could impact students' understanding of electronics concepts and might not be internally valid. Additionally, not every student attended every lesson., which could also impact the study's results.

Organisation of the Study

The thesis is divided into four main sections, excluding the "Introduction" section: Chapter Two is titled "Review of Related Literature," “Chapter Three” is titled "Research Methods," “Chapter Four” is titled "Results and Discussion," and “Chapter Five” is titled "Summary, Conclusions, and Recommendations." “Chapter Two” critically reviews relevant literature related to the research, comprising an analysis of the investigation's empirical findings, a conceptual framework, and theoretical review. “Chapter Three” includes detailed information about the research methods, including the study type and design, as well as the logic behind them. The population, sampling techniques, data gathering tools, data collection techniques, data processing, and data analysis are all covered in great detail.

In “Chapter Four”, the study's outcomes are presented and analysed based on the research inquiries and hypotheses posed. Additionally, relevant literature is included to substantiate the findings. Chapter Five summarises the study and methods, as well as a summary of the key results and their explanations. Lastly, the deductions of the findings are discussed, and recommendations are made, as well as prospective future study fields.

CHAPTER TWO

LITERATURE REVIEW

This study aimed to compare the effects of STAD and Jigsaw cooperative learning models on senior high school students’ learning outcomes of concepts in electronics. Specifically, the research examined how effectively the STAD and jigsaw models improve students' achievement in electronics, alter their misconceptions, and influence their attitudes and motivation toward learning. The research questions and hypotheses guided the review of related literature. First, the theoretical views that underlie the study were examined, including cooperative learning theories, conceptual change theories, students' attitudes and willingness to learn, and the notion of electronics. Second, the conceptual framework that guided the study was presented. Finally, an empirical review based on the research questions and hypotheses was presented.

Theoretical Review

Constructivism served as the overall philosophy that guided this investigation. Three sub-theories within the constructivist framework informed the research: Dweck's (2006) growth mindset theory on students' attitude and motivation to learn; Posner, Strike, Hewson, and Gerzog's (1982) theory of conceptual change; and Slavin's (1996) four theoretical perspectives on cooperative learning. Constructivism is an educational paradigm that proposes that students gain understanding and knowledge via experiences and reflection on those experiences (Bada & Olusegun, 2015). Influential figures including John Dewey, Jean Piaget, Lev Vygotsky, Jerome Bruner, and David Ausubel have all provided distinct perspectives on this idea. Constructivist techniques stress the significance of social interaction in producing shared meaning and believe that knowledge is built by active thinking, such as selective attention, information organising, and the integration or correction of existing knowledge (Bada & Olusegun, 2015; Cakir, 2008). Consequently, successful learning necessitates active conceptual and behavioural participation.

Constructivist pedagogies are student-centred and directed, focusing on collaborative and cooperative learning among students as well as interactions with instructors and experts. They emphasise linking new information to existing cognitive structures and use interactive, socially engaging teaching settings (Dewey, 1938; Prince & Felder, 2006). Constructivism has a strong influence on cooperative learning, conceptual change, accomplishment, attitude, and motivation, resulting in an overall improvement of educational experiences (Bruner, 1996; Dewey, 1938; Piaget, 1977; Posner et al., 1982; Vygotsky, 1978). This paradigm promotes cooperative learning by highlighting how knowledge is created via social interactions and cooperation (Johnson & Johnson, 2009; Lou et al., 1996; Slavin, 1996; Iraola et al., 2024). Students in constructivist classrooms actively participate in group discussions, projects, and activities, which is consistent with cooperative learning practices (Adeowu & Bakare, 2024). By collaborating, students articulate their understanding, challenge each other's ideas, and build on one another’s knowledge. This teamwork enhances comprehension and fosters a deeper understanding of the subject matter (Ramos-Vallecillo et al., 2024).

Constructivism facilitates conceptual change by emphasising the importance of prior knowledge and addressing misconceptions (Nurhasnah & Kustati, 2024; Schur & Guberman, 2024). It introduces cognitive conflict through challenging scenarios, prompting students to revise their beliefs and integrate new information into existing knowledge (Duit & Treagust, 2003; Özdemir & Clark, 2007; Uke, Ebenezer & Kaya, 2024). This process helps replace misconceptions with accurate concepts (Atchia & Gunowa, 2024; Trevors, 2024). Constructivist approaches also enhance academic achievement by fostering deep learning and understanding rather than rote memorization (Arık & Yılmaz, 2020; Gezim & Xhomara, 2020; Olaoye, Honmane & Audu, 2024). These methods make learning personally relevant and meaningful, improving student engagement and comprehension, which leads to better academic performance (Solomo, 2020; Zhang, 2021). Additionally, constructivism fosters positive attitudes toward learning by creating a conducive, and collaborative atmosphere where students feel recognised and valued (Zajda & Zajda, 2021; Shakeela & Naik, 2023). It gives students more control over their learning, promoting a sense of ownership and responsibility. As a result, students develop more positive attitudes when their contributions are meaningful and they have a say in their educational experiences (Ramzan et al., 2023; Vijayakumar Bharathi & Pande, 2024). Finally, constructivism enhances students' motivation by engaging them in meaningful and relevant activities, fostering intrinsic motivation (Biggs, 2003; Getz et al., 2024). It focuses on understanding and mastery rather than rote learning, aligning with students' goals for competence and self-improvement (Sánchez & Ríos, 2020). When students find the material engaging and view learning as personal growth, their motivation to learn increases significantly.

To summarise, constructivism encourages cooperative learning, conceptual transformation, academic accomplishment, and good attitudes and motivation. Constructivism promotes overall student growth and achievement by fostering an active, student-centred, and meaningful learning environment. It promotes teamwork, clears misunderstandings, improves comprehension, and increases intrinsic drive, resulting in a more successful educational experience.

Cooperative learning

Cooperative learning has received a lot of attention over the last 30 years, thanks to comprehensive research that has shown its academic and social benefits. Key research has shown that students who collaborate to achieve common goals have better learning results and social skills (Johnson & Johnson, 2009; Lou et al., 1996; Slavin, 1996). Ecclesiastes 4:9-10, 12 emphasises the need for cooperation:

> "Two are better than one since they receive a nice recompense for their efforts. For if one of them falls, the other will help him up. But woe to him who falls alone and has no one to help him get back up. And if a man may triumph over one who is alone, two will resist him - a triple chord is not easily broken."

In cooperative learning, students collaborate in groups of varying skill levels and get prizes based on the success of the group. Small groups of two to five people are more successful (Morgan & Keitz, 2010). This collaborative contact enables students to investigate problems, exchange ideas, resolve disagreements, and gain new insights (Mercer, Wegerif, & Dawes, 1999; Webb & Mastergeorge, 2003). When students interact well, they become more engaged in conversations, have higher discourse sophistication, interrupt less, and give more intellectually intriguing ideas (Gillies, 2006; Iraola et al., 2024). They get an understanding of the team's goals and the value of supporting one another's development. This awareness drives people to help their peers by offering information, prompts, reminders, and encouragement (Mohammed & Kinyó, 2020; Vijayakumar Bharathi & Pande, 2024; Yang, 2023). Cooperative learning is grounded in learning theory, often framed by Slavin's Four Theoretical Perspectives (Yang, 2023). Four major viewpoints were recognised by Slavin (1996) - social cohesiveness, cognitive-developmental, motivational, and cognitive elaboration. - that explains how cooperative learning improves student outcomes.

The motivational perspective highlights how cooperative learning boosts students' motivation. Slavin suggests that in cooperative learning, each student's success is linked to the group's success, enhancing motivation to contribute and assist peers (John et al., 2023). It also promotes intrinsic motivation by addressing students' needs for connection and competence (Deci & Ryan, 2012). The social cohesion perspective underscores how group solidarity and interpersonal relationships impact cooperative learning (Sahharon, Zulkefli & Ibnu, 2023). It posits that positive interactions and recognition within the group enhance students' motivation to support each other. This foster increased effort, mutual support, and commitment to shared goals (Schiefer & Van der Noll, 2017; Sahharon et al., 2023), emphasising the benefit of forming a positive classroom environment where students are connected and responsible for one another's learning (Dyson, Howley & Shen, 2021).

The cognitive developmental perspective, based on Piaget and Vygotsky's theories, emphasizes the importance of social interaction in cognitive growth (Pedapati, 2022; Rubtsov, 2020). It argues that cooperative learning creates opportunities for socio-cognitive conflict, where students encounter and reconcile different viewpoints, thereby advancing their cognitive development (Liu, 2020; Yang, 2023). Vygotsky’s Zone of Proximal Development (ZPD) is key here, as cooperative learning enables students to learn from peers and reach higher levels of understanding than they could alone (Erbil, 2020; Irshad et al., 2021). The cognitive elaboration approach focuses on how cooperative learning enhances cognitive processes. It suggests that by explaining concepts to peers, asking questions, and articulating their knowledge, students engage in deeper information processing (Costouros, 2020; Loh & Ang, 2020). This elaborative rehearsal enhances memory retention and understanding (Kooloos et al., 2020; McDermott, 2021). Teaching others helps students organise their ideas, correct misunderstandings, and refine their knowledge, while discussions and debates with peers increase cognitive engagement and conceptual clarity (Chew & Cerbin, 2021; Dellantonio & Pastore, 2021; Sartania et al., 2022). Slavin's (1996) perspectives offer a comprehensive view of why cooperative learning is effective. By enhancing motivation, social connections, cognitive development, and deep information processing, cooperative learning significantly improves both academic performance and social skills.

The Johnson and Johnson paradigm is among the most acclaimed cooperative learning models. Five key components are outlined in this strategy to ensure successful cooperative learning:

1. Positive Interdependence: This component indicates that a student's achievement is reliant on that of their classmates. Students will believe they will "sink or swim together" in a well-structured cooperative session, according to Johnson and Johnson (1999) (p. 2).
2. Face-to-Face Interaction: In this type of learning, students engage in conversations where they clarify, debate, expand upon, and make connections between newly learned content and previously acquired information in environments that encourage eye contact and sufficient social space (Johnson & Johnson, 1999).
3. Individual Accountability: Every group member must actively engage and take responsibility for their contribution. This guarantees that nobody is dependent on others to do all tasks. There is no room for "hitchhiking" because each team member is responsible for both their own and their teammates' education (Kagan, 1990).
4. Interpersonal and Small Group Skills (Social Skills): According to Morgan and Keitz (2010), students are required to practice and use certain social skills under the supervision of an instructor. Social skills are crucial for group productivity, according to the study of group dynamics (Johnson & Johnson, 1999).

Group Processing: This entails giving students the chance to evaluate the work of their team and determine how to get better for assignments in the future (Morgan & Keitz, 2010).

It is anticipated that any cooperative learning paradigm that is successfully implemented will follow these five guidelines.

STAD and Jigsaw Cooperative learning models

There are several cooperative learning methods, including STAD, Jigsaw, Team-Games-Tournament (TGT), Learning Together, Group Investigation, Cooperative Integrated Reading and Composition (CIRC), Think-Pair-Share, Numbered Heads Together, Round Robin, and Three-Step Interview (Millis, 2023). Each of these models has distinct qualities and may be selected based on the educational objectives, student needs, and classroom setting. They all share a focus on interaction, interdependence, and individual accountability within a collaborative framework (Mishra, 2020; Millis, 2023).

STAD and Jigsaw are widely used cooperative learning paradigms owing to their efficacy. STAD, established by Robert Slavin and colleagues at Johns Hopkins University in the early 1970s, is one of the most extensively studied approaches (Mishra, 2020). It was created to improve student success and social relations among different students by integrating cooperative learning and individual accountability (Millis, 2023). STAD students work in varied teams, and individual quiz results contribute to the team's total success, pushing them to help each other learn (Shafiee Rad, Namaziandost, & Razmi, 2023). STAD is one of the widely used cooperative learning models. Its popularity can be attributed to several reasons (Aslan, Berzener, & Deneme, 2021):

1. Ease of Implementation: STAD is straightforward to implement in a classroom setting. Teachers can easily create diverse teams and administer individual quizzes or assessments.
2. Accountability and Individual Learning: Each student's performance contributes to the team's success, promoting both individual accountability and team cooperation. This dual focus helps ensure that all students are engaged and motivated to perform well.
3. Positive Interdependence: STAD fosters a sense of positive interdependence, where students work together to ensure everyone understands the material. This can lead to improved academic achievement and better social skills.
4. Research Support: Numerous studies have shown that STAD can improve student achievement and attitudes toward learning. This research backing has contributed to its widespread adoption.

The Jigsaw cooperative learning model reduces racial conflict in desegregated schools and enhances learning outcomes (Millis, 2023). This model fosters cooperation and interdependence by creating a classroom environment where students rely on each other to succeed. The Jigsaw method has gained widespread adoption due to its effectiveness in promoting academic achievement, improving student relationships, and fostering a supportive learning environment (Amin, Nur & Damayanti, 2020; Karacop, 2017). Research indicates that students engaged in

Jigsaw activities exhibit greater empathy, reduced prejudice, and improved academic performance compared to those in traditional classrooms (Nolan et al., 2018). Jigsaw has also gained significant patronage due to the following reasons (Amin et al., 2020; Karacop, 2017):

1. Promotes Deep Understanding: By requiring students to become "experts" in a specific part of the topic and then teach it to their peers, Jigsaw encourages a deeper understanding of the material. Students must not only learn their segment well but also be able to explain it effectively to others.
2. Encourages Collaboration and Communication: Jigsaw naturally encourages students to collaborate and communicate, as each student's contribution is essential for the group to understand the entire topic. This can improve students' teamwork and communication skills.
3. Reduces Competition: Unlike some competitive models, Jigsaw reduces competition and promotes a cooperative learning environment where students rely on each other's knowledge.
4. Versatility: Jigsaw can be used across various subjects and grade levels, making it a versatile tool for educators.

Both STAD and Jigsaw excel due to their practical, easy-to-implement strategies that can be adapted to various classroom contexts (Millis, 2023). They emphasize individual accountability and group interdependence, which are essential for successful cooperative learning (Mishra, 2020; Millis, 2023). Additionally, extensive research supports their effectiveness in enhancing academic outcomes and social skills (Millis, 2023). In summary, STAD and Jigsaw are popular because of their simplicity, emphasis on both individual and group success, promotion of deep understanding and collaboration, and robust research backing their effectiveness in diverse educational settings.

Conceptual change

Conceptual change involves updating or relinquishing current ideas to comply with scientific theories (Özdemir & Clark, 2007; Hayes et al., 2022). It entails fundamentally modifying prior knowledge (Manz, Lehrer, & Schauble, 2020). According to Duit and Treagust (2003), conceptual transformation often entails moving from basic notions to scientific concepts that students must acquire. This means that learning may involve changing current beliefs rather than just adding new information (Fujii, 2020). According to Hewson and Hewson (1992), conceptual change is changing the status of a particular conception. The new thought gains status when it is recognised, comprehended, and regarded as valuable, while the status of an alternative conception decreases. They emphasised that conceptual shifts shouldn't be seen as the eradication or replacement of earlier ideas. The term "change" in conceptual change should not be construed as simply replacing pre-instructional beliefs with scientific knowledge. Instead, it refers to the learning process in which learners' pre-instructional conceptual frameworks must be radically reconstructed to comprehend scientific notions. According to Özdemir and Clark (2007), students' conceptual notions are shaped by their own experiences and necessitate significant alterations in thinking. Still, they often object to novel ideas. It takes a more forceful approach to dispel preconceived beliefs. The first conceptual change theory was developed by Posner et al. (1982), combining Piaget's assimilation and accommodation theory with Kuhn's paradigm shift theory. Posner et al. stated that if a learner's current thought is valuable and assists them in addressing problems within their existing conceptual framework, they are not driven to change it.

Hewson (1992) claims that inquiry-based or constructivist education is an effective technique for promoting conceptual transformation. These strategies take into account students' early ideas before formal training begins. They entail providing students with circumstances that contradict their preconceived notions, resulting in a sensation of disequilibrium or conceptual conflict. This disagreement pushes students to ponder and overcome the contradiction (Özdemir & Clark, 2007). When a student's previous notion clashes with a new one, the new concept is integrated into their pre-conceptual framework, resulting in accommodation. After learning new concepts, students must integrate them into their thinking and apply them to new contexts (Özdemir & Clark, 2007). Posner et al. proposed four conditions necessary for conceptual change:

1. Dissatisfaction: Learners need to acknowledge contradictions in their own reasoning and acknowledge that the issue at hand cannot be resolved with their present comprehension.
2. Intelligibility: The learners must be able to successfully explain and discuss the new concepts, and they must make sense of them.
3. Plausibility: The new idea ought to tackle the problem more effectively and make more sense than the previous one. Students should be able to recollect

instances in which they can apply the new idea and be able to recognise how it fits into their way of thinking.

4. Fruitfulness: In addition to resolving the existing issue, the novel idea ought to pave the way for further research.

Hewson (1992) suggests that learning occurs smoothly if a new conception meets four conditions. However, science educators often face challenges in implementing these conditions to promote conceptual change. Posner et al.'s theory was attacked by Strike and Posner (1992) for being excessively linear and logical. They said that the theory assumed that students had clear-cut misunderstandings or alternative conceptions for the majority of scientific topics, which is not always the case. Cognitive, emotional, and social elements all play a role in the complex phenomena of conceptual transformation (Manz et al., 2020). It involves stages like recognizing discrepancies, engaging in sense-making activities, and integrating new knowledge into existing cognitive structures (Ha, Park & Chen, 2024). Effective strategies for promoting conceptual change include hands-on activities, inquiry-based approaches, and opportunities for collaborative discussion and reflection (Hayes et al., 2022). By encouraging active engagement and directly addressing misconceptions, educators can facilitate conceptual change and enhance understanding of complex concepts (Fujii, 2020).

Implementing cooperative learning methods can foster conceptual change among students (Millis, 2023). Cooperative environments encourage interaction with peers who present diverse viewpoints, challenging existing beliefs and prompting reconsideration of conceptions (Gill et al., 2022). Through cooperative tasks and problem-solving activities, students actively engage with the material, discovering discrepancies between their prior understanding and new knowledge, leading to re-evaluation and revision of their conceptual frameworks (Chen & Techawitthayachinda, 2021). Models like STAD and Jigsaw promote peer teaching, requiring students to explain concepts to peers, which deepens their understanding and facilitates conceptual shifts through feedback (Matuk & Linn, 2023). Cooperative learning underscores the social nature of learning, where knowledge is co-constructed through interaction (Millis, 2023). Collaborative discussions and problem-solving exercises enable students to negotiate and enhance their conceptual understandings with their classmates (Fuji, 2020). Cooperative learning activities frequently include reflection and metacognitive exercises, allowing students to critically analyse their thought processes and learning experiences. This critical review identifies inconsistencies or gaps in understanding, facilitating conceptual transformation (Gill et al., 2022).

To summarise, cooperative learning approaches promote conceptual change by exposing students to a variety of views, encouraging active engagement and investigation, permitting peer teaching and feedback, supporting social knowledge production, and motivating reflection and metacognition. These characteristics foster an environment suitable for challenging and changing students' preconceived notions in search of deeper knowledge.

Growth mindset theory

This theory motivates and improves students' attitudes toward learning. Carol Dweck's concept of a growth mindset, introduced in 2006, posits that knowledge can be developed through dedication and effort, unlike a fixed mindset that views abilities as static (Yeager & Dweck, 2020). Students with a growth mindset perceive intelligence through perseverance and see learning as a process involving challenges. They seek out difficult tasks as opportunities for growth and view failure as a stepping stone to improvement (Rhew et al., 2018; Cook & Artino Jr., 2016). This mindset fosters resilience and a love for learning, essential for overcoming obstacles and achieving long-term goals. Effort is seen as essential for mastery. Students with a growth mindset invest time and energy in their studies, practice regularly, and seek feedback to improve (Yeager & Dweck, 2020). They embrace constructive criticism as valuable feedback, using it to identify areas for improvement and make adjustments. They view others' success as inspiration and a source of valuable insights and strategies (Rhew et al., 2018). Educators can foster a growth mindset by praising effort, strategies, and progress rather than innate ability, and by focusing feedback on the learning process and effective strategies (Jennings & Cuevas, 2021).

Providing opportunities for students to tackle challenging tasks and emphasizing that struggle and mistakes are natural parts of learning can reinforce the growth mindset (Rhew et al., 2018). Activities that require problem-solving, critical thinking, and resilience help develop this mindset. Creating a supportive, non-judgmental classroom environment where mistakes are seen as learning opportunities encourages a growth mindset. Students should feel safe to take risks and make errors without fear of negative judgment (Jennings & Cuevas, 2021). Collaborative learning and peer feedback support a growth mindset by enabling students to learn from each other and appreciate diverse problem-solving approaches (Yeager & Dweck, 2020). Students with a growth mindset typically achieve higher academic performance due to their engagement with challenging material, persistence through difficulties, and continuous improvement. Beyond academics, a growth mindset fosters resilience, adaptability, and a proactive approach to life's challenges, better-equipping individuals to navigate complexities and pursue their goals with determination (Cook & Artino Jr, 2016; Rhew et al., 2018).

Concept of electronics

Electronics, a branch of physics and engineering, focuses on the behaviour and movement of electrons in various materials and devices (Nelson et al., 2017). Students face significant challenges in learning electronics, primarily due to the abstract nature of its concepts. These concepts are difficult to grasp because the relevant phenomena are not easily observed in the real world. By this, students often struggle to comprehend electronics principles (Alessandrini, 2023; Twissell, 2018).

The lack of practical application contributes to students' difficulties in understanding electronic concepts. Electronics education often prioritizes theoretical knowledge over hands-on experience, making it challenging for students to connect abstract concepts to real-world scenarios (Yildiz Durak, 2021). The curriculum frequently emphasizes principles and laws, such as Ohm's Law and Kirchhoff's Laws, without sufficient practical application, leading to a disconnect between theory and practice (Li, 2012). For instance, while understanding how a transistor works theoretically is essential, without practical experience in building circuits and observing transistor behaviour, students may not fully grasp its functionality (Hargis & Chun, 2020). This emphasis on theory can result in a superficial understanding, where students can recite principles but struggle to apply them in practical situations. To address this issue, educational institutions should integrate more practical components into their electronics curricula. This could include laboratory work, internships, collaborative projects, and the use of simulation software to provide virtual hands-on experience (Mills & Treagust, 2003).

The complexity of different circuit types poses another challenge for students. Electronics encompasses various circuit types, such as analog and digital circuits, which can be difficult to differentiate and understand, especially when applying theoretical knowledge to practical design and analysis (Irwin & Nelms, 2020). Distinguishing between analog and digital circuits and knowing when to use each type can be challenging. Analog circuits require a nuanced understanding of signal variations and noise considerations, whereas digital circuits focus on logical operations and timing analysis. The transition between these two paradigms can be confusing, particularly in mixed-signal systems that incorporate both analog and digital components (Li, 2012).

Misconceptions and preconceived notions can significantly impede students' understanding of electronics concepts. Students often enter electronics courses with inaccurate pre-existing ideas about how electronic systems work, leading to misunderstandings and errors in problem-solving and circuit design. For instance, they might confuse voltage with current or misunderstand resistance and its effects on a circuit (Mulhall, McKittrick, & Gunstone, 2001). Preconceived notions may arise from everyday experiences with electronic devices or informal knowledge, such as believing that higher wattage always means a brighter light without understanding the roles of voltage and current (Cohen, Eylon, & Ganiel, 1983). These misconceptions can persist, affecting students' ability to design circuits correctly and grasp more advanced concepts (Driver, Squires, Rushworth, & Wood-Robinson, 1994).

Cognitive load significantly impacts students' ability to learn electronics. Understanding electronics involves processing complex information about current, voltage, circuit components, and their interactions. This cognitive load can overwhelm students, especially if they lack effective strategies to manage and integrate this information. Electronics education requires students to grasp various concepts, each with its own rules and applications. For instance, students must understand how current and voltage interact within circuits, involving principles like Ohm’s Law and Kirchhoff's Laws, and the behaviours of components like resistors, capacitors, and inductors (Li, 2012). The relationships between these concepts add to the complexity, such as how resistors affect series versus parallel circuits, requiring abstract thinking and mental simulation (Burde & Wilhelm, 2020). According to cognitive load theory, the human brain has a limited capacity for processing new information. Introducing too many concepts simultaneously can exceed this capacity, causing confusion and frustration. Effective learning occurs when cognitive load is managed so students can process information without becoming overwhelmed (Sweller, 2020).

By addressing these problems via active involvement and chances for practical application, instructors may assist students in acquiring electronics principles and improving their comprehension of this complicated topic. Encourage students to work in groups to disperse cognitive burdens, allowing them to learn from one another and solve complicated issues more successfully. Cooperative learning methods such as STAD and Jigsaw can be very beneficial in this context (Slavin, 1996).

Conceptual Framework

The three theories that guided this study are Slavin's (1996) four theoretical perspectives on cooperative learning, Posner, Strike, Hewson, and Gerzog's (1982) theory of conceptual change, and Dweck's (2006) growth mindset theory. Combining cooperative learning, conceptual change theory, and a growth mindset offers several advantages for improving student learning outcomes. Firstly, structuring lessons around cooperative learning tasks taps into students' motivation by incorporating collective responsibility, encouraging them to support each other's learning. This fosters a growth mindset by highlighting the importance of effort in achievement. Secondly, the social interaction inherent in cooperative learning creates a supportive environment where students can confidently share ideas, ask questions, and take risks, all crucial for conceptual change. Lastly, by designing cooperative learning activities that challenge students' existing conceptions and encourage them to test new ideas, educators can facilitate deeper understanding and knowledge construction.

The conceptual model of this study, which is based on these three theories, is presented in Figure 1.

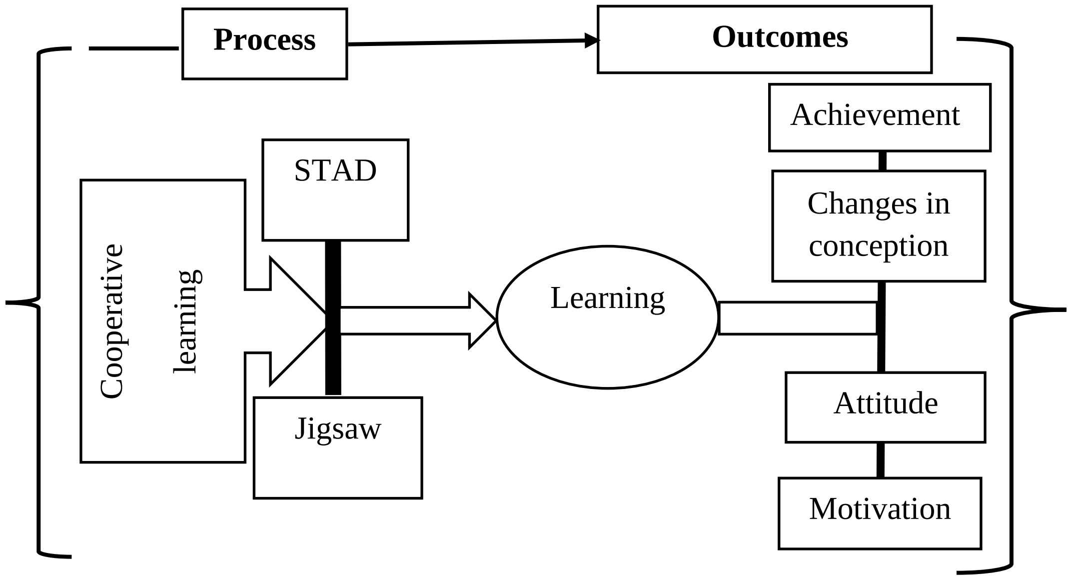

Figure 1: Conceptual model of the study.

The study's framework, shown in Figure 1, consists of two key phases: process and outcome. The process phase details how cooperative learning interventions were designed and implemented using three core theories: cooperative learning, conceptual change, and growth mindset. This phase emphasises that effective implementation of these theories is crucial for achieving positive student learning outcomes. The outcome phase focused on evaluating the impact of these interventions on students' achievement in electronics, as well as their conceptual understanding, attitudes, and motivation toward learning electronics.

Empirical Review

Key themes in the research question and hypotheses guided this review.

Extent of implementation of STAD and Jigsaw cooperative learning models in teaching

Numerous studies have been carried out to examine the effect of Jigsaw and STAD cooperative learning models on students' conceptual success across a range of academic subjects and educational levels. Two categories can be formed from these investigations. While the second group looks at the impact of STAD on Jigsaw, the first group compares Jigsaw or STAD with other teaching styles.

In the first set of research, Khan and Inamullah (2011) looked at the impact of the cooperative learning technique STAD versus regular lectures on students' academic progress. The study involved 30 grade 12 chemistry students from Jamrud Government Higher Secondary School in Khyber Pakhtunkhwa, Pakistan, who were randomly assigned to control and experimental groups by stratified random sampling. Using a posttest-only control group design, the results showed no statistically significant change in performance. However, the experimental group taught using STAD had a higher mean score than the control group, indicating better performance. The study was flawed due to a Type II error, incorrect parametric analysis, and the absence of a pretest, all of which may have resulted in non-significant results. Simamora (2017) investigated how the STAD cooperative learning paradigm influenced students' ability to understand mathematical ideas. The study sought to determine how STAD influenced academic progress and attitudes toward mathematics among 74 ninth-grade students at a Vietnamese high school. A total of 42 students from two classes (VA with 20 students and VB with 22 students) were employed, with VA serving as the experimental group and VB as the control group. The results demonstrated that the experimental group had higher self-efficacy and academic accomplishment than the control group. The study indicated that cooperative learning enhances academic success and creates good attitudes about mathematics. Eshetu, Gebeyehu and Alemu (2017) examined the impact of the cooperative learning method, specifically the STAD approach, on high school students' physics achievement in Ethiopia. The study involved students from grades 9 and 10 at Robe Galema Secondary School. It was found out that students instructed with the STAD method performed better on post-tests compared to those taught with traditional methods. The STAD method was effective for teaching various physics topics and improved the performance of both low and high-achievers. The study concluded that STAD is a beneficial teaching method for enhancing physics achievement and recommended its use in classrooms.

Jamaludin and Mokhtar (2018) investigated the effectiveness of STAD on students' attitudes and teamwork satisfaction in tourism geography using students from Polytechnic Sultan Idris Shah, Malaysia. The experimental group included 43 students, while the control group had 41 students, all from two tourism geography classes at the university. The findings showed that the experimental group had greater improvements in achievement and attitudes towards tourism geography, and the students were more satisfied working in teams within the STAD environment. The study concluded that STAD is effective in enhancing students' achievement and teamwork satisfaction in tourism geography and should be used frequently in instruction. However, the methodological flaw identified in this study was that the intact classes used were from the same institution and the results could be affected by interaction effect. Further research in this direction should be mindful of this flaw. Khan, and Farooq (2020) explored the impact of STAD on 9^{th} grade students' achievement in chemistry. The study aimed to identify potential differences in achievement between STAD (cooperative learning) and traditional teaching methods and to compare students of varying intelligence levels. Forty-two students from the same class at Government Boys High School, No. 1 Nowshera Kalan, were divided equally into experimental and control groups. The results showed that students taught using STAD outperformed those taught by traditional methods. Additionally, both high and low achievers in the experimental group outperformed their peers in the control group. The study concluded that STAD was more effective for learning chemistry than traditional approaches. However, the flaw noted was that only 42 out of 100 students from the same class were randomly selected for the study, leaving the majority of 9^{th} grade students unexamined. Again, an interaction effect could be introduced since both groups were from the same class and school.

Maftei and Popescu (2012) investigated the efficiency of the jigsaw approach for teaching atomic physics in secondary school. They included 12^{th} grade physics students from a Romanian high school who were separated into diverse groups to investigate various areas of atomic physics. The study discovered that the jigsaw approach helped students grasp concepts including the hydrogen spectrum, energy levels, photon energies, and the Rydberg constant. It also boosted students' self-esteem, communication abilities, critical thinking, and individual and group accountability. The strategy enhanced students' attention, motivation, and academic achievement, making it a useful and interesting way to teach atomic physics. Pelobillo (2018) investigated the jigsaw technique's impact on problem-solving skills and physics test results among senior high school students. The study included 100 grade 12 STEM students from the University of Mindanao, separated into two groups: control and experimental. The study found that the jigsaw methodology considerably enhanced students' knowledge and performance in physics when compared to standard teaching techniques. Aydinand Biyikli (2017) investigated the effects of the jigsaw approach on students' ability to recognize and use laboratory objects in a General Physics Lab-I course. The research, conducted with 63 students from the Department of Science Education at a Turkish public university during the 2012-2013 academic year, compared a jigsaw group (32 students) to a control group using traditional techniques (31 students). The findings revealed that the jigsaw strategy considerably enhanced laboratory abilities and generated a more effective learning environment than traditional techniques. The jigsaw approach also improved student achievement, involvement, and active engagement in laboratory activities, so improving both academic performance and knowledge of physics investigations. Atsumbe et al. (2018) studied how scaffolding and collaborative teaching techniques affect students' progress in Basic Electronics. Addressing the ongoing issue of high failure rates in public examinations for science and technology topics, the study sought to determine how various techniques improve cognitive success and whether gender influences this achievement. Purposive sampling was used to choose 105 students (77 males and 28 females) from four schools from a total of 122 senior secondary students studying basic electronics in North Central. The study discovered that collaborative teaching approaches were more successful than scaffolding in boosting students' achievement in basic electronics.

For the second group of studies, Andarini (2014) examined the effectiveness of the Jigsaw and Student Teams-Achievement Divisions (STAD) techniques in promoting reading comprehension among second-grade pupils at MTs Salafiyah Depok. The study focused on inadequate reading comprehension among Indonesian students studying English as a foreign language, identifying variables such as a lack of desire, interest, vocabulary, and previous information. The study included 80 students, separated into two experimental groups: one utilizing the Jigsaw methodology and the other using the STAD method. The results indicated that both strategies considerably enhanced reading comprehension, although the Jigsaw strategy outperformed STAD. The study showed that, while both approaches are successful, the Jigsaw methodology provides more benefits and is recommended for teaching reading comprehension. Perwitasari, Setiyadi and Putrawan (2018) investigated the use of the Jigsaw approach and the STAD to teach reading. The study, which included 26 students from classes VIII B and VIII C at SMPN 1 Abung Surakarta during the 2016/2017 academic year, identified six challenges through interviews and observations: (1) limited vocabulary knowledge, (2) text difficulty, (3) noisy classroom environment, (4) lack of background knowledge, (5) reluctance to express opinions, and (6) dominance of more capable students. The study indicated that these barriers reduced the efficiency of the Jigsaw and STAD strategies for teaching reading comprehension. Fika (2020) evaluated the efficiency of the Jigsaw and STAD cooperative learning methods in pharmaceutical mathematics. The research, which included 66 students from the Pharmaceutical Academy of Dwi Farma, examined two experimental groups: one using the Jigsaw model and the other using the STAD model. Although student activity did not change significantly between the two models, students in the Jigsaw model outperformed the STAD model. The Jigsaw approach produced better academic outcomes, demonstrating that it is more successful in pharmaceutical mathematics training than the STAD paradigm. Both models boosted student engagement in equal measure, but the Jigsaw approach had a stronger favourable influence on learning outcomes.

Berlyana and Purwaningsih (2019) examined the impact of the STAD and Jigsaw learning models on student success and motivation. The study included 108 X-grade IPS students from SMA Negeri 3 Boyolali during the 2017-2018 academic year, divided into two groups of 72 students each: an experimental class using the STAD model and a control class using the Jigsaw model. According to the findings, the STAD model outperformed the Jigsaw model in terms of improving students' economics learning outcomes, particularly among students with strong learning motivation. As a result, the STAD model was found to be more effective in improving economic learning success when students were motivated. Jabeen, Kalsoom, and Khanam (2020) did experimental research to determine the effect of cooperative learning approaches on secondary students' physics achievement. The study included 60 female 10th-grade science students from a public school, who were randomly assigned to experimental and control groups of 30 each. The findings revealed that both the STAD and Jigsaw II cooperative learning approaches were more successful than standard teaching methods. These cooperative strategies increased student involvement, interaction, and collaboration, resulting in higher academic achievement compared to the control group.

Implementation of STAD and Jigsaw cooperative learning models on students' motivation and attitude towards learning

Amedu and Gudi (2017) evaluated if the Jigsaw cooperative learning technique may enhance student attitudes in chosen secondary schools in Nasarawa State. The study comprised 179 SS 1 biology students from three public high schools who were recruited purposefully. Two classes from each school were randomly assigned to either the experimental (Jigsaw method) or control groups. The findings demonstrated that students in the experimental group had significantly greater positive attitudes toward the teaching approach. Tran (2019) explored whether cooperative learning is more successful than lecture-based learning in improving students' attitudes and motivation in higher education. The study included 72 second-year Vietnamese students from An Giang University's Faculty of Education, who were separated into two groups: 36 experimental students and 36 control students. The experimental group, which was exposed to cooperative learning, had considerably higher learning motivation than the control group, which was taught using standard lecture techniques. The findings indicate that cooperative learning should be adopted to improve learning outcomes.

Gambari and Yusuf (2017) investigated the impact of computer-supported cooperative learning practices on secondary school students' performance, attitudes, and retention in physics. The study included 167 second-year physics students from four senior high schools in Minna, Niger State, Nigeria. They were placed into four groups: STAD, Jigsaw II, TAI, and ICI. The experimental groups comprised computer-supported STAD (46 students), computer-supported Jigsaw II (42 students), and computer-supported TAI (41 students), whereas the control group (38 students) got individualized computer instruction (ICI). The study discovered that all three computer-supported cooperative learning methodologies significantly enhanced student attitudes toward physics compared to ICI. Ural, Ercan, and Gençoğlan's (2017) study on learners' attitudes towards cooperative learning in school indicated considerable beneficial benefits. The study used a quantitative methodology and included 65 male elementary non-native English speakers aged 16 to 18, all of whom were new to the Department of Common first year. Participants reported that cooperative learning facilitated learning, boosted motivation, improved teacher-student connections, and encouraged idea expression. The technique was viewed as creating a friendly environment, assisting with grasping complicated topics, and encouraging cooperation, with more adept learners assisting others who were less experienced. The study emphasizes the benefits of cooperative learning for attitudes, motivation, interaction, and overall learning results.

Students' alternative conceptions of concepts in electronics

Students often have alternative conceptions about various sub-concepts in electronics, as reported in textbooks and research. For example, in band theory of solids, many students believe that electrons are always free to move in solids (Woods-Robinson et al., 2020). In reality, this is true only for conductors, where electrons in the conduction band can move freely. In insulators and semiconductors at low temperatures, most electrons are in the valence band and cannot move freely (Rockett, 2007). The large energy gap in insulators prevents electrons from moving to the conduction band, while in semiconductors, the smaller gap allows some electrons to move to the conduction band when thermal energy is sufficient.

Students also mistakenly believe that there are no energy gaps in conductors (Wittmann, Steinberg, & Redish, 2002). While it is true that conductors have overlapping valence and conduction bands, this does not mean there is no energy gap. Instead, the energy gap is either negligible or non-existent due to the overlap, allowing electrons to move freely and making conductors efficient at conducting electricity. Understanding this nuance is crucial for grasping why conductors behave differently from insulators and semiconductors. Additionally, students often think that all semiconductors are the same (Peter & Cardona, 2010). In reality, semiconductors vary significantly in their band gaps and electrical properties. For instance, silicon, with a band gap of about 1.1 eV, differs from germanium, which has a band gap of about 0.66 eV. These differences affect their electrical characteristics and suitability for various applications. Silicon is widely used in most electronic devices due to its stable properties and abundant availability, while germanium is used in some high-speed devices.

Another misconception students hold is that insulators cannot conduct electricity at all (Rockett, 2007; Peter & Cardona, 2010). In reality, insulators can conduct electricity if subjected to high enough voltages, causing a phenomenon known as electrical breakdown. During breakdown, the high voltage provides sufficient energy for electrons to transit from the valence band to the conduction band, aiding current to flow. This process can damage the insulating material and is not typical of normal operating conditions. Another misconception is that all semiconductors are intrinsic (Yacobi, 2003). However, most practical semiconductors are extrinsic, meaning they are doped with impurities to control their electrical properties. Intrinsic semiconductors are pure and have limited conductivity. Doping introduces donor or acceptor atoms, enhancing the material's ability to conduct electricity and enabling the creation of p-type and n-type semiconductors, which are essential for electronic devices. Additionally, students may believe that higher doping levels always improve conductivity. While doping increases the number of charge carriers, excessive doping can lead to increased scattering of these carriers, reducing their mobility and, consequently, the material's conductivity. Optimal doping levels are crucial to balance the number of carriers and their mobility for efficient device performance.

Students often have alternative conceptions about p-n junctions. One such misconception is that the depletion region is always neutral (Fruchtman et al., 2008). In reality, the depletion region in a p-n junction is not electrically neutral;

it contains ionized donor and acceptor atoms that create an electric field. While the overall charge is balanced, with positive charges on one side and negative charges on the other, leading to an electrically neutral region as a whole, this electric field is crucial for the junction's rectifying behaviour, allowing current to flow primarily in one direction. Another misconception is that p-n junctions always allow current to flow easily (Fruchtman et al., 2008). Scientifically, p-n junctions do not always permit easy current flow. They allow current to flow readily in the forward-biased direction but block it in the reverse-biased direction, up to a certain voltage. This blocking capability is essential for diodes' rectifying function, enabling them to convert alternating current (AC) to direct current (DC). Significant current flows in the reverse direction only when the reverse bias exceeds a specific breakdown voltage, which can damage the diode if not controlled.

One alternative conception the students hold about rectification and biasing is that diodes conduct equally well in both directions (Fruchtman et al., 2008). However, diodes are designed to conduct current primarily in one direction (forward bias) and block current in the opposite direction (reverse bias). In forward bias, the diode's internal barrier is reduced, allowing current to flow. In reverse bias, the barrier is increased, preventing current flow except for a small leakage current due to minority carriers. This rectifying behaviour is fundamental for applications like converting AC to DC. Another misconception is that reverse bias completely stops current flow (Yacobi, 2003). In reality, a diode in reverse bias does not completely stop current flow; a small leakage current still flows due to minority carriers. This leakage current is typically very small compared to the forward current and results from the thermal generation of electron-hole pairs within the diode. Understanding this behaviour is crucial for designing circuits that rely on precise current control.

Students hold some alternative conceptions about transistors (Khin et al., 2024). First, they may think that transistors are just like resistors with variable resistance. However, transistors are much more than variable resistors. They are active components capable of amplifying signals and switching currents. Their operation involves complex interactions of charge carriers in different regions. For example, in a bipolar junction transistor (BJT), small changes in the base current result in large changes in the collector current, enabling amplification. This is due to the transistor's ability to control a large current flow with a small input current, a fundamental property that resistors do not possess. The second misconception is that increasing the voltage always increases current in a transistor (Yacobi, 2003). However, in a transistor, increasing the voltage does not always result in a corresponding increase in current. Beyond a certain point, known as saturation, the current becomes relatively constant, and further increases in voltage do not significantly affect the current. Additionally, if the voltage exceeds certain limits, it can lead to breakdown and damage to the transistor.

Very few research has been done on students' alternate conceptions of electronics. Chen et al. (2013), for example, studied the impact of a simulation-based learning environment supported by a conceptual change model on the correction of electronic misunderstandings. This study aimed to clarify common misconceptions regarding diodes and develop a conceptual-change learning system utilising simulation-based learning methodologies and prediction-observation-explanation (POE). A total of thirty-four sophomore engineering students took part in the experiments. The results demonstrated that the method effectively corrected students' wrong conceptions about diodes and enhanced their performance. The study also demonstrated that POE could effectively correct misconceptions by generating scenarios that are at odds with preexisting knowledge structures. More than 80% of misconceptions about diode models and semiconductor characteristics were corrected. However, difficulty in correcting misconceptions depends on the fundamental definition of voltage, circuit analysis, or the interaction between different diode concepts.

Summary of Literature Review

Constructivism guided this investigation, incorporating Dweck's growth mindset theory, Posner et al.'s theory of conceptual change, and Slavin's perspectives on cooperative learning. Constructivism posits that understanding is built through experiences and reflection (Bada & Olusegun, 2015). Influential figures like Dewey, Piaget, Vygotsky, Bruner, and Ausubel have contributed to this paradigm, emphasizing social interaction and active thinking in learning (Bada & Olusegun, 2015; Cakir, 2008). Constructivist pedagogies are student-centred, fostering collaborative and cooperative learning to connect new information to existing knowledge (Dewey, 1938; Prince & Felder, 2006). This approach enhances educational experiences, promoting cooperative learning and conceptual change (Bruner, 1996; Dewey, 1938; Piaget, 1977; Posner et al., 1982; Vygotsky, 1978).

Students articulate and build on each other's ideas in group settings, deepening comprehension (Ramos-Vallecillo et al., 2024).

Cooperative learning, supported by research over 30 years, improves academic and social outcomes by fostering collaboration (Johnson & Johnson, 2004; Lou et al., 1996; Slavin, 1996). Ecclesiastes 4:9-10, 12 underscores the value of cooperation. Effective cooperative learning involves mixed-ability groups working toward common goals (Mercer, Wegerif, & Dawes, 1999; Webb & Mastergeorge, 2003). Slavin's Four Theoretical Perspectives - motivational, social cohesion, cognitive-developmental, and cognitive elaboration - explain its effectiveness (Yang, 2023). These perspectives enhance motivation, social connections, cognitive development, and deep information processing (Deci & Ryan, 2012; Schiefer & Van der Noll, 2017; Dyson et al., 2021). Johnson and Johnson's model outlines five essential elements: positive interdependence, face-to-face interaction, individual accountability, interpersonal and small group skills, and group processing (Morgan & Keitz, 2010). Popular cooperative learning models include STAD and Jigsaw. STAD is simple to implement and fosters both individual and group success (Aslan, Berzener & Deneme, 2021). Jigsaw promotes cooperation and deep understanding, reducing competition and fostering empathy (Amin, Nur & Damayanti, 2020; Karacop, 2017).

Conceptual change, involving updating or relinquishing ideas to align with scientific theories, requires modifying prior knowledge (Özdemir & Clark, 2007; Hayes et al., 2022). Posner et al.'s conceptual change theory emphasizes dissatisfaction with current understanding, intelligibility, plausibility, and fruitfulness as necessary conditions (Hewson, 1992). Inquiry-based or constructivist education promotes conceptual change by addressing students' preconceptions and introducing cognitive conflict (Özdemir & Clark, 2007). Cooperative learning supports conceptual change by exposing students to diverse perspectives and encouraging active engagement (Gill et al., 2022). Peer teaching and feedback in models like STAD and Jigsaw deepen understanding and facilitate conceptual shifts (Matuk & Linn, 2023).

Dweck's growth mindset theory posits that abilities can be developed through effort, fostering resilience and a love for learning (Yeager & Dweck, 2020). Students with a growth mindset view challenges as opportunities for growth and use effort and feedback to improve (Rhew et al., 2018). Educators can foster this mindset by praising effort and strategies, providing challenging tasks, and creating a supportive environment (Jennings & Cuevas, 2021). Collaborative learning and peer feedback also support a growth mindset (Yeager & Dweck, 2020).

In summary, constructivism encourages cooperative learning, conceptual transformation, and positive attitudes and motivation, fostering an active, student-centred learning environment. It promotes teamwork, clears misunderstandings, improves comprehension, and increases intrinsic motivation, leading to successful educational experiences.

CHAPTER THREE

RESEARCH METHODS

This chapter defines the research methods of the study. The demographic, sampling strategy, data collection instruments, data processing and analysis, and study design are all covered.

Research Design

This study used a quasi-experimental design, especially the pretest-posttest non-equivalent group treatment design (Cohen, Manion, & Morrison, 2007; Creswell, 2012), to investigate the effects of STAD and jigsaw cooperative learning models on Form 2 SHS science students' learning outcomes in electronics, such as achievement, conceptual changes, attitude, and motivation. This method was selected because it enables the utilisation of entire classrooms in their natural settings without randomly assigning students to groups (Cohen & Manion, 1994; Creswell, 2012). Although this design may have lower internal validity compared to randomised experiments due to uncontrolled extraneous variables and potential interaction between experimental groups (Trochim, 2000), these issues are mitigated by the geographical separation of the schools and the boarding status of most students, reducing the likelihood of interaction.

To carry out this quasi-experimental design, two entire classes from various senior high schools teaching the General Science program were randomly allocated to two groups: Experimental Group 1 (STAD model) and Experimental Group 2 (Jigsaw model). The researcher taught the concepts to both groups. In the first step, students in each group completed an electronics pretest to examine their entry knowledge, followed by a Group Assessment of Logical Thinking (GALT) test to classify them as HD, MA, or EI thinkers. The intervention took place in the second phase, during which each group was taught either the STAD or Jigsaw cooperative learning models. In the final phase, students took a posttest to measure their academic achievements and conceptions. They also completed two questionnaires to assess their attitudes and motivation towards learning post-intervention. The independent variable was the cooperative learning method (STAD or Jigsaw), while the dependent variables were the students' achievement scores and their responses to the attitude and motivation scales.

This design utilised both quantitative and qualitative data collection methods. Quantitative data were obtained from achievement tests and questionnaires assessing attitudes and motivation. Qualitative data came from the open-ended sections of the achievement tests, both pretest and posttest, which provided insights into how students' conceptions evolved throughout the study.

Population

Form 2 students from 10 public senior high schools in the Cape Coast metropolis that offer the general science programme made up the study's target population. Students in Form 2 were deliberately chosen because, as per the curriculum for physics, electronics - a major area of study - is taught in the second term of the second year (Ministry of Education, 2010).

Sampling Procedure

The sample comprised 103 second-year science students from two classes in two separate high schools in the Cape Coast Metropolis. These schools were randomly selected from a pool of ten using computer-generated random numbers. Within each chosen school, one intact science class was randomly selected to participate. The assignment of students to the STAD and Jigsaw cooperative learning model groups was also done randomly. Additionally, students were categorised into HD, MA, and EI levels based on their GALT scores, which facilitated the formation of cooperative learning groups.

Data Collection Instruments

Five instruments were used for data collection: the Electronics Achievement Test (EAT), the Electronic Conception Test (ECT), attitude and motivation scale questionnaires, and the Group Assessment of Logical Thinking (GALT) test. Both the EAT and ECT were developed by the researcher following a thorough literature review and were used for the pretest and posttest. The EAT (refer to Appendix A), which was used to determine students' level of achievement, consisted of 30 multiple-choice questions with four options each, covering the five key topics addressed in the physics syllabus for senior high school.

The ECT comprised 10 two-tier items designed to assess students' conceptual understanding of electronics (refer to Appendix B). Each item had two components: the first tier included multiple-choice questions with four options, while the second tier required students to explain their reasoning for selecting a particular option. This structure aimed to reveal students' alternative conceptions and provide deeper insights into their understanding of the concepts.

Questionnaires measuring students' attitudes toward learning (refer to Appendix C) and motivation (refer to Appendix D) made up the third and fourth data-collecting tools. These measures were developed by adapting attitude and motivation scales that were previously available in the literature. The items were changed to better fit the study's objectives. Following the two sessions of intervention, items on these assessments assisted in demonstrating whether or not students are motivated and have established acceptable attitudes about learning.

The GALT test, created by Roadrangka, Yeany, and Padilla (1983), was the fifth tool used to assess students' reasoning skills. It was divided into several subscales, including combinatorial, probabilistic, conservational, proportional, controlling variables, and probabilistic reasoning. GALT was implemented and is used to assess students' degree of reasoning proficiency. This assisted in determining the formation group's HD, MA, and EI reasoning levels for the two cooperative learning approaches.

Validity

All five instruments' construct validity and content were assessed by having my supervisor and two other seasoned physics educators review the material to make sure the domains were sufficiently covered. The group of supervisors and the two physics lecturers from Science Education reviewed the five lesson plans that were created to teach the fundamentals of electronics to provide their evaluation. These made it possible to make more changes to get the study's final shape.

Pilot testing

Two of the instruments (EAT and ECT) were field tested after being adjusted following expert recommendations. To assess their reliability and validity, the examinations were conducted on Form 3 students enrolled in optional physics at one of Komenda-Edina-Eguafo-Abirem Municipal's senior high schools. Students in Form 3 were picked. They were more equipped to respond to the questions because they had learned electronics in Form 2.

Reliability

The EAT and ECT were completed in about an hour by the seventy Form 3 students who participated. The range of the students' overall scores on ECT was 0 to 30 out of 30 items, whereas the range on ECT was 0 to 20 out of 10 items. The reliability coefficient for the ECT, as determined by Cronbach alpha, was .79, while the reliability coefficient for the EAT, as determined by the KR-20 formula, was .75. Since there were three levels of scoring (a correct choice selected and a matching correct explanation granted two points; a correct option chosen and an incorrect explanation rewarded one mark; while a wrong option with an appropriate explanation was given one mark), the ECT employed Cronbach alpha. The EAT used KR-20 because the items were dichotomously scored. Soon after the test, both the EAT and ECT question papers and response sheets were collected.

Data Collection Procedures

To assess students' understanding of electronic concepts (i.e., pretest) and scientific reasoning abilities before the treatments, the researcher worked with the teachers in the two classes to administer the EAT, ECT, and GALT to the STAD and Jigsaw groups. The researcher got permission from the two schools' headmasters, department heads, and physics teachers to use the classes in question for the study. The researcher next divided the students in both groups into four or five-member diverse ability groups. These skill-mix groupings of pupils were formed based on their GALT results. Students who scored between 0 and 3 were categorised as EI students, those who scored between 4 and 7 as MA students, and those who scored between 8 and 12 as HD students, according to Lou et al. (1996). The Jigsaw group was taught using the Jigsaw cooperative learning model by the researcher with assistance from the permanent physics teacher, whereas the STAD group was instructed using the STAD cooperative learning model (see Appendix E for a sample lesson).

Following the interventions, posttests on the EAT and ECT were given. Additionally, the motivation and attitude questionnaires were given out. The pretest, intervention, and posttest phases of the study took place over two months.

Description of interventions

The two teaching strategies employed in this study are both student-centred, therefore the students received all necessary instructional materials - texts and videos - at least one day prior to the start of each lesson. Students were able to get ready for every class far in advance because to this.

STAD cooperative learning model.

The five main steps of the STAD cooperative learning paradigm were followed in this investigation.

a. Preparation
    1. The teacher pre-prepared lessons on electronics sub-concepts.
    2. After administering the GALT test during the pretest phase, the teacher divided the class into four to five heterogeneous-ability members. Throughout the investigation, these groupings remained intact.

b. Teaching
    1. The teacher incorporates videos into the traditional teaching approach to deliver the lesson to the full class.

2. The teacher highlights the key ideas and abilities that students must acquire.

c. Team Study

1. After the teacher has given the lesson, students work in groups to master the material. They assist one another in understanding the material, solve problems, and finish exercises.
2. The teacher supplies the students with the resources they need, including textbooks, prepared notes, and videos on phones, tablets, and laptops.

d. Individual Assessment

1. Students completed individual examinations or quizzes on the material they had learned. The purpose of these tests was to gauge each student's comprehension of the topic in question.
2. To guarantee individual responsibility, students completed these tests independently.

e. Closure

1. To conclude the class, the teacher asks groups to do a presentation of their task.
2. The teacher acknowledges and rewards group efforts. This is accomplished by determining the team score based on how well each team member performed in comparison to their prior results. This motivates every student to play a part in the success of the team.
3. The topic and resources for the following lesson are given by the teacher.

Jigsaw cooperative learning model.

The Jigsaw cooperative learning paradigm utilized in this study proceeded through three major stages, shown in Figure 2.

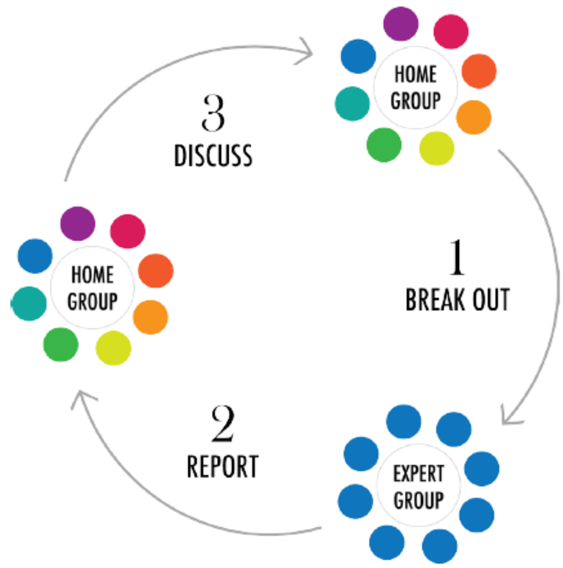

Figure 2: Principal stages of the Jigsaw cooperative learning model

These three principal stages - breakout, report and discuss - followed 12 very important steps to make the implementation of the Jigsaw cooperative learning model complete. Each stage and the specific steps followed is presented in Table 1.

Table 1: Principal Stages and Steps in Jigsaw Cooperative Learning Model

Stage	Steps
Breakout into groups	1. Teacher placed students into 4 to 5 heterogeneous-ability members after taking the GALT test at the pretest stage and allocate each one a number (i.e., 1, 2, 3, 4). This formed their home group. 2. One of the high-ability students was from each of the groups as the leader. 3. Students were asked to find others with the same number as them and create a separate group. This formed the expert group. This group was also heterogeneous in nature. 4. The day's lesson was divided into 4 to 5 segments or subtopics. 5. Each expert group was assigned a subtopic. Individual students were given time to read over their subtopics for at least twice in order to become familiar with it. The subtopics were given to them at least a day before the main lesson. 6. Before the lesson, the teacher provides students with necessary resources such as textbooks, pre-prepared notes, and videos on phones, tablets and laptops to help students make references. 7. During the lesson, students in their expert groups were given time to discuss the main points of their subtopic and to rehearse the presentation they will make to their jigsaw group (home group). As a group, they determined a way to explain their piece of the puzzle to others.
Report back to home group	8. Students were brought back into their home jigsaw group. 9. Students explain their piece of the puzzle, ensuring that all their home group members understand the material. Students in each group were encouraged to ask questions for clarification. 10. The teacher moved from one group to another to observe the process and help those in difficulties.
Discuss with home group	11. Students were asked to connect the various pieces and put together the whole jigsaw, so that students are able to see where each part fits into the bigger picture.
Summary	12. Teacher discussed the whole Jigsaw with students and gave a test to the students on the materials learnt for the day. Students were made aware that the scores obtained count to their overall gains.

Sources (Amedu & Gudi, 2017; Andarini, 2014).

Data Processing and Analysis

Data for question one was investigated using means and standard deviations, which are the most acceptable statistical tools for assessing students' achievement levels in electronics. Frequencies, percentages, means, standard deviations, the independent samples t-test, and the paired samples t-test were the instruments employed to answer research question two. These tools were the most suitable as frequencies and percentages effectively illustrate the response patterns, while the mean and standard deviation are useful for assessing the level of students' conceptual understanding. The independent samples t-test was used to compare the mean scores of students' understanding of electronics concepts between those taught using the STAD and Jigsaw cooperative learning methods in the pretest and posttest. Additionally, the paired samples t-test facilitated the comparison of pretest and posttest results within both the STAD and Jigsaw groups.

Means, standard deviations, and MANOVA were used for analysing the data for research question three. Means and standard deviations were adequate for assessing the extent to which STAD and Jigsaw increased students' motivation and attitudes toward learning electronics. MANOVA was used to examine students' motivation and attitudes (dependent variables) toward learning in two separate groups.

Null hypothesis one was tested using the independent samples t-test and the paired samples t-test. The independent samples t-test was ideal for comparing the mean scores of students' achievements between the STAD and Jigsaw groups in the pretest and posttest. Students' achievements from pretest to posttest for both the STAD and Jigsaw groups were compared using the paired samples t-test.

The McNemar Chi-Square test was used to determine the significance of change under Null Hypothesis 2. This test was chosen because it properly assesses the extent of students' change in conceptions from pretest to posttest. This test was administered using a table that reflected students' pretest and posttest responses. Figure 3 displays the table's properties, with positive (+) and negative (-) marks representing different student responses.

		Afterwards -	Afterwards +
Earlier	+	A	B
	-	C	D

Figure 3: A table used to assess changes in conception

The "–" symbol indicates if an alternative conception existed before to or during the intervention, but the "+" symbol indicates that one did not. If a student's notion shifts from "+" to "–," they are classified in cell "A," and if it shifts from "–" to "+," they are classified in cell "D." Thus, only cells "A" and "D" show variations in conception before and after the intervention. In contrast, if the student's notion remains unchanged, they are classified in cell 'B' if their response is '+' both before and after and in cell 'C' if their reaction is '–'. McNemar formula is derived from these as follows:

$$\chi^2 = \frac{(|A-D|-1)^2}{A+D} \quad \text{with } df = 1$$

This equation is used to determine the amount of change between the pretest and posttest conceptions. According to Glantz (2005), a critical value of 3.84 at α =.05 and df = 1 shows a substantial influence on pretest and posttest reasoning. If $\chi^2 \geq$

3.84, the null hypothesis of identical proportions between groups is rejected due to a p-value smaller than 0.05.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents and analyses the findings in relation to the research questions and the hypotheses tested. Each hypothesis was evaluated at a 0.05 level of significance.

Pre-Experimental Study Results

To examine the assumptions for using parametric analytical methods to test the two hypotheses, pre-experimental screening of the data was conducted. For the STAD and Jigsaw groups, these include the presumptions regarding the size of the sample, the degree of measurement, random sampling, the existence of outliers, the normal distribution, the independence of observation, and the homogeneity of variance. To determine if parametric analyses ought to be the most reliable method for analysing this study, these presumptions were put to the test.

The assumption of a large sample size was upheld, as the 103 students selected from the schools provided an adequate sample. Pallant (2020) and Tabachnick and Fidell (2013) support this, indicating that a sample size of 30 or more is suitable for this type of research. The participating students were randomly selected. To maintain the independence of observation, students were required to complete the Electronics Achievement Test (EAT), Electronics Conception Test (ECT), and attitude and motivation questionnaires alone and without contacting colleagues. For this reason, before students reacted to the instruments, the researcher spaced them with the help of the permanent teachers. This assumption was also not violated.

The level of measurement for EAT and ECT were at the interval scale since they were scores obtained from students' performances. Though the questionnaires for attitude and motivation were created using a five-point Likert scale, which is conventionally ordinal in nature, the output is interpreted as an interval scale since they become scores and so marked by equal intervals. This assumption was also not violated.

By investigating the presumptions of outliers and normalcy, the data for the two independent variables (STAD and Jigsaw cooperative learning models, i.e., teaching method) and the dependent variables (scores from EAT and ECT). These procedures were carried out for both the pretest and posttest. Table 2 presents the analysis of outliers for the EAT and ECT pretest scores. As indicated in Table 2, no outliers were identified in the EAT and ECT pretest scores for either group.

Table 2: Assumption of outliers for EAT and ECT pretest scores

Dependent variable	**Group**			**Case Number**	**Value**
EAT pretest	STAD	Highest	1	39	13.0
			2	6	12.0
			3	15	12.0
			4	16	12.0
			5	17	12.0[a]
		Lowest	1	20	6.0
			2	11	6.0
			3	10	6.0
			4	35	7.0
			5	34	7.0[b]
	Jigsaw	Highest	1	55	14.0
			2	44	13.0
			3	47	13.0
			4	48	13.0
			5	50	13.0[c]

Table 2, Continued

		Lowest	1	86	2.0
			2	56	5.0
			3	100	6.0
			4	97	6.0
			5	96	6.0[d]
	STAD	Highest	1	21	13.00
			2	6	12.00
			3	24	12.00
			4	10	11.00
			5	16	11.00
		Lowest	1	8	2.00
			2	39	3.00
			3	35	3.00
			4	28	3.00
			5	25	3.00[e]
ECT pretest	Jigsaw	Highest	1	92	13.00
			2	62	12.00
			3	51	11.00
			4	68	11.00
			5	96	11.00
		Lowest	1	93	2.00
			2	52	3.00
			3	99	4.00
			4	91	4.00
			5	87	4.00[f]

Table 3 shows the analysis of outliers for EAT and ECT posttest scores. As shown in Table 3, there were no outliers detected for EAT and ECT posttest scores for both groups. This suggests that the pretest and posttest scores for EAT and ECT across both groups fell within an acceptable range, indicating consistency in the data.

Table 3: Assumption of outliers for EAT and ECT posttest scores

Dependent variable	Group			Case Number	Value
EAT posttest	STAD	Highest	1	23	29.00
			2	15	26.00
			3	21	26.00
			4	27	26.00
			5	41	26.00
		Lowest	1	37	14.00
			2	28	15.00
			3	22	15.00
			4	20	15.00
			5	3	15.00
	Jigsaw	Highest	1	43	29.00
			2	47	29.00
			3	56	29.00
			4	61	29.00
			5	73	29.00[a]
		Lowest	1	102	15.00
			2	91	15.00
			3	95	16.00
			4	81	17.00
			5	74	17.00
ECT posttest	STAD	Highest	1	4	17.00
			2	10	17.00
			3	24	17.00
			4	41	17.00
			5	17	16.00[b]
		Lowest	1	26	10.00
			2	32	11.00
			3	23	11.00
			4	27	12.00
			5	22	12.00[c]
	Jigsaw	Highest	1	101	19.00
			2	43	18.00
			3	51	18.00
			4	58	18.00
			5	63	18.00[d]
		Lowest	1	98	12.00

Table 3, continued

	2	102	13.00
	3	97	13.00
	4	95	13.00
	5	82	13.00[e]

However, further analyses were done to check whether the assumption was violated or not for the variable. These were done by removing the top and bottom 5 % (i.e., 5 % trimmed mean) of the scores of the variables and then new mean values calculated. As shown in Table 4, the original mean values and the new trimmed mean values are very similar indicating no presence of outliers and therefore there were no violations of this assumption for scores of EAT and ECT.

Table 4: Comparison of original and trimmed means for EAT and ECT pretest and posttest scores

Dependent variable	Independent variables		Statistic
EAT pretest	STAD	Mean	9.68
		5% Trimmed Mean	9.73
	Jigsaw	Mean	10.02
		5% Trimmed Mean	10.15
ECT pretest	STAD	Mean	6.66
		5% Trimmed Mean	6.57
	Jigsaw	Mean	6.85
		5% Trimmed Mean	6.78
EAT posttest	STAD	Mean	21.12
		5% Trimmed Mean	21.14
	Jigsaw	Mean	23.03
		5% Trimmed Mean	23.13
ECT posttest	STAD	Mean	14.24
		5% Trimmed Mean	14.30
	Jigsaw	Mean	15.27
		5% Trimmed Mean	15.25

To test whether the data sets for the variables were normally distributed, several analyses were done. First, skewness and kurtosis values were inspected. Table 5 reveals positive and negative skewness and kurtosis values for the variables, indicating that the scores were distributed toward the left and right at relatively high values, with noticeable peaks. This suggests that the data did not follow a normal distribution. Nonetheless, Tabachnick and Fidell (2013) note that with sufficiently large sample sizes, deviations in skewness and kurtosis are unlikely to have a significant impact on the analysis.

Table 5: Comparison of original and trimmed means of STAD and Jigsaw scores

Dependent variable	Independent variables	Descriptive	Pretest	Posttest
EAT scores	STAD	Skewness	-.400	-.188
		Kurtosis	-.983	-.686
	Jigsaw	Skewness	-.767	-.005
		Kurtosis	.394	-.949
ECT scores	STAD	Skewness	.602	-.395
		Kurtosis	.180	-.251
	Jigsaw	Skewness	.523	.362
		Kurtosis	-.014	-.724

Additionally, the Kolmogorov-Smirnov and Shapiro-Wilk tests were conducted to further assess the normality of the score distributions. As shown in Table 6, results for both STAD and Jigsaw scores, EAT and ECT pretest and posttest, were non-significant with very few significant results. These suggest a slight violation of the assumption and so require further investigations.

Table 6: Test for normality for STAD and Jigsaw scores

Dependent variable	Group	Kolmogorov-Smirnov[a] Statistic	df	p	Shapiro-Wilk Statistic	df	p
EAT pretest scores	STAD	.159	41	.051	.920	41	.047
	Jigsaw	.175	62	.074	.929	62	.053
ECT pretest scores	STAD	.180	41	.062	.938	41	.066
	Jigsaw	.178	62	.070	.960	62	.040
EAT posttest scores	STAD	.108	41	.200	.966	41	.250
	Jigsaw	.147	62	.042	.941	62	.055
ECT posttest scores	STAD	.152	41	.089	.953	41	.088
	Jigsaw	.189	62	.090	.933	62	.062

Again, the normal Q-Q plots and boxplots were inspected to support the non-violation of the normality assumption. The normal Q-Q plots presented in Figures 4 and 5 displayed reasonably straight lines, and approximately 50% of the scores fell within the whiskers of the boxplots for both the pretest and posttest scores in the STAD and Jigsaw groups. These findings further support the conclusion that the assumption of normality was not violated. Finally, the detrended normal Q-Q plots for the scores indicated clustering of plotted scores around the zero-line indicating fairly normal distribution of the scores. The fairly non-violation of these assumptions of normality shows that parametric analysis can be performed for all the data collected for this study without doubts of any kind.

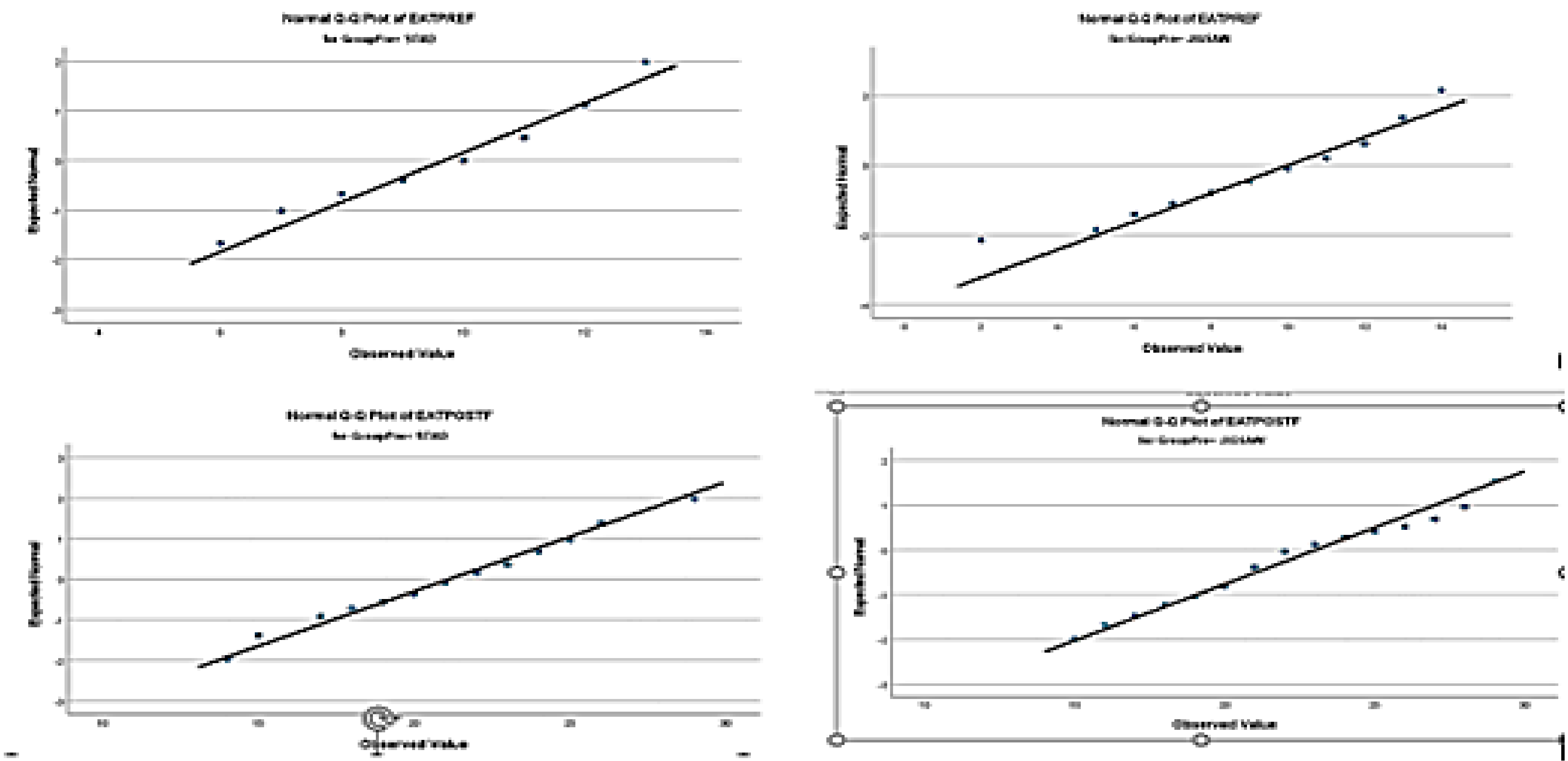

Figure 4: STAD and Jigsaw Normal Q-Q plots for pretest and posttest EAT scores.

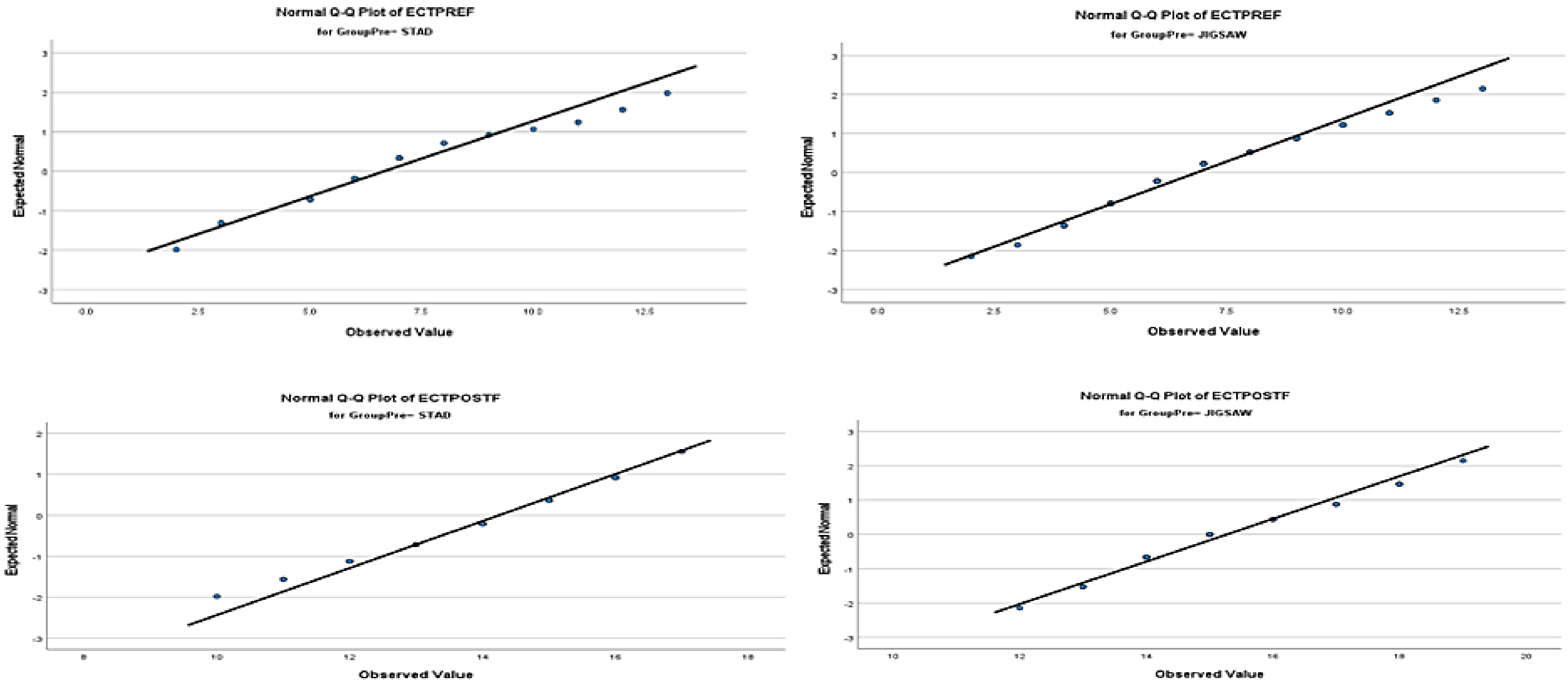

Figure 5: STAD and Jigsaw Normal Q-Q plots for pretest and posttest ECT scores.

Level of Students' Achievement of Concepts in Electronics Taught with STAD and Jigsaw Cooperative Learning Models

The first research question explored the extent of students' achievement in electronic concepts using the STAD and Jigsaw cooperative learning strategies. To address this, the score distributions for both the STAD and Jigsaw groups were examined for the pretest and posttest. Table 7 provides a summary of these score distributions.

Table 7: Score distributions of pretest and posttest for the STAD and Jigsaw groups

STAD (N = 41)						Jigsaw (N= 62)					
Pretest			Posttest			Pretest			Posttest		
Score	N	%	Score	N	%	Score	N	%	Score	N	%
6	3	7.3	14	1	2.4	2	1	1.6	15	2	3.2
7	6	14.6	15	4	9.8	5	1	1.6	16	1	1.6
8	2	4.9	17	4	9.8	6	5	8.1	17	2	3.2
9	6	14.6	18	1	2.4	7	2	3.2	18	3	4.8
10	7	17.1	19	3	7.3	8	8	12.9	19	2	3.2
11	8	19.5	20	3	7.3	9	6	9.7	20	5	8.1
12	8	19.5	21	6	14.6	10	11	17.7	21	13	21.0
13	1	2.4	22	2	4.9	11	4	6.5	22	4	6.5
			23	5	12.2	12	15	24.2	23	4	6.5
			24	4	9.8	13	8	12.9	24	4	6.5
			25	3	7.3	14	1	1.6	25	2	3.2
			26	4	9.8				26	3	4.8
			29	1	2.4				27	4	6.5
									28	6	9.7
									29	7	11.3

As shown in Table 7, it can be observed that the pretest scores for the STAD group ranged from 6 to 13 while those of the Jigsaw group ranged from 2 to 14. Also, the posttest scores for the STAD group ranged from 14 to 29 while those of the Jigsaw group ranged from 15 to 29. These give an overview of how the scores for the STAD and Jigsaw groups were distributed.

The research question was analysed using the mean and standard deviation. A mean value of 0–10 was regarded as low achievement, 11–20 as moderate achievement, and 21–30 as high achievement in the interpretation of these results. It should be noted that simple approximation rules apply. Table 8 displays the average scores and variability for the STAD and Jigsaw groups on the pretest and posttest scores.

Table 8: Means and standard deviations of STAD and Jigsaw groups for pretest and posttest scores

	Pretest		**Posttest**	
	M	**SD**	**M**	**SD**
STAD (N = 41)	9.68	2.01	21.12	3.71
Jigsaw (N = 62)	10.02	2.49	23.03	3.97

Table 8 shows that students' initial achievement scores were low in the STAD group [*M* = 9.68, *SD* = 2.01] and the Jigsaw group [*M* = 10.02, *SD* = 2.49]. The spread around the mean was relatively small for the STAD group, ranging from 7.67 to 11.69, and similarly small for the Jigsaw group, ranging from 7.53 to 12.51. This indicates that both groups appear similar in achievement and started the interventions at almost the same level.

As shown in Table 8, the level of students' achievement in the posttest means scores for both the STAD [*M* = 21.12, *SD* = 3.71] and Jigsaw [M = 23.03, SD = 3.97] groups were high based on the pre-established criteria. The spread of the posttest scores around the mean for the STAD group was small ranging from 17.41 – 24.83 while that of the Jigsaw group was also small ranging from 19.06 – 27.00. Although the STAD group's mean score appears higher than Jigsaw's, both groups achieved highly. This implies that the level of students' achievement of electronic concepts taught with STAD and Jigsaw cooperative learning models was reasonably high.

Difference in Students' Achievement of Concepts in Electronics between Senior High School Students taught using STAD and Jigsaw Cooperative Learning Models

The first null hypothesis of this study sought to assess whether a statistically significant difference existed between senior high school students taught using Jigsaw cooperative learning and STAD methods regarding their mean achievement scores in electronics concepts. Before testing this hypothesis, Levene's test of equality of variance was conducted to verify the assumption of homogeneity of variance. The findings indicated that the variances in mean scores for students in the STAD and Jigsaw groups were considered equal [$F = 1.246$, $p = .267$]. This finding was further supported by the posttest Levene's test for equality of variance [$F = .697$, $p = .406$]. Consequently, an independent-samples t-test was conducted to compare the pretest results of the two groups. able 9 shows that, regarding EAT scores before instruction, there was no statistically significant difference between the Jigsaw group [$M = 10.02$, $SD = 2.49$] and the STAD group [$M = 9.68$, $SD = 2.01$], as indicated by the independent-samples t-test [$t(101) = .717$, $p = .475$]. The findings show that, on average, students in both groups began the treatments with almost the same degree of understanding and had similar preconceptions about electronics concepts.

Table 9: Independent Samples t-test results for STAD and Jigsaw Groups' Pretest Scores

	N	M	SD	t	df	p
STAD	41	9.68	2.01			
				.717	101	.475
Jigsaw	62	10.02	2.49			

p > .05 not statistically significant

Since there were no significant differences in pretest mean scores between the STAD and Jigsaw groups, paired samples t-tests were conducted within each group to compare pretest and posttest mean scores. According to Table 10, the STAD group demonstrated a statistically significant improvement from pretest [M = 9.68, SD = 2.01] to posttest [M = 21.12, SD = 3.71], t(40) = 19.787, p < .001. The effect size for this improvement was 1.11, indicating a moderate effect and suggesting that the STAD cooperative learning model accounts for approximately 11.1% of the variance in students' posttest success.

Table 10: Paired Samples t-test Results for Pretest and Posttest Scores in the STAD and Jigsaw groups

	Variable	N	M	SD	t	df	p
	Pretest	41	9.68	2.01			
STAD					19.787	40	.000*
	Posttest	62	21.12	3.71			
	Pretest	41	10.02	2.49			
Jigsaw					23.332	61	.000*
	Posttest	62	23.03	3.97			

*p<.05 significant

Table 10 reveals that the Jigsaw group showed a significant increase in mean scores from pretest [M = 10.02, SD = 2.49] to posttest [M = 23.03, SD = 3.97], t(61) = 23.332, $p < .001$. The effect size was 1.13, indicating a moderate effect, meaning the Jigsaw cooperative learning model explains approximately 11.3% of the variance in students' posttest success. These findings demonstrate that both cooperative learning methods, STAD and Jigsaw, had substantial positive effects on improving students' understanding of electronic concepts.

An independent samples t-test was performed to examine whether there was a significant difference in posttest mean scores between students who participated in the STAD group and those in the Jigsaw group. The STAD group achieved a mean score of 21.12 with a standard deviation of 3.71, while the Jigsaw group attained a higher mean of 23.03 with a standard deviation of 3.97. The analysis revealed that this difference was statistically significant, t(101) = 2.453, p = .016, indicating that the observed difference in performance was unlikely due to chance. Furthermore, the effect size, quantified as 0.06, suggests a moderate practical significance of the difference between the two groups. This implies that the Jigsaw method had a meaningful impact on students' learning outcomes compared to the STAD method. Based on these findings, the null hypothesis, which proposed no difference in posttest achievement between the groups, was rejected.

Table 11: Results for Posttest for STAD and Jigsaw groups

	N	**M**	**SD**	**t**	**df**	**p**
STAD	41	21.12	3.71			
				2.453	101	.016*
Jigsaw	62	23.03	3.97			

*$p < .05$ statistically significant

Level of Students' Conceptual Understanding of Concepts in Electronics taught with STAD and Jigsaw Cooperative Learning Models

Research question two focused on evaluating the level of students' conceptual understanding of electronic concepts when taught using STAD and Jigsaw cooperative learning models. To address this, the study analysed the students' pretest and posttest scores from the ECT using descriptive statistics. The analysis applied categorisation criteria adapted from Anim-Eduful and Adu-Gyamfi (2021), classifying student understanding into three levels: "no scientific understanding," "partial scientific understanding," and "full scientific understanding." Using this framework allowed for a nuanced assessment of how effectively each instructional method (STAD and Jigsaw) facilitated conceptual grasp of electronic concepts by indicating shifts in understanding from pretest to posttest within and between groups.

The 10 ECT items have a maximum score of two marks each, for a total of 20 marks for the items. For every item, a score of two denotes complete scientific comprehension, a score of one denotes moderate knowledge, and a score of zero denotes no scientific comprehension of the idea. Table 12 presents the criteria used to analyse the degrees of students' conceptual grasp of electronics concepts, which may be used to interpret the mean results.

4. Table 12: Categorisation of Level of Conceptual Understanding

Level	Mean range	Interpretation
1	1.50 - 2.00	Full Scientific Understanding
2	0.50 - 1.49	Partial Scientific Understanding
3	0.00 - 0.49	No Scientific Understanding

Table 13 provides the frequency, percentages, means, and standard deviations used to provide information on the level of conceptual understanding of students taught with the Jigsaw cooperative learning model in the concepts of electronics.

Items 1 and 2 on ECT sought to determine students' level of conceptual understanding of the band theory of solids. As shown in Table 13 for Item 1, students demonstrated partial scientific understanding [M = .63, SD = .68] of statements about the band theory of solids that is incorrect at pretest. The data in Table 13 indicate that before the Jigsaw cooperative learning intervention, 48.4% of students had no scientific understanding of the electronics concepts, 40.3% had partial scientific understanding, and only 11.3% exhibited full scientific understanding. Following the intervention, there was a marked improvement in conceptual understanding, reflected in the posttest mean score (M = 1.51, SD = 0.72). Post-intervention, 64.5% of students demonstrated full scientific understanding, while 22.6% had partial understanding and 12.9% had no scientific understanding. This demonstrates that the Jigsaw model significantly enhanced students' comprehension of electronics concepts.

Item 2 attempted to assess students' grasp of a material's electrical resistivity using the band theory of solids. As indicated in Table 13, students displayed incomplete scientific Understanding [M =.97, SD =.60] during the pretest. This was clear since 19.4% had no scientific understanding, 64.5% had some scientific awareness, and just 16.1% had a complete scientific grasp of the topic. However, at the posttest, students displayed a thorough scientific understanding of the idea [M = 1.69, SD =.72]. It revealed that 8.1% had no scientific understanding, 14.5% had limited scientific awareness, and only 77.4% had a complete scientific grasp of the topic.

Table 13: Results on Level of Students' Conceptual Understanding of Concepts in Electronic taught with Jigsaw Cooperative Learning Model

	Pretest								Posttest							
Item	No Scientific Understanding		Partial Scientific Understanding		Full Scientific Understanding		M	SD	No Scientific Understanding		Partial Scientific Understanding		Full Scientific Understanding		M	SD
	n	%	n	%	n	%			n	%	n	%	n	%		
1	30	48.4	25	40.3	7	11.3	.63	.68	8	12.9	14	22.6	40	64.5	1.51	.72
2	12	19.4	40	64.5	10	16.1	.97	.60	5	8.1	9	14.5	48	77.4	1.69	.62
3	26	41.9	27	43.5	9	14.5	.73	.70	1	1.6	13	21.0	48	77.4	1.76	.47
4	16	25.8	40	64.5	6	9.7	.84	.58	4	6.5	21	33.9	37	59.7	1.53	.62
5	29	46.8	28	45.2	5	8.1	.61	.64	1	1.6	16	25.8	45	72.6	1.71	.49
6	20	32.3	39	62.9	3	4.8	.73	.55	7	11.3	18	29.0	36	59.7	1.48	.69
7	31	50.0	26	41.9	5	8.1	.58	.64	4	6.5	32	51.6	26	41.9	1.35	.60
8	30	48.4	28	45.2	4	6.5	.58	.62	1	1.6	18	29.0	43	69.4	1.68	.50
9	29	46.8	31	50.0	2	3.2	.56	.56	8	12.9	29	46.8	25	40.3	1.27	.68
10	18	29.0	39	62.9	5	8.1	.79	.58	9	14.5	25	40.3	28	45.2	1.31	.74
Grand Mean		**38.9**		**52.1**		**9.0**	**.70**	**.62**		**7.8**		**31.5**		**60.8**	**1.53**	**.61**

Items 3 and 4 on ECT sought to determine students' level of conceptual understanding of the classification of semiconductors. As shown in Table 13 for Item 3, students demonstrated partial scientific understanding [*M* = .73, *SD* = .70] on what determines whether a semiconductor is N-type or P-type at pretest. This was clear, as 41.9% of students lacked scientific understanding, 43.5% had partial understanding, and only 14.5% had a complete understanding of the concept. However, in the posttest, students exhibited full scientific understanding of the concept [M = 1.76, SD = .47]. It showed that, after the Jigsaw intervention, 1.6 % had no scientific understanding, 21.0 % had partial scientific understanding while only 77.4 % had full scientific understanding of the concept.

Item 4 attempted to determine students' grasp of the right statement about semiconductor categorization. As indicated in Table 13, students displayed incomplete scientific Understanding [M =.84, SD =.58] during the pretest. This was clear since 25.8% had no scientific Understanding, 64.5% had some scientific awareness, and just 9.5% had a complete scientific understanding of the idea. However, at the posttest, students displayed a thorough scientific Understanding of the subject [M = 1.53, SD =.62]. It revealed that 6.5% had no scientific Understanding, 33.9% had limited scientific awareness, and only 59.7% had a complete scientific grasp of the idea.

Items 5 and 6 on the ECT assessed students' conceptual grasp of the P-N junction. As indicated in Table 13 for Item 5, students displayed incomplete scientific awareness [M =.61, SD =.64] of what occurs to charge carriers at the p-n junction in a forward-biased situation at the pretest. This was clear since 46.8% had no scientific understanding, 45.2% had limited scientific awareness, and just 8.1% had a complete scientific understanding of the idea. However, at the posttest, students exhibited a thorough scientific understanding of the idea [M = 1.71, SD =.49]. It revealed that, following the Jigsaw intervention, 1.6% had no scientific Understanding, 25.8% had limited scientific awareness, and only 72.6% had a complete scientific grasp of the topic.

Item 6 aimed to assess students' grasp of what happens when current flows over a reverse-biased p-n junction. As indicated in Table 13, students displayed incomplete scientific Understanding [M =.73, SD =.55] during the pretest. This was clear since 32.3% had no scientific understanding, 62.9% had limited scientific awareness, and just 4.8% had a complete scientific understanding of the idea. At the posttest, students exhibited a limited scientific understanding of the idea [M = 1.48, SD =.69]. The results revealed that 11.3% had no scientific understanding, 29.0% had limited scientific awareness, and only 59.7% had full scientific grasp of the topic.

Items 7 and 8 on the ECT assessed students' conceptual grasp of bias and correction. As indicated in Table 13 for Item 7, students displayed incomplete scientific understanding [M =.58, SD =.64] on assertions concerning biasing in a p-n junction that was wrong during pretest. This was obvious since 50.0% had no scientific understanding, 41.9% had some scientific awareness, and just 8.1% had complete scientific grasp of the subject. At the posttest, pupils exhibited a limited scientific understanding of the subject [M = 1.35, SD =.60]. It revealed that, following the Jigsaw intervention, 6.5% had no scientific understanding, 51.6% had limited scientific awareness, and just 41.9% had a complete scientific grasp of the topic.

Item 8 intended to test students' understanding of which statement concerning correction is inaccurate. As indicated in Table 13, students displayed incomplete scientific understanding [M =.58, SD =.62] during the pretest. This was clear since 48.4% had no scientific understanding, 45.2% had moderate scientific awareness, and just 6.5% had a complete scientific understanding of the idea. However, at the posttest, students displayed a thorough scientific understanding of the subject [M = 1.68, SD =.50]. It revealed that 1.6% had no scientific understanding, 29.0% had limited scientific awareness, and only 69.4% had a complete scientific grasp of the topic.

Items 9 and 10 on the ECT assessed students' conceptual grasp of transistors. As indicated in Table 13 for Item 9, students displayed incomplete scientific understanding [M =.56, SD =.56] of how the direction of current flow compares in NPN and PNP transistors during pretest. This was clear since 46.8% had no scientific understanding, 50.0% had some scientific awareness, and just 3.2% had a complete scientific understanding of the idea. At the posttest, students displayed a limited scientific understanding of the idea [M = 1.27, SD =.68]. It revealed that, following the Jigsaw intervention, 12.9% had no scientific understanding, 46.8% had limited scientific awareness, and only 40.3% had a complete scientific grasp of the topic.

Item 10 was designed to assess students' awareness of the purpose of a transistor's collector terminal. As indicated in Table 13, students displayed incomplete scientific understanding [M =.79, SD =.58] during the pretest. This was clear since 29.0% had no scientific understanding, 62.9% had limited scientific awareness, and just 8.1% had a complete scientific understanding of the idea. At the posttest, students exhibited a limited scientific understanding of the idea [M = 1.31, SD =.74]. It revealed that 14.5% had no scientific understanding, 40.3% had limited scientific awareness, and just 45.2% had a complete scientific grasp of the topic.

As demonstrated in Table 13, the Jigsaw cooperative learning paradigm was able to increase students' conceptual understanding, as seen by the grand mean [M = 1.53] and an average percentage improvement of around 61%.

Table 14 shows the descriptive statistical tools utilised to assess students' conceptual knowledge of electronic concepts taught using the STAD cooperative learning methodology. The first and second ECT items attempted to measure students' conceptual understanding of solid band theory. As indicated in Table 14 for Item 1, students displayed incomplete scientific understanding [M =.61, SD =.67] of inaccurate claims concerning solid band theory on the pretest. This was clear since 48.8% had no scientific understanding, 41.5% had some scientific awareness, and just 9.8% had a complete scientific grasp of the subject. At the posttest, students still displayed a limited scientific understanding of the subject [M = 1.47, SD =.78]. It revealed that, following the STAD intervention, 17.1% had no scientific understanding, 19.5% had limited scientific awareness, and only 23.4% had complete scientific grasp of electronics concepts.

Item 2 attempted to assess students' grasp of a material's electrical resistivity using the band theory of solids. As indicated in Table 14, students displayed incomplete scientific understanding [M =.78, SD =.52] during the pretest. This was clear since 26.8% had no scientific understanding, 68.3% had limited scientific awareness, and just 4.9% had a complete scientific understanding of the idea. However, at the posttest, students displayed a thorough scientific understanding of the idea [M = 1.66, SD =.66]. It revealed that 9.8% had no scientific understanding, 14.6% had moderate scientific awareness, and only 75.6% had a complete scientific grasp of the topic.

Items 3 and 4 on the ECT assessed students' conceptual understanding of semiconductor categorisation. As indicated in Table 14 for Item 3, students displayed incomplete scientific awareness [M =.78, SD =.69] of what determines whether a semiconductor is N-type or P-type during the pretest. This was clear since 36.6% had no scientific understanding, 48.7% had some scientific awareness, and just 14.6% had a complete scientific grasp of the subject. However, at the posttest, students displayed a thorough scientific understanding of the subject [M = 1.73, SD =.58]. It revealed that, following the STAD intervention, 2.4% had no scientific understanding, 24.4% had moderate scientific understanding, and only 75.6% had complete scientific grasp of the topics.

Table 14: Results on Level of Students' Conceptual Understanding of Concepts in Electronic taught with STAD Cooperative Learning Model

	Pretest								Posttest							
Item	**No Scientific Understanding**		**Partial Scientific Understanding**		**Full Scientific Understanding**		**M**	**SD**	**No Scientific Understanding**		**Partial Scientific Understanding**		**Full Scientific Understanding**		**M**	**SD**
	n	**%**	**n**	**%**	**n**	**%**			**n**	**%**	**n**	**%**	**n**	**%**		
1	20	48.8	17	41.5	4	9.8	.61	.67	7	17.1	8	19.5	26	23.4	1.47	.78
2	11	26.8	28	68.3	2	4.9	.78	.52	4	9.8	6	14.6	31	75.6	1.66	.66
3	15	36.6	20	48.8	6	14.6	.78	.69	1	2.4	9	24.4	31	75.6	1.73	.50
4	9	22.0	29	70.7	3	3.7	.85	.53	3	7.3	17	41.5	21	51.2	1.44	.63
5	16	39.0	25	61.0	0	0.00	.61	.49	1	2.4	15	36.6	25	61.0	1.59	.55
6	13	31.7	28	68.3	0	0.00	.68	.47	4	9.8	18	43.9	19	46.3	1.37	.66
7	23	56.1	15	36.6	3	7.3	.51	.62	4	9.8	25	61.0	12	29.3	1.20	.60
8	20	48.8	19	46.3	2	4.9	.56	.59	1	2.4	19	46.3	21	51.2	1.49	.55
9	18	43.9	21	51.2	2	4.9	.61	.59	8	19.5	21	51.2	12	29.3	1.10	.70
10	14	34.1	27	65.9	0	0.00	.66	.48	6	14.6	20	48.8	15	36.6	1.22	.69
Grand Mean		**38.8**		**55.9**		**5.0**	**.67**	**.57**		**9.5**		**38.8**		**48.0**	**1.42**	**.63**

Item 4 attempted to determine students' grasp of the right statement about semiconductor categorization. As indicated in Table 14, students displayed incomplete scientific understanding [M =.85, SD =.53] during the pretest. This was clear since 22.0% had no scientific understanding, 70.7% had limited scientific awareness, and just 3.7% had a complete scientific understanding of the idea. At the posttest, students exhibited a limited scientific understanding of the idea [M = 1.44, SD =.63]. It revealed that 7.3% had no scientific understanding, 41.5% had limited scientific awareness, and only 51.2% had complete scientific grasp of the topic.

Items 5 and 6 on the ECT assessed students' conceptual grasp of the P-N junction. As indicated in Table 14 for Item 5, students displayed incomplete scientific understanding [M =.61, SD =.49] of what occurs to charge carriers at the p-n junction in a forward biased state at the pretest. This was clear since 39.0% had no scientific understanding, 61.0% had limited scientific awareness, and just 0.0% had a complete scientific understanding of the subject. However, at the posttest, students displayed a thorough scientific understanding of the idea [M = 1.59, SD =.55]. It revealed that, following the STAD intervention, 2.4% had no scientific understanding, 36.6% had limited scientific awareness, and only 61.0% had complete scientific grasp of the concept.

Item 6 aimed to assess students' grasp of what happens when current flows over a reverse biased p-n junction. As indicated in Table 14, students displayed incomplete scientific understanding [M =.68, SD =.47] during the pretest. This was clear since 31.7% had no scientific understanding, 68.3% had limited scientific awareness, and just 0.0% had a complete scientific understanding of the subject. At the posttest, students exhibited a limited scientific understanding of the idea [M = 1.37, SD =.66]. It revealed that 9.8% had no scientific understanding, 43.9% had limited scientific awareness, and just 46.3% had a complete scientific grasp of the topic.

Items 7 and 8 on the ECT assessed students' conceptual grasp of bias and correction. As indicated in Table 14 for Item 7, students displayed incomplete scientific understanding [M =.51, SD =.62] on assertions concerning biasing in a p-n junction that were inaccurate on the pretest. This was clear since 56.1% had no scientific understanding, 36.6% had moderate scientific awareness, and just 7.3% had a complete scientific understanding of the idea. At the posttest, students exhibited a limited scientific understanding of the idea [M = 1.12, SD =.60]. It revealed that, following the STAD intervention, 9.8% had no scientific understanding, 61.0% had limited scientific understanding, and only 29.3% had a complete scientific grasp of the idea.

Item 8 intended to test students' understanding of which statement concerning correction is inaccurate. As indicated in Table 14, students displayed incomplete scientific understanding [M =.56, SD =.59] at the pretest. This was clear since 48.8% had no scientific understanding, 46.3% had some scientific awareness, and just 4.9% had a complete scientific grasp of the subject. At the posttest, pupils exhibited a limited scientific understanding of the idea [M = 1.49, SD =.55]. It revealed that 2.4% had no scientific understanding, 46.3% had limited scientific awareness, and only 51.2% had a complete scientific grasp of the idea.

Items 9 and 10 on the ECT assessed students' conceptual grasp of transistors. As indicated in Table 14 for Item 9, students displayed incomplete scientific understanding [M =.61, SD =.59] of how the direction of current flow compares in NPN and PNP transistors during pretest. This was clear since 43.8% had no scientific understanding, 51.2% had some scientific awareness, and just 4.9% had a complete scientific understanding of the idea. At the posttest, students exhibited a limited scientific understanding of the subject [M = 1.10, SD =.70]. It revealed that, following the STAD intervention, 19.5% had no scientific understanding, 51.2% had limited scientific understanding, and only 29.3% had complete scientific grasp of the concept.

Item 10 was designed to assess students' awareness of the purpose of a transistor's collector terminal. As indicated in Table 14, students displayed incomplete scientific understanding [M =.66, SD =.48] during the pretest. This was clear since 34.1% had no scientific understanding, 65.9% had limited scientific awareness, and just 0.0% had a complete scientific understanding of the subject. At the posttest, students exhibited a limited scientific understanding of the idea [M = 1.22, SD =.69]. It revealed that 14.6% had no scientific understanding, 48.8% had limited scientific awareness, and just 36.6% had complete scientific grasp of the topic.

As indicated in Table 14, the STAD cooperative learning paradigm improved students' conceptual understanding marginally, but only partially, as seen by the grand mean [M = 1.42], with an average percentage improvement of around 48%. In comparison, the Jigsaw cooperative learning model demonstrated better effectiveness than the STAD cooperative learning model in improving students' conceptual understanding. To provide quantitative evidence for this conclusion, an independent samples t-test was used to compare the students' ECT results.

First, students' pretest ECT scores were compared after validating all parametric analysis assumptions and finding no breaches. As shown in Table 15, the mean scores of the STAD group [M = 6.66, SD = 2.62] did not significantly differ from the Jigsaw [M = 6.85, SD = 2.29] group in terms of ECT before instruction [t (101) =.402, p =.689]. The findings indicate that students in both groups exhibited similar levels of conceptual understanding of electronic concepts, starting the interventions with nearly identical levels of knowledge.

Table 15: Results of ECT Pretest Scores for STAD and Jigsaw Groups

	N	M	SD	t	df	p
STAD	41	6.66	2.62	.402	101	.689
Jigsaw	62	6.85	2.29			

p > .05 not statistically significant

Since there were no significant differences in the mean scores between the STAD and Jigsaw groups on the ECT pretest, a paired samples t-test was conducted to compare each group's pretest and posttest results. The pretest and posttest results revealed a statistically significant difference, as presented in Table 16. The STAD group scored considerably better on the posttest [M = 14.24, SD = 1.74] compared to the pretest [M = 6.66, SD = 2.62, t (40) = 16.146, p <.001]. The STAD group showed a moderate difference in mean scores, with an effect size of .87. This implies that the STAD cooperative model accounts for around 8.7% of students' posttest success.

Table 16: Results for the ECT Pretest and Posttest Scores of STAD and Jigsaw Groups

	Variable	N	M	SD	t	df	p
	Pretest	41	6.66	2.62			
STAD					16.146	40	.000*
	Posttest	62	14.24	1.74			
	Pretest	41	6.85	2.29			
Jigsaw					25.414	61	.000*
	Posttest	62	15.27	1.61			

*p<.05 significant

Furthermore, Table 16 demonstrates that the Jigsaw group had a significantly higher mean posttest score [M = 15.27, SD = 1.61] compared to their pretest score [M = 6.85, SD = 2.29, t(61) = 25.414, p < .001]. The control group showed a moderate difference in mean scores, with an effect size of .91, suggesting that the Jigsaw cooperative model contributed to approximately 9.1% of the students' posttest success. These findings imply that both cooperative learning methods (STAD and Jigsaw) had a considerable impact on improving students' conceptual understanding of electronics.

Finally, the mean scores of the STAD [M = 14.24, SD = 1.74] and Jigsaw [M = 15.27, SD = 1.61] groups in the posttest were compared using an independent samples t-test to determine if there was a significant difference in their level of conceptual understanding. Table 17 shows that the mean scores on the ECT posttest for the two groups differed significantly [t(101) = 3.075, p = .003].

Table 17: Results for ECT Posttest Scores of STAD and Jigsaw Groups

	N	M	SD	t	df	p
STAD	41	14.24	1.74	3.075	101	.003*
Jigsaw	62	15.27	1.61			

*p < .05 statistically significant

Students in the Jigsaw group outperformed those in the STAD group. The overall difference in posttest scores between the STAD and Jigsaw groups was moderate, with a standardized effect size index of 0.09. This indicates that the Jigsaw cooperative learning model had a greater impact on enhancing students' conceptual understanding of electronics compared to the STAD cooperative learning model.

Changes in Conception in Electronics between the Jigsaw and STAD Cooperative Learning Groups

The second hypothesis examined whether senior high school students taught using the Jigsaw cooperative learning technique and those taught using the STAD cooperative learning method differed statistically significantly in the extent of changes in their notion of electronics. To investigate this hypothesis, an analysis was conducted on the responses submitted by students for the second tier of the Electronics Conception Test (ECT) to determine the amount to which their alternative conception of electronics changed between the pretest and the posttest.

For each issue, the pretest and posttest results for the two groups included exact quotations of the students' alternative ideas, together with the numbers and percentages of students who hold different conceptions and the extent of their transformation. The extent of changes in students' alternative conceptions for each question was determined using McNemar chi-square test. Using the McNemar method, Table 16 presents the extent to which students' alternative conceptions for each issue changed for the Jigsaw and STAD groups from the pretest to the posttest.

The percentage of students in the Jigsaw group who had alternative concepts fell from about 37 out of 41 (88%) to 18 out of 41 (44%) compared to the STAD group, and the Jigsaw group's number and percentage decreased from approximately 57 out of 62 (91%) to approximately 25 out of 62 (39%) after intervention, as indicated in Table 18. For each of the ten electronics-related questions, the Jigsaw group's different ideas about the degree of changes were determined to be statistically significant ($\chi2 \geq 3.84$). Table 18 illustrates that, for nine of the ten electronics items, the Jigsaw group's alternative conceptions of the students differed more from the STAD group's, statistically significant. It is also noteworthy that a higher proportion of students in the Jigsaw group than in the STAD group replaced their alternative, non-scientifically incorrect concepts about electronics with scientifically right conceptions.

The percentage of students in the Jigsaw group having alternative conceptions declined from 90.32% to 35.48%, while the STAD group's percentage decreased from 87-80% to 51.21%, as shown by Table 18 for Question 1. The Jigsaw and STAD groups both showed a statistically significant decrease in alternative conceptions ($\chi2=30.25$ for the Jigsaw group and $\chi2=10.32$ for the STAD group). Table 16 illustrates that, in the Jigsaw group, 1 out of 62 students (1.62 %)

generated alternative ideas as a result of the intervention, whereas 35 out of 62 students (56.42%) swapped their wrong conceptions for the scientifically accepted one. Conversely, in the STAD group, 2 out of 41 students (4.88 %) generated alternative ideas as a consequence of the method, whereas 17 out of 41 students (41.46 %) substituted their conceptions for the scientific idea.

As shown in Table 18, students with naive conceptions reduced from 83.87 % to 20.97 % in the Jigsaw group and from 60.98 % to 24.39 % in the STAD group in respect to Question 2. Both the Jigsaw and STAD groups had a substantial decrease in alternative conceptions ($\chi2$=30.72 for Jigsaw and $\chi2$=9.33 for STAD). Table 18 indicates that, in the Jigsaw group, 4 out of 62 students (6.45%) generated alternative ideas as a result of the intervention, whereas 43 out of 62 students (69.35%) modified their alternate notions of the scientifically accepted notion. In contrast, 3 out of 41 (7.32%) students in the STAD group formed alternative conceptions, whereas 18 out of 41 (43.9%) students switched from their alternative conceptions to the scientifically accepted idea.

For Question 3 and as shown in Table 18, students with naive conceptions reduced from 83.87% to 20.97% in the Jigsaw group and from 75.61% to 41.46% in the STAD group. It was observed that there was a decline in alternative conceptions in both the Jigsaw and STAD groups ($\chi2$=33.58 for the Jigsaw group and $\chi2$=9.39 for the STAD group). Table 18 indicates that, in the Jigsaw group, 2 out of 62 students (3.23%) generated alternative ideas as a result of the intervention, whereas 41 out of 62 students (66.13%) changed their alternative conceptions. In contrast, 2 out of 41 students (4.88 %) in the STAD group formed alternative conceptions, whereas 16 out of 41 students (39.02 %) switched from their alternative conceptions to the scientifically accepted idea.

For Question 4 on Table 18, students with wrong conceptions reduced from 91.94% to 41.94% in the Jigsaw group and from 95.12% to 48.78% in the STAD group. For both Jigsaw and STAD, there were statistically significant drops in alternative conceptions ($\chi2$=25.71 for Jigsaw and $\chi2$=14.09 for STAD). However, as indicated in Table 18, for the Jigsaw group, 33 out of 62 (53.23%) students altered their alternative conceptions, whereas 2 out of 62 (3.23%) students created alternative conceptions in response to the intervention. In the STAD group, 21 out of 41 (51.23%) students replaced their alternative conceptions with scientifically acceptable ideas, whereas 2 out of 41 (4.88%) generated alternative conceptions.

Question 5, as shown in Table 18, students alternative conceptions declined from 91.94% to 25.81% for the Jigsaw group and from 95.12% to 31.71% for the STAD group. Statistically substantial decreases in alternative conceptions were seen in the Jigsaw and STAD groups ($\chi2$=39.09 for Jigsaw and $\chi2$=20.83 for STAD). However, as indicated in Table 18, for the Jigsaw group, 41 out of 62 (66.13%) students modified their alternative conceptions for the scientifically acceptable idea, whereas 0 out of 62 (0%) students acquired alternative conceptions. The STAD group, conversely, saw 28 out of 41 (68.29%) students shift their conceptions of the scientific idea, whereas 2 out of 41 (4.88%) created alternative conceptions in response to the intervention.

For Question 6 on Table 18, students with alternative conceptions declined from 95.16 % to 41.94 % and from 95.12 % to 31.71% for the Jigsaw and STAD groups respectively. For both Jigsaw and STAD, there were statistically significant drops in alternative conceptions ($\chi2$=29.25 for the Jigsaw group and $\chi2$=24.04 for the STAD group). Table 18 indicates that, in the Jigsaw group, 1 out of 62 students (1.61 %) generated alternative ideas students modified their alternative conceptions for the scientifically acceptable idea, whereas 34 out of 62 students (54.84 %) modified their alternative conceptions for the scientific one. In contrast, 26 out of 41 (63.41%) students in the STAD group substituted their alternative conceptions for the notion that is widely accepted in science, while 0 out of 41 (0%) students created new concepts.

For Question 7 on Table 18, students with alternative conceptions declined from 93.55% to 59.68% and from 92.68% to 29.27% for the Jigsaw and STAD groups respectively. Statistically significant decreases in alternative conceptions were seen in the Jigsaw and STAD groups ($\chi2$=14.81 for Jigsaw and $\chi2$=24.04 for STAD). However, as indicated in Table 18, for the Jigsaw group, 34 out of 62 (54.84%) students altered their conceptions for the scientific view, whereas 3 out of 62 (4.84%) formed naive conceptions. In the STAD group, 26 out of 41 (63.41%) students replaced their alternative conceptions with scientifically acceptable idea, whereas 0 out of 41 (0%) students generated wrong conceptions.

For Question 8 on Table 18, students with alternative conceptions declined from 95.16% to 33.87% and from 90.24% to 41.46% for the Jigsaw and STAD groups respectively. Statistically significant decreases in conceptions were seen in the Jigsaw and STAD groups ($\chi2$=36.03 for Jigsaw and $\chi2$=15.04 for STAD). However, as indicated in Table 18, for the Jigsaw group, 38 out of 62 (61.29%)

students replaced their naive conceptions with the scientific idea, whereas 0 out of 62 (0%) students generated wrong conceptions. For the STAD group, 22 out of 41(53.66 %) students modified their thinking for the scientific one, while 2 out of 41(4.88 %) students developed naive conceptions.

For Question 9 on Table 18, students with alternative conceptions declined from 100% to 65.85% and from 98.39% to 596.8% for the Jigsaw and STAD groups respectively. A statistically significant decline in alternative conceptions was seen in both the Jigsaw and STAD groups ($\chi2$=20.35 for the Jigsaw group and $\chi2$=12.07 for the STAD group). Table 18 indicates that, in the Jigsaw group, 1 out of 62 students (1.61 %) generated alternative ideas as a consequence of the intervention, whereas 25 out of 62 students (40.32 %) changed their conceptions for the scientific notion. For the STAD group on the other hand, 14 out of 41(34.15 %) students changed their conceptions while 0 out of 41(0 %) students developed naive conceptions.

Lastly for Question 10 on Table 18, students with alternative conceptions declined from 91.94% to 53.23%, and from 90.24% to 70.73% for the Jigsaw and STAD groups respectively. The Jigsaw group showed a statistically significant drop in alternative conceptions ($\chi2$=15.56), but the STAD groups did not show a statistically significant decrease in alternative conceptions ($\chi2$=3.06). Table 18 illustrates that, in the Jigsaw group, 5 out of 62 students (8.06%) acquired wrong conceptions, whereas 29 out of 62 students (46.77%) swapped their initial conceptions for the scientifically accepted idea. For the STAD group on the other hand, 12 out of 41(29.27 %) students altered their naive conceptions for the correct one while 4 out of 41(9.77 %) students developed wrong conceptions.

In conclusion, it suggests that compared to the STAD cooperative learning approach, the Jigsaw cooperative learning method was more effective in transforming students' alternative concepts of electronics. This is due to the fact that when the Jigsaw cooperative learning method was applied, there was a significant change in the students' conceptions in each of the ten questions; in contrast, the STAD cooperative learning method produced significant changes in conceptions in nine of the questions.

Table 18: Students' Changes in Conceptions for the Jigsaw and STAD Groups

	Students in Jigsaw group [N = 62]							Students in STAD group [N = 41]						
Item	A	B	C	D	Pretest	Posttest	χ^2	A	B	C	D	Pretest	Posttest	χ^2
1	1	5	2	1	35 56(90.32)	22(35.48)	30.25*	2	3	19	17	36(87.80)	21(51.21)	10.32*
2	4	6	9	43	52(83.87)	13(20.97)	30.72*	3	13	7	18	25(60.98)	10(24.39)	9.33*
3	2	8	11	41	52(83.87)	13(20.97)	33.58*	2	8	15	16	31(75.61)	17(41.46)	9.39*
4	2	3	24	33	57(91.94)	26(41.94)	25.71*	2	0	18	21	39(95.12)	20(48.78)	14.09*
5	0	5	16	41	57(91.94)	16(25.81)	39.02*	2	0	11	28	39(95.12)	13(31.71)	20.83*
6	1	2	25	34	59(95.16)	26(41.94)	29.25*	0	2	13	26	39(95.12)	13(31.71)	24.04*
7	3	1	34	24	58(93.55)	37(59.68)	14.81*	0	3	12	26	38(92.68)	12(29.27)	24.04*
8	0	3	21	38	59(95.16)	21(33.87)	36.03*	2	2	15	22	37(90.24)	17(41.46)	15.04*
9	1	0	36	25	61(98.39)	37(59.68)	20.35*	0	0	27	14	41(100.0)	27(65.85)	12.07*
10	5	0	28	29	57(91.94)	33(53.23)	15.56*	4	0	25	12	37(90.24)	29(70.73)	3.06
Average					**57(91 %)**	**25(39 %)**						**37(88 %)**	**18(44 %)**	

Numbers in brackets are percentages *Significant at $\chi^2 \geq 3.84$

Extent of the Implementation of STAD and Jigsaw Cooperative Learning Models in Improving Students' Motivation and Attitude Towards Learning Concepts in Electronics

The third research question looked at how much senior high school students' motivation and attitude toward studying electronics concepts was improved by using the Jigsaw and STAD cooperative learning methods. The mean and standard deviation of the questions on the Students' Level of Attitude Questionnaire (SLTQ) and Students' Level of Motivation Questionnaire (SLMQ) are displayed in Table 19. To address the first study question, which concerned the degree of change in students' motivation and attitudes toward learning electronics, means and standard deviations were employed. These results were interpreted as follows: a mean value between 0 and 2.4 indicated poor motivation or attitude, whereas a range between 3.4 and 5.0 indicated great motivation or attitude. Additionally, all items with negative ratings were recoded to ensure uniformity in the study.

Table 19 demonstrates how the use of both the Jigsaw and STAD cooperative learning methods raised students' motivation and attitudes toward studying electronics concepts.

Table 19: Grand mean and standard deviation of students' motivation and attitude

Variable	Jigsaw		STAD	
	M	SD	M	SD
Motivation	3.95	.68	3.88	.43
Attitude	3.79	.55	3.62	.34

Again, students' level of motivation and attitudes were compared between the Jigsaw and STAD cooperative learning groupings. MANOVA was used to analyse the data since there were two dependent variables (motivation and attitude) and one independent variable (cooperative learning technique) at two levels (Jigsaw and STAD groupings). Once more, assumption testing was done to verify the following: homogeneity of covariance matrices, test of equality of error variance, multivariate outliers and multivariate normalcy, linearity and multicollinearity, and normality. There were found to be no infractions.

Table 20 presents an overview of the MANOVA results regarding students' motivation and attitudes towards learning electronics. The Wilka' Lambda was employed to assess the differences between the MANOVAs. Table 20 indicates that there was no statistically significant difference in the mean scores between the Jigsaw and STAD groups for the combined dependent variables: $F(1, 101) = 1.953$, $p = .162$, Wilks' Lambda =.964. This indicates that both the Jigsaw and STAD groups' students' motivation and attitude levels when studying electronics are comparable.

Table 20: Summary of MANOVA Effect on Students' Motivation and Attitude in Learning Electronics

Dependent	Multivariate F	Wilks' Lambda	df	p
Motivation				
	1.953	.964	1, 101	.162
Attitude				

Not Significant, since p > .05

Discussion

The first result of this study indicated that the level of students' achievement of concepts in electronics taught with STAD and Jigsaw cooperative learning models were reasonably high. The high level of students' achievement in electronics suggests that both STAD and Jigsaw cooperative learning models are effective instructional strategies. These methods promote active learning, collaboration, and peer support, which are key factors in enhancing understanding of complex concepts (Johnson & Johnson, 1999; Kagan, 1990; Morgan & Keitz, 2010). This active involvement likely contributed to higher achievement levels, as students are more motivated to learn and understand the material when they are responsible for both their learning and the learning of their peers (Mishra, 2020; Millis, 2023). The structure of STAD promoted accountability and ensured that all team members contributed to the learning process (Shafiee Rad et al., 2023). This structured approach might have helped in reinforcing concepts and improving overall students' achievement. The Jigsaw model, on the other hand, not only deepened the understanding of the individual student but also ensured that students can communicate and explain concepts effectively, reinforcing their learning (Nolan et al., 2018, Amin et al., 2020; Karacop, 2017). The success of the Jigsaw model in this context indicates that it can be particularly effective in topics that require a deep understanding of interconnected concepts.

The study's second set of data revealed that, despite statistical disparities between the two groups from the pretest to the posttest, students in the Jigsaw group did better than their peers in the STAD group in the posttest. This is hardly a surprise discovery. This is because the Jigsaw model's framework, which places a strong emphasis on peer teaching and individual accountability, may have encouraged a higher degree of cognitive processing and understanding. This peer teaching aspect can enhance retention and understanding, as students must thoroughly understand and be able to explain their portion of the material to their peers (Nolan et al., 2018, Amin et al., 2020; Karacop, 2017). This finding confirms the studies by Andarini (2014), and Fika (2020). The superior performance of the Jigsaw group aligns with Social Interdependence Theory, which posits that cooperative efforts are more productive when group members perceive their goals as positively interdependent (). The Jigsaw model's structure fosters a high degree of interdependence, as each student's contribution is essential for the group's overall understanding. It must also be noted that while the Jigsaw model may lead to higher achievement in some contexts, the STAD model also shows significant benefits as evident in literature. A balanced approach that incorporates elements of both models could potentially maximize learning outcomes. For example, initial instruction, using STAD's team study could be followed by Jigsaw's peer teaching to reinforce and deepen understanding (Jabeen et al., 2020)

The third result indicated that while students in the Jigsaw group substantially improved their conceptual understanding, the STAD improved marginally. This significant gain suggests that the Jigsaw model is highly effective in fostering deep understanding of complex concepts in electronics. Though the improvement in students' conceptual understanding was appreciable when instructed with STAD, was not as pronounced as with the Jigsaw model, suggesting that the depth of engagement and individual accountability might be less intensive in STAD compared to Jigsaw. The result aligns with constructivist theories of learning, which emphasize the active construction of knowledge through meaningful interactions (Yeager & Dweck, 2020; Jennings & Cuevas, 2021). The Jigsaw model, in particular, facilitates this by requiring students to engage deeply with the material and teach it to their peers, thus reinforcing their own understanding (Amin et al., 2020; Millis, 2023). Teachers should consider incorporating the Jigsaw model for teaching complex and interrelated concepts. Its success in fostering conceptual understanding suggests that it can be particularly effective for concepts like electronics, where a deep understanding of principles and their applications is crucial.

The finding that the Jigsaw cooperative learning method is more effective than the STAD method in changing students' alternative conceptions in electronics underscores the importance of peer teaching and individual accountability in learning (Matuk & Linn, 2023). The Jigsaw method's structure promotes deep engagement and accurate understanding, making it particularly effective in addressing misconceptions (Fujii, 2020; Yeager & Dweck, 2020; Ha et al., 2024). Educators should consider incorporating the Jigsaw method for conceptually challenging topics and ensure they receive adequate training to implement it effectively. By balancing cooperative learning methods and continuously assessing student understanding, educators can enhance learning outcomes and ensure students develop accurate and deep conceptual understandings.

The finding that both the Jigsaw and STAD cooperative learning methods led to an improvement in students' motivation and attitudes towards learning electronics concepts aligns with research that suggests that cooperative learning, in general, has a beneficial impact on students' affective domain (Amedu & Gudi, 2017; Tran, 2019). The collaborative nature of these methods helps students feel more supported and confident in their learning. The positive reinforcement from peers and the satisfaction of contributing to group success can enhance students' self-efficacy and overall attitude towards learning. The fact that the mean scores for the combined dependent variables of motivation and attitude did not show a statistically significant difference between the Jigsaw and STAD groups suggests that both approaches are equally successful in these domains.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Overview of the study

The purpose of this research was to examine how senior high school students learned electronic concepts using the Jigsaw and STAD cooperative learning models. The study primarily examined changes in students' alternative conceptions, attitudes, and motivation towards learning in the Cape Coast Metropolis, as well as the extent to which STAD and jigsaw models may increase students' success in electronics. In this study, two null hypotheses were evaluated at the .05 level of significance and three research questions were addressed. A total of 103 second-year general science students were randomly selected to participate in the study using computer-generated random numbers. In this study, 62 students from one school labelled as the Jigsaw group and 41 children in one intact class from another school classified as the STAD group participated in a quasi-experimental pretest-posttest non-equivalent groups treatment design. While the Jigsaw group received instruction using that technique, the STAD group was trained using the STAD cooperative learning strategy. Before the treatments, tests of scientific reasoning, achievement, and conceptual understanding were administered to each group to determine their prior understanding of electronics. Following the different instructions, students answered achievement and conceptual understanding posttests to ascertain their learning outcomes for the methodologies utilized in electronics. Following the sessions, students also answered a questionnaire on motivation and attitude. Working with the class teachers, the researcher taught all 10 lessons, or five lessons each group.

The study employed research methods that integrated both quantitative and qualitative approaches to collect data. Together with motivation and attitude ratings, the quantitative data consisted of achievement and conceptual understanding of electronics scores. The justifications provided by students for each of the 10 ECT items constituted the qualitative aspect. They were used to ascertain the students' alternative conception of electronics. A key limitation of this study was that not all students attended every lesson, which could have influenced the study's results. Again, students' progress (i.e., EI and MA students) could not be traced. Further, scores of quizzes given at the end of each lesson were not used for analysis. These are the major limitations of this study.

Key findings

1. Level of students' achievement of concepts in electronics taught with STAD and Jigsaw cooperative learning models. The study found that the achievement level of senior high school students in electronic concepts, taught using the STAD and Jigsaw cooperative learning models, was relatively high.
2. Difference in students' achievement of concepts in electronics between senior high school students taught using STAD and Jigsaw cooperative learning models. It was found that:

   a. the pretest and posttest results for the two groups differed statistically significantly. The mean score from the posttest for the STAD group was considerably higher than the mean score from the pretest.
   b. the Jigsaw group's mean score from posttest was significantly higher than that of the pretest.
   c. mean posttest scores for EAT differed significantly between the two groups. Students in the Jigsaw group outperformed those in the STAD group.
3. The extent of senior high school students' conceptual understanding of electronic concepts taught using the STAD and Jigsaw cooperative learning models. It was found that:
   a. that the Jigsaw cooperative learning model was able to improve students' level of conceptual understanding as evident in the grand mean with the average percentage improvement at about 61 %.
   b. the STAD cooperative learning model, though showed marginal improvement in students' level of conceptual understanding, their level was still partial as evident in the grand mean [M = 1.42] with the average percentage improvement at about 48 %.
   c. the STAD group's mean score from posttest was significantly higher than the mean score from the pretest.
   d. the Jigsaw group's mean score from posttest was significantly higher than that of the pretest.

e. the Jigsaw group outperformed the STAD group in posttests for ECT, resulting in a statistically significant difference in mean scores.

4. A comparison of how much the Jigsaw and STAD cooperative learning groups' conceptions of electronics have changed over time. It was discovered that when it came to altering students' alternate concepts of electronics, the Jigsaw cooperative learning technique outperformed the STAD cooperative learning method.
5. Extent of the implementation of STAD and jigsaw cooperative learning models in improving students' motivation and attitude towards learning concepts in electronics. It was found that:

a. the level of students' motivation and attitudes towards learning concepts in electronics improved after the implementation of both the Jigsaw and STAD cooperative learning methods.

b. on the combined dependent variables, there was no statistically significant difference in mean scores between the Jigsaw and STAD groups.

Conclusions

Many conclusions may be made in light of the findings. Related to the level of students' achievement of concepts in electronics taught with STAD and Jigsaw cooperative learning models, it can be concluded that both methods improved the level of students' achievement to a reasonably high level. This provides empirical evidence that cooperative learning models, specifically STAD and Jigsaw, are effective in enhancing students' achievement in electronics. This supports the broader educational theory that cooperative learning can lead to better academic outcomes compared to traditional teaching methods. Additionally, the Jigsaw cooperative learning model is more effective than the STAD model in enhancing students' conceptual understanding and changing alternative conceptions in electronics. This is evidenced by the higher posttest scores and greater average percentage improvement in the Jigsaw group. This contributes to the literature by emphasizing the importance of selecting appropriate cooperative learning models for different subjects and learning objectives.

Further, the implementation of STAD and Jigsaw cooperative learning models improves students' motivation and attitudes towards learning electronics. These models create a more engaging and supportive learning environment. This adds to the understanding of the affective benefits of cooperative learning, which are often as important as cognitive gains in educational settings. Overall, these findings enrich the literature on cooperative learning by providing detailed comparative insights, demonstrating significant improvements in both cognitive and affective domains, and offering practical implementation guidance.

Recommendations

The conclusions and results support the following recommendations:

1. Senior high school teachers should integrate STAD and Jigsaw cooperative learning models into their teaching strategies, particularly for complex topics like electronics, to enhance student achievement and understanding.
2. Given its superior effectiveness in improving conceptual understanding and correcting students' alternative conceptions, teachers should prioritise the

Jigsaw model when teaching topics that require a deep understanding of concepts.

3. School authorities and educational institutions should provide comprehensive training for teachers on the implementation of STAD and Jigsaw cooperative learning models.
4. Curriculum designers should embed cooperative learning activities within lesson plans and assessments. This will ensure that the collaborative approach is systematically integrated into the teaching and learning process.
5. Teachers should use cooperative learning models to enhance student motivation and attitudes. Activities should be designed to be engaging, interactive, and relevant to students' interests and real-world applications.

Suggestions for Further Research

Several recommendations for further study may be made based on the findings.:

1. Longitudinal studies should be conducted to examine the long-term effects of STAD and Jigsaw cooperative learning models on students' academic achievement, conceptual understanding, and attitudes. This can provide insights into the sustainability and lasting impact of these models.
2. Investigation of the effectiveness of STAD and Jigsaw models in other topics beyond electronics. This can help determine the versatility and adaptability of these cooperative learning strategies across different content areas.
3. Explore the effects of cooperative learning models on diverse student populations, including students with different learning abilities,

socioeconomic backgrounds, and cultural contexts. This research can help identify best practices for inclusive education.

4. Investigate students' perspectives and experiences with cooperative learning models through qualitative research methods. This can provide deeper insights into how students perceive and benefit from these models.

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APPENDICES

APPENDIX A

Electronics Achievement Test (EAT)

CAREFULLY READ THE DIRECTIONS BELOW:

A. The test has no bearing on your overall grade.
B. Please consider your responses to each question.
C. There is only one CORRECT answer for each question (feel free to use the calculator).
D. Circle the right answer in the answer booklet for each item using a pencil. Complete all preliminary work on the blank papers attached.
E. You have one hour to finish the exam. Please review your work to make sure there are no mistakes before turning in the exam and answer booklets if you finish early.

ADDITIONAL INFORMATION FOR THE TEST

Before choosing your answer, please carefully read the questions. The four alternatives on the questions are numbered A through D. For each question, circle the appropriate response.

Time Allowed: 1hour

1. Which of the following statements accurately describes a difference between electric and electronic devices? Electric devices ________
   A. are limited to basic on/off functionality.
   B. are typically portable and battery-powered.
   C. operate without the need for an electrical power source.
   D. **utilise electronic components to control and process electrical signals.**

2. The electrons in the conduction band are free to transport __________.
   A. vibrations
   B. signals
   C. **charge**
   D. impulses

3. Energy band gap of an insulating material is __________.
   A. 0eV
   B. equal to 1eV
   C. greater than 5eV
   D. less than 5eV

4. In terms of energy bands, how can semiconductors be defined?
   A. A nearly full valence band and an empty conduction band with an extremely small width.
   B. An empty conduction band and an almost filled valence band with a very high energy gap.
   C. **An empty conduction band and a low filled valence band with a very narrow energy gap.**
   D. full conduction band and an almost filled valence band with a very narrow energy gap between the conduction and valence bands.

5. At which temperature will a pure semiconductor behave slightly as a conductor?
   A. High temperature
   B. Low temperature
   C. Room temperature
   D. Supercritical temperature

6. Which of the following statements accurately describes the relationship between temperature and electrical resistivity for materials with a negative temperature coefficient of resistance? Conductivity _____
   A. and resistivity have an unpredictable relationship with temperature.
   B. decreases with increasing temperature, resulting in an increase in resistivity.
   C. increases with increasing temperature, resulting in a decrease in resistivity.
   D. remains constant with changing temperature, resulting in no change in resistivity.

7. What happens when an electron encounters a hole in a semiconductor material? The _____.
   A. broken covalent bond is re-established, and this process is called recombination.
   B. electron and hole combine to form a new covalent bond, leading to ionization.
   C. electron moves to a higher energy state, creating an exciton.
   D. hole is filled with another electron from a neighbouring atom.

8. At room temperature, what happens to covalent bonds in a semiconductor material? Covalent bonds _________
   A. become stronger and more stable.
   B. break, releasing electrons as charged carriers.
   C. remain unaffected at room temperature.
   D. undergo ionization, forming positive and negative ions.

9. At absolute zero temperature (0 K), how do semiconductors behave as insulators? Semiconductors behave as _________
   A. insulators, blocking the flow of electric current completely.
   B. conductors, allowing the flow of electric current without any resistance.
   C. **insulators, but there is a small probability of electron movement**.
   D. insulators, but there is a small probability of covalent bond formation.
10. How does the behaviour of semiconductors change as more heat energy is supplied? Semiconductors _______
    A. **transition from insulators to conductors**.
    B. transition from conductors to insulators.
    C. remain as insulators, but with higher resistivity.
    D. undergo a phase transition to a different material type.
11. What is the role of impurities in semiconductors? Impurities _________ semiconductors.
    A. create additional charge carriers in
    B. decrease the conductivity of
    C. neutralize the charge carriers in
    D. stabilize the crystal structure of
12. What is the significance of the donor level in semiconductor devices? It ______
    A. affects the doping concentration of the semiconductor.
    B. determines the electron affinity of the semiconductor.
    C. determines the valence band structure.
    D. influences the availability of mobile electrons for conduction.
13. When a forward bias voltage is applied to a p-n junction, the P-side becomes ______.
    A. more negative and the n-side becomes more positive
    B. more positive and the n-side becomes more negative
    C. negatively charged and the n-side becomes positively charged
    D. positively charged and the n-side becomes negatively charged
14. The current in a p-n junction diode under forward bias is mainly due to the flow of ________.
    A. electrons in the p-region and holes in the n-region
    B. electrons in the n-region and holes in the p-region
    C. electrons in both the p and n-regions
    D. holes in both the p and n-regions
15. In reverse bias, the majority charge carriers in the p-n junction diode _______.
    A. become trapped in the depletion region
    B. move away from the junction
    C. move towards the junction
    D. remain stationary

16. What is the role of the P-N junction in a diode? It _________
    A. allows or blocks current flow depending on the direction.
    B. amplifies the electrical signals passing through the diode.
    C. controls the voltage output of the diode.
    D. regulates the current flow in the diode.

17. What completes the current path when an electron leaves the crystal in an electrical circuit?
    A. Electrons from the battery's positive terminal enter the crystal.
    B. The crystal receives electrons from the battery's negative end.
    C. Positively charged particles from the battery's positive terminal enter the crystal.
    D. No other particle enters the crystal, and the path is incomplete.

18. What is the significance of the potential barrier in a semiconductor junction? It ______
    A. allows free movement of carriers across the junction.
    B. creates a potential difference that affects the behaviour of the junction.
    C. prevents the formation of the depletion region.
    D. reduces the conductivity of the semiconductor material.

19. What effect does connecting the positive terminal of a power source to the P-type semiconductor and the negative terminal to the N-type semiconductor have on the resistivity of the semiconductor? The resistivity of the semiconductor _________.
    A. cannot be determined.
    B. decreases
    C. increases
    D. remains unchanged.

20. Why is a P-N junction commonly used as a rectifier? It _________
    A. allows current flow in both directions equally.
    B. blocks all current flow in both directions.
    C. conducts current readily in one direction and offers more resistance in the opposite direction.
    D. exhibits high resistance in both forward and reverse biased modes.

21. During which half cycle of the AC voltage does the diode conduct current?
    A. Both positive and negative half cycles
    B. Diode does not conduct current in an AC circuit
    C. Negative half cycle
    D. Positive half cycle
22. What effect does the charging of the capacitor have on the rectifier circuit? It ______.

A. increases the output voltage of the circuit
B. increases the resistance of the circuit
C. reduces the output voltage of the circuit
D. stabilizes the output voltage and reduces voltage ripple

23. What is the purpose of centre tapping the transformer in a rectifier circuit? To ______.
A. provide voltages across the two diodes
B. increase the voltage output of the circuit
C. eliminate the need for diodes in the circuit
D. decrease the voltage output of the circuit

24. Which of the following is NOT an advantage of a bridge circuit over a center-tapped transformer?
A. Greater flexibility in transformer selection
B. Higher efficiency
C. Improved voltage regulation
D. Reduced magnetic interference

25. What is the main function of a transistor? To _________.
A. amplify signals
B. generate electricity
C. regulate voltage
D. store data

26. What is the significance of the arrowhead in transistor symbols? It _______
A. indicates the direction of current flow.
B. indicates the direction of electron flow.
C. **represents the direction of hole flow**.
D. shows the orientation of the transistor.

27. Which regions of a transistor are involved in controlling the flow of current carriers?
A. Base region
B. Emitter region
C. Collector region
D. Junction region

28. Why is the Common-Emitter configuration widely used in transistor circuits? It ________
A. offers higher temperature stability.
B. offers higher voltage gain.
C. **provides higher input resistance**.
D. provides higher output resistance.

29. How is the base-collector junction of a transistor biased during operation?
A. Forward bias

B. No bias
C. Reverse bias
D. Variable bias

30. What is a key advantage of using transistors in electronic circuits?
A. Compact size and low power consumption
B. Compatibility with high voltages
C. High mechanical strength
D. High resistance to temperature fluctuations

APPENDIX B

Electronics Conception Test (ECT)

Time Allowed: 1hour

CAREFULLY READ THE DIRECTIONS BELOW:

A. The test has no bearing on your overall grade.
B. Please consider your responses to each question.
C. There is only one CORRECT answer for each question (feel free to use the calculator).
D. Use a pen to circle the right answer for each item. Do preliminary work on the empty papers attached to the answer booklet.
E. Please review your work to make sure there are no mistakes before turning in the exam booklets if you finish early.

ADDITIONAL INFORMATION FOR THE TEST

There are 10 questions on the exam to gauge your understanding of electronic topics. Kindly respond to all inquiries and offer a justification in the designated areas for every inquiry. Your answers to the questions are crucial.

I appreciate your cooperation.

1. Which one of the following statements about the band theory of solids is INCORRECT?
   A. Electrons in the conduction band have higher energy than those in the valence band.
   B. The energy gap between the valence and conduction bands determines the material's conductivity.
   C. At absolute zero temperature, all electrons occupy the valence band.
   D. The movement of electrons from the valence band to the conduction band creates electrical conductivity.

Explain your reasoning:
…………………………………………………………………………………………
…………………………………………………………………………………………

Explanation:
At absolute zero temperature, electrons occupy the lowest available energy levels, including both the valence band and, if excited, the conduction band.

2. What determines the electrical resistivity of a material, according to the band theory of solids? The __________
   A. number of electrons in the valence band.
   B. presence of energy gaps between the valence and conduction bands.
   C. speed of electrons in the conduction band.
   D. direction of electron flow within the solid.

Explain your reasoning:
…………………………………………………………………………………………
…………………………………………………………………………………………

Explanation:
This alternative conception suggests that the number of electrons in the valence band determines the electrical resistivity. However, in the band theory of solids, the presence of energy gaps between the valence and conduction bands plays a crucial role in determining the electrical resistivity of a material.

3. According to the classification of semiconductors, what determines whether a semiconductor is N-type or P-type? The _________
   A. type of crystal structure of the semiconductor material.
   B. presence of free electrons in the valence band.
   C. bandgap energy of the semiconductor material.
   D. type and concentration of impurities introduced into the material.

Explain your reasoning:
…………………………………………………………………………………………
…………………………………………………………………………………………

Explanation:
This alternative conception suggests that factors such as crystal structure, presence of free electrons, or bandgap energy determine the classification of semiconductors. However, the correct answer is the intentional introduction of specific impurity atoms and their concentration, which results in the excess of either electrons (N-type) or holes (P-type).

4. According to the classification of semiconductors, which statement is correct?
   A. Intrinsic semiconductors are heavily doped.
   B. N-type semiconductors have a higher electrical resistivity than P-type semiconductors.
   C. N-type semiconductors have an excess of holes.
   D. P-type semiconductors have an excess of electrons.

Explain your reasoning:

……………………………………………………………………………………………
……………………………………………………………………………………………

Explanation:

This alternative conception suggests that N-type semiconductors have a higher electrical resistivity than P-type semiconductors. However, in reality, N-type semiconductors have a lower electrical resistivity due to the abundance of free electrons for conduction.

5. What happens to the charge carriers at the p-n junction in a forward biased condition?
   A. **Electrons flow from the n-region to the p-region, and holes flow from the p-region to the n-region**.
   B. Electrons flow from the p-region to the n-region only.
   C. Electrons flow from the p-region to the n-region, and holes flow from the n-region to the p-region.
   D. Holes flow from the n-region to the p-region only.

Explain your reasoning:

……………………………………………………………………………………………
……………………………………………………………………………………………

Explanation:

This alternative conception suggests that electrons flow from the p-region to the n-region and holes flow in the opposite direction. However, in a forward biased condition, electrons from the n-region move towards the p-region, while holes from the p-region move towards the n-region, resulting in a continuous flow of both charge carriers.

6. What happens to the current flow across a reverse biased p-n junction? Current flow ________
   A. easily across the junction due to the increased voltage.
   B. **is blocked completely due to the increased voltage**.
   C. remains the same as in the forward biased condition.
   D. reverses direction across the junction.

Explain your reasoning:

……………………………………………………………………………………………
……………………………………………………………………………………………

Explanation:

This alternative conception suggests that current flows easily across the reverse biased p-n junction. However, in a reverse biased condition, the increased voltage creates a strong electric field across the junction, which opposes the flow of charge carriers and effectively blocks the current flow.

7. Which of the following statements about biasing in a p-n junction is incorrect?
   A. Forward biasing allows current to flow through the junction.
   B. Forward biasing increases the barrier potential.
   C. Reverse biasing blocks current flow through the junction.
   D. Reverse biasing creates a wider depletion region.

Explain your reasoning:
………………………………………………………………………………………
………………………………………………………………………………………
Explanation:
This statement is incorrect. In a p-n junction, forward biasing reduces the barrier potential by applying a positive voltage to the p-side and a negative voltage to the n-side. This reduction in barrier potential allows the majority carriers to easily flow across the junction, resulting in the conduction of current.

8. Which of the following statements about rectification is incorrect?
   A. Rectification is used in various electronic devices, such as power supplies.
   B. Rectification converts AC to DC.
   C. Rectification allows current flow in both directions.
   D. A diode is a device commonly used for rectification.

Explain your reasoning:
………………………………………………………………………………………
………………………………………………………………………………………
Explanation:
This statement is incorrect. Rectification is the process of converting AC to DC by allowing current flow in one direction while blocking it in the opposite direction. A diode, which is commonly used for rectification, permits current flow only in the forward-biased direction (from anode to cathode) and blocks it in the reverse-biased direction. This characteristic of diodes is essential for rectification.

9. How does the direction of current flow compare in NPN and PNP transistors? Current flows from the _________
   A. base to the emitter in NPN transistors and from the emitter to the base in PNP transistors.
   B. collector to the emitter in both NPN and PNP transistors.
   C. emitter to the base in both NPN and PNP transistors.
   D. emitter to the collector in NPN transistors and from the base to the emitter in PNP transistors.

Explain your reasoning:

……………………………………………………………………………………
……………………………………………………………………………………

Explanation:

This misconception suggests that the current flow direction is the same in both NPN and PNP transistors. However, in NPN transistors, current flows from the base to the emitter, while in PNP transistors, current flows from the emitter to the base. The direction of current flow is an important characteristic that distinguishes between NPN and PNP transistors.

10. What is the purpose of the collector terminal in a transistor? To ______
    A. provide the input signal.
    B. control the output voltage.
    C. control the base current.
    D. **collect the majority carriers.**

Explain your reasoning:

……………………………………………………………………………………
……………………………………………………………………………………

Explanation:

This misconception suggests that the purpose of the collector terminal in a transistor is to provide the input signal. However, in reality, the collector terminal is responsible for collecting the majority carriers (electrons in an NPN transistor or holes in a PNP transistor) and allowing their flow to the external circuit or power supply. It plays a crucial role in the amplification or switching process.

APPENDIX C
Students' Attitude Questionnaire

Dear Student,

This questionnaire is designed to investigate your attitude toward Cooperative Learning. The researcher really appreciates your cooperation and participation.

Age range: 14-16 ☐ 17 -19 ☐ 20 - 22 ☐

INSTRUCTION: To respond to this questionnaire, please put a check mark (√) in the appropriate box to indicate your level of agreement or disagreement with the statements: Strongly disagree = SD; Disagree = D; Uncertain = U; Agree = A; and Strongly agree = SA

No.	STATEMENT	SD	D	U	A	SA
1	Cooperative learning environments develop positive relationships in class.					
2	Cooperative learning environments provide respect to each other's ideas.					
3	While studying in cooperation, students guide each other.					
4	Individual studying is more enjoyable than working in groups.					
5	While studying in cooperation, students help each other.					
6	Cooperative learning environments develop trust towards classmates.					
7	Cooperative learning environments develop individual learning.					
8	Individual study offers better results.					
9	Cooperative studying motivates the group members.					
10	In most of the activities, I developed full understanding of concepts.					
11	I feel confident when I work in a group.					
12	I find group work activities boring and always feel sleepy in class.					
13	I just sit to see what other students do.					
14	I hate group work, but I have no choice.					
15	Whenever I have question, I turn to my teacher or classmates for help.					
16	I willingly participate in cooperative learning activities.					
17	When I work with other students, I achieve more than when I work alone.					
18	Cooperative learning has improved my attitude towards learning.					
19	Cooperative learning helps me to socialize more.					

20	Cooperative learning enhances good working relationships among students.					
21	Cooperative learning enhances class participation.					
22	Creativity is facilitated in the group setting.					
23	Group activities make the learning experience easier.					
24	I learn to work with students who are different from me.					
25	I enjoy the material more when I work with other students.					
26	My work is better organized when I am in a group.					
27	I prefer that my teachers use more group activities/ assignments.					
28	Cooperative learning makes or creates self-confidence.					

APPENDIX D
Students' Motivation Questionnaire

Dear Student,

This questionnaire is designed to investigate your motivation towards learning of concepts in physics. The researcher really appreciates your cooperation and participation.

INSTRUCTION: To respond to this questionnaire, please put a check mark (√) in the appropriate box to indicate your level of agreement or disagreement with the statements: Strongly disagree = SD; Disagree = D; Uncertain = U; Agree = A; and Strongly agree = SA

No.	STATEMENT	SD	D	U	A	SA
1	I feel the type of cooperative learning method used in teaching helped me to think more critically about the concepts in electronics.					
2	I feel the type of cooperative learning method used helped me to work collaboratively in a group.					
3	I feel the type of cooperative learning method used engaged me as an active participant in my learning.					
4	I feel the type of cooperative learning method used benefited my learning over standard traditional lectures used by my teachers.					
5	I would like the type of cooperative learning method to be used more in class sessions.					
6	Compared to other methods our teachers use in teaching, the type of cooperative learning method used required me to participate more often.					
7	I would like to be taught most topics with the type of cooperative learning methods.					
8	I feel the type of cooperative learning method used helped me to deal with group related problems of everyday life.					
9	I felt the type of cooperative learning method used helped me to use the knowledge gained to solve problems without assistance.					
10	I can see how the type of cooperative learning method used will help me in my education and in work related situations upon graduation.					
11	I can see how the type of cooperative learning method's principles can be applied across all academic disciplines.					
12	I am certain I can understand the most difficult concepts in school if teaching is done using this method.					
13	I often find myself questioning things I hear or read in this topic to decide if I find them convincing.					
14	When I become confused about a concept I have read, I consult my group members to try and figure it out.					

15	When a theory, interpretation or conclusion is presented in class, I try to decide if there is good supporting evidence.					
16	When studying for this topic, I often set aside time to discuss the contents with a group of students from the class and that motivates me to learn more.					
17	I try to change the way I study in order to fit the course requirements and the teacher's teaching style.					
18	I try to identify students in this class whom I can ask for help when the need be.					

APPENDIX E
Sample Lesson Plan

TOPIC: Classification of Semiconductors

DURATION: 120 minutes

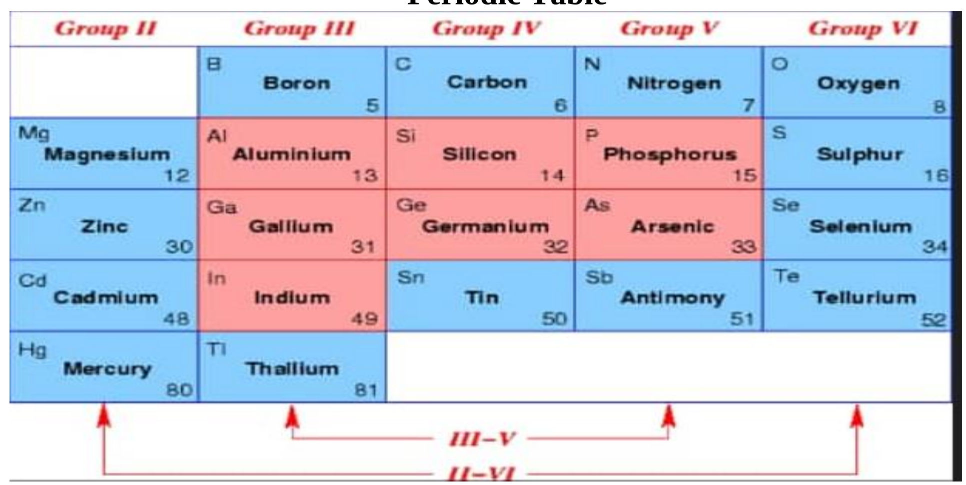
RELEVANT PREVIOUS KNOWLEDGE: Students have been taught the differences among conductors, insulators and semiconductors using the band theory of solids.

SPECIFIC OBJECTIVES: By the end of the lesson, the student should be able to:

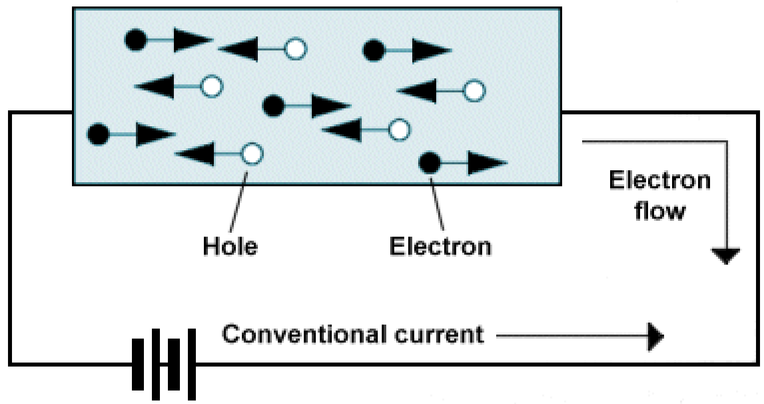
1. identify semiconductor elements using the periodic table.
2. describe the conduction process in intrinsic semiconductors.
3. explain the doping process of semiconductors.
4. describe the types of extrinsic semiconductors.

TEACHING/LEARNING MATERIALS: Printed materials on the topic.

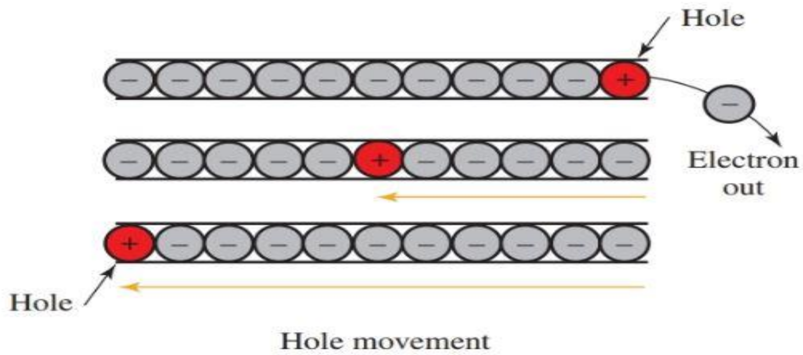
ADVANCED PREPARATION: Teacher puts students into teacher-made heterogeneous ability groupings and gets relevant reading materials on the topic for students to read in advance before the lesson.

Stage/Step/ Content/Estimated Time	**Teaching and Learning Activity**		**Main Ideas**
	Teacher Activity	**Student Activity**	
Introduction (5 min)	Teacher reviews students' previous knowledge on the characteristics of semiconductors.	Students' state some of the characteristics of semiconductors	
Content Development Step one Identification of semiconductor elements (10 min)	With the aid of the periodic table, teacher guides students in groups to identify semiconductor elements	Students in groups identify semiconductor elements on the periodic table.	**Periodic Table**  The semiconductor elements are those within the enclosed area. Of these, silicon (Si) and Germanium (Ge) have received a great deal of attraction because of their technical importance. Extensive studies have shown that in the metallic compound formed between the elements of group 2 and 6 and group 3 and 5 have semiconductor properties similar to those of Si and Ge. There are two classifications of semiconductors and they are intrinsic and extrinsic

<table>
<tr><th rowspan="2">Stage/Step/ Content/Estimated Time</th><th colspan="2">Teaching and Learning Activity</th><th rowspan="2">Main Ideas</th></tr>
<tr><th>Teacher Activity</th><th>Student Activity</th></tr>
<tr><td></td><td></td><td></td><td>semiconductors. Two factors which affect the conductivity of semiconductors are impurities and temperature</td></tr>
<tr><td>Step two
Conduction process in intrinsic semiconductors
(30 min)</td><td>Teachers discusses the conduction process in intrinsic semiconductors with students in their groups.</td><td>Students discuss the conduction process in intrinsic semiconductors with their peers and teacher.</td><td>Conduction Process in Intrinsic Semiconductors
1. A highly purified semiconductor exhibits intrinsic conductivity, implying there are equal number of free electrons (i.e., negatively charged carriers) and holes (i.e., positively charged carriers).
2. An intrinsic semiconductor is a pure semiconductor in which thermal vibration liberates thermal carriers. In the crystal structure of a semiconductor, all the valence electrons are tied in covalent bonds, and there are no free electrons. Semiconductors, therefore, seem to act as ideal insulators at 0 K, when there is no energy to excite the atoms. As more heat energy is introduced, covalent bonds are occasionally broken.
3. At room temperature, covalent bonds break, allowing more electrons to acquire enough energy to move into the conduction band and act as charge carriers.
4. When a voltage is applied to such a semiconductor crystal containing these conduction band electrons, the electrons move towards the applied voltage and this movement is called electron current flow. Holes move in the direction of the applied voltage and the electrons in the opposite direction.</td></tr>
</table>

Stage/Step/ Content/Estimated Time	Teaching and Learning Activity		Main Ideas
	Teacher Activity	Student Activity	
			 5. There is still another type of current created in a semiconductor. As electrons are set free, a hole or vacancy is created around the atom from which they escaped. An atom that becomes deficient in electrons gains a net positive charge and begins to attract and remove electrons from the valence band of neighbouring atoms to fill its holes. In doing so, new holes are created in the neighbouring atoms, which may be filled similarly. 6. A random movement of valence electrons and holes occurs throughout the crystal. Although an electron moves from one covalent bond to another, it is crucial to remember that the hole itself is also moving. 7. Therefore, since the process of conduction resembles the movement of holes rather than electrons, it is termed as *hole current flow*.

<table>
<tr><th rowspan="2">Stage/Step/ Content/Estimated Time</th><th colspan="2">Teaching and Learning Activity</th><th rowspan="2">Main Ideas</th></tr>
<tr><th>Teacher Activity</th><th>Student Activity</th></tr>
<tr><td></td><td></td><td></td><td>8. Hole flow is similar to electron flow, except that holes move towards the negative terminal or potential, in the opposite direction of the electrons.

9. Since hole flow results from the breaking of covalent bonds which are at the valence band level, the electrons associated with this type of conduction contain only valence band energy and must remain in the valence band.
10. However, the electrons associated with electron flow have conduction band energy and can therefore move throughout the crystal.
11. As shown in the figure below, two current carriers are created by the breaking of the covalent bond (i.e., the negative electrons and the positive holes). These carriers are called electron-hole pairs.

</td></tr>
</table>

<table>
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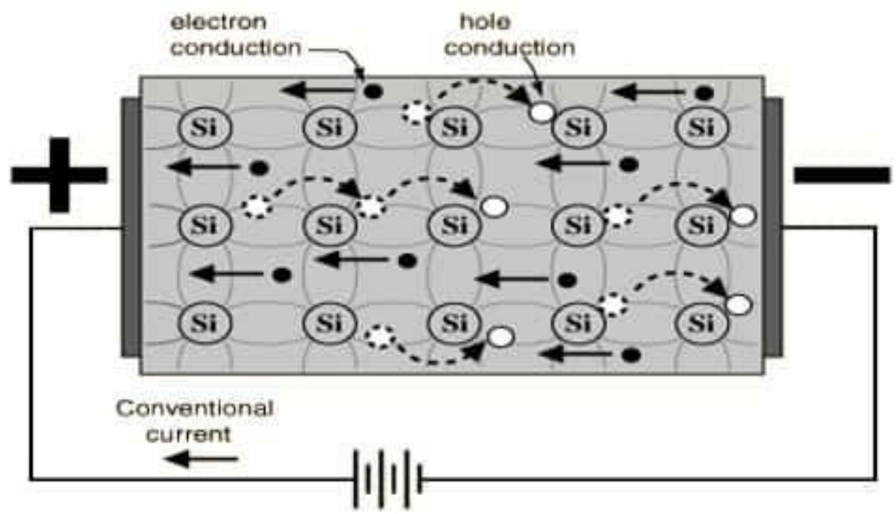
<tr><td></td><td></td><td></td><td>

12. When an electron encounters a hole, the broken covalent bond is re-established and this process is called recombination. The generation and recombination of electron hole pairs are permanently in equilibrium.
13. The higher the temperature, the higher the generation rate and the higher the generation rate, the higher the recombination.
14. From the time of generation to the time of recombination of carriers is called life time and the average distance a carrier travels during this life time are called diffusion length.</td></tr>
</table>

<table>
<tr><th rowspan="2">Stage/Step/ Content/Estimated Time</th><th colspan="2">Teaching and Learning Activity</th><th rowspan="2">Main Ideas</th></tr>
<tr><th>Teacher Activity</th><th>Student Activity</th></tr>
<tr><td>Step Three
Doping process of semiconductors
(10 min)

Step Four
Types of extrinsic semiconductors
(40 min)</td><td>Teacher discusses the doping process of semiconductors with students.

Teacher through discussion with students describe the types of</td><td>Students take part in the discussion with their group members and the entire class.

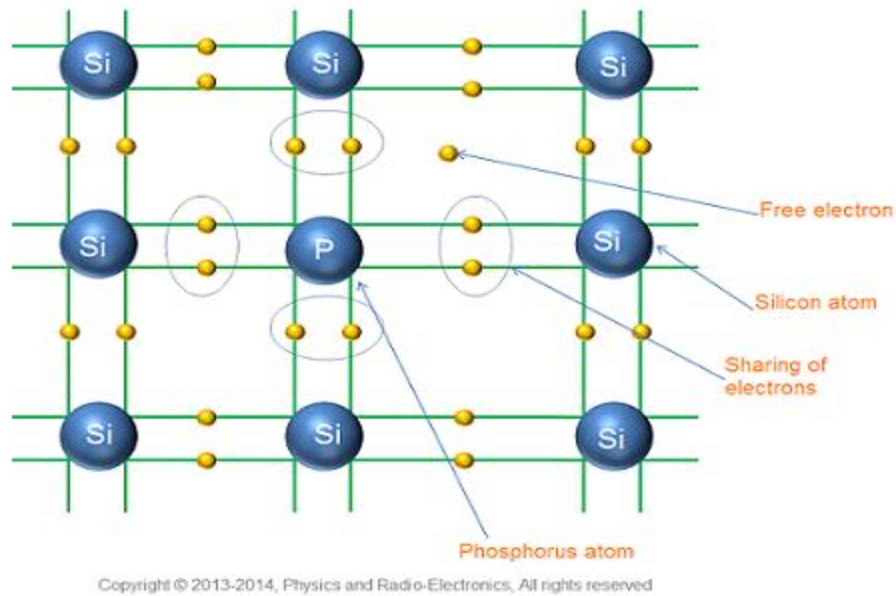
Students discuss the types of extrinsic semiconductors</td><td>Doping Process
1. Doping is the process of introducing impurities or foreign substances into a semiconductor to enhance its electrical conductivity.
2. A pure semiconductor (i.e., intrinsic semiconductor) is essentially neutral and does not contain free electrons in its conduction band. Even when thermal energy is applied, only a few covalent bonds are broken.
3. To increase current flow in a semiconductor and make it more efficient, very small amounts of additives are added to them (i.e., approximately 1 in 10^{10}).
4. These additives are called impurities and the process of adding them to crystals is called doping.
5. The purpose of semiconductor doping is to increase the number of free charges that can be moved by extreme applied voltage.
6. An impurity that increases the number of electrons in a semiconductor is known as a donor impurity, while an impurity that increases the number of holes in the semiconductor is called an acceptor impurity.

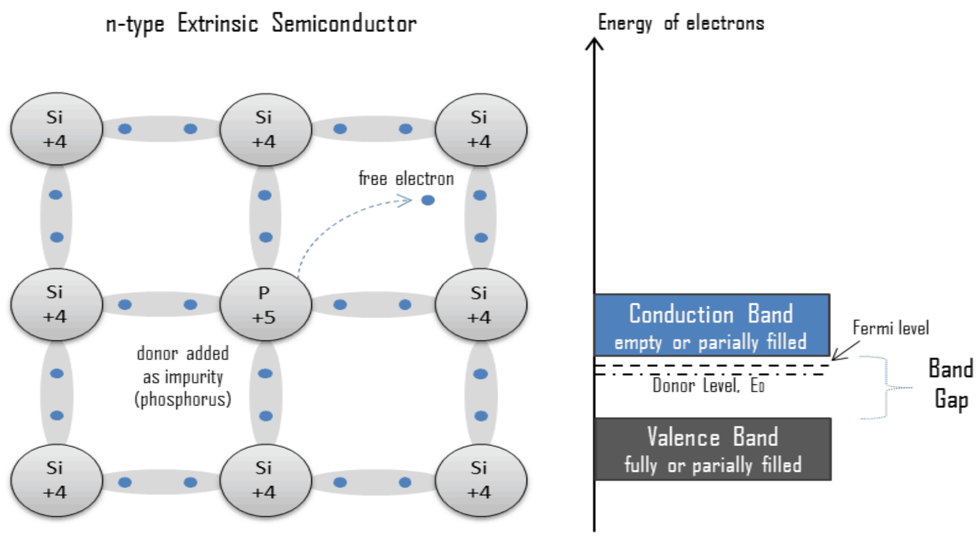
Extrinsic (Impure) Semiconductor
1. It is a semiconductor that has been doped with an impurity, resulting in an unequal number of holes and free electrons.
2. When an impurity increases the number of free electrons, the dopped semiconductor is said to be negative or N-type and the impurity that is added is called the N-type impurity. However, an impurity that reduces the number of electrons and causes more holes creates a positive or a P-type semiconductor and impurity that was added is known as a P-type impurity.</td></tr>
</table>

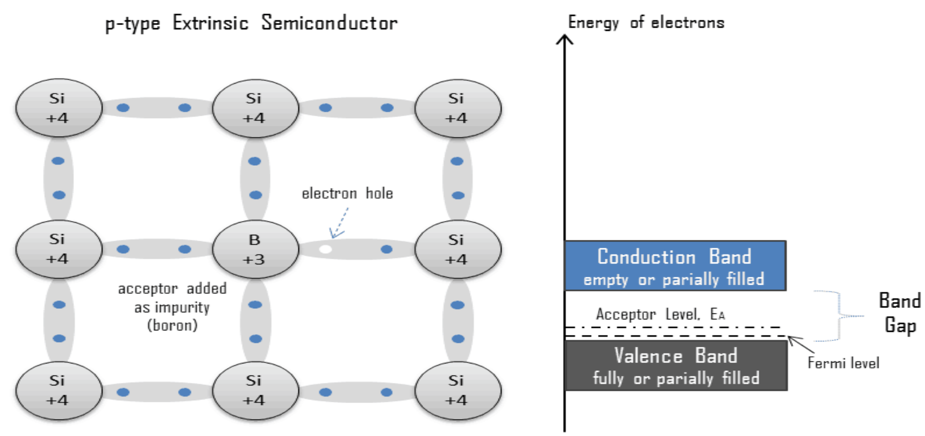
<table>
<tr><th rowspan="2">Stage/Step/ Content/Estimated Time</th><th colspan="2">Teaching and Learning Activity</th><th rowspan="2">Main Ideas</th></tr>
<tr><th>Teacher Activity</th><th>Student Activity</th></tr>
<tr><td></td><td>extrinsic semiconductors.</td><td>with their group members and the entire class.</td><td>3. Semiconductors which are dopped in this manner either with N-type or P-type impurity are referred to as extrinsic semiconductor.
4. In practice, the impurity elements are either a pentavalent (i.e., Arsenic, Antimony or Phosphorus) or a trivalent (i.e., Indium, Gallium or Aluminium).

Types of Extrinsic Semiconductors
1. N-type semiconductor
2. P-type semiconductor

N-type Semiconductor
1. This is an extrinsic semiconductor produced by doping a tetravalent element (i.e., element having four valence electrons) with a pentavalent element (i.e., element having five valence electrons).
2. Suppose a Silicon (Si) or Germanium (Ge) (i.e., Group 4 element) is dopped with a small amount of pentavalent element such as Phosphorus (P) which has five valence electrons.
3. Each P atom will set up covalent bonds with the four atoms of Si or Ge leaving a spare electron unbonded in the lattice structure as shown below.</td></tr>
</table>

Stage/Step/ Content/Estimated Time	Teaching and Learning Activity		Main Ideas
	Teacher Activity	Student Activity	
			 4. This surplus free electron is not bounded to its parent atom and so free to move about in the crystal lattice even if there is no thermal energy to generate electron hole pairs. 5. However, electron hole pairs are still produced by the thermal agitation of the lattice. The number of electrons are therefore more greater than the number of holes. Thus, negative charges predominate and the crystal is said to be N-type. 6. Since the impurity atom donates free electron to the crystal lattice, the impurity atom is called the N-type impurity atom or donor atom.

Stage/Step/ Content/Estimated Time	Teaching and Learning Activity		Main Ideas
	Teacher Activity	Student Activity	
			7. Note that in N-type semiconductor, majority charge carriers are electrons and minority charge carriers are the holes. 8. The donor impurity creates another energy level below the conduction band called the *donor level* as shown in the figure below. 

Stage/Step/ Content/Estimated Time	Teaching and Learning Activity		Main Ideas
	Teacher Activity	Student Activity	
			P-type Semiconductor 1. It is an extrinsic semiconductor which is produced by doping a tetravalent element with a trivalent element where holes are the majority charge carriers and electrons are the minority charge carriers. 2. Suppose Si or Ge which has four valence electrons is dopped with a small amount of a trivalent element such as Indium (In) which has three valence electrons. 3. Each Indium atom will form a covalent bond with each of the Si atom. Indium, however, has only three valence electrons and so only three of the bonds can be completed. 4. One hole is introduced in the lattice structure as shown below.  5. The free hole is able to move in the crystal structure.

Stage/Step/ Content/Estimated Time	**Teaching and Learning Activity**		**Main Ideas**
	Teacher Activity	**Student Activity**	
Application (15 min) **Closure** (10 min)	Teacher gives students this task for them to perform in their groups: What is the differences between N-type and P-type semiconductors? Teacher summaries the lesson and evaluates the lesson by asking the following questions: 1. Identify semiconductor elements using the periodic table.	Students listen and, in their groups, perform the task. Students listen and answer the questions.	6. In this case the holes are the majority charge carriers while electrons are the minority. The impurity is called the *acceptor or P-type impurity*. 7. The acceptor impurity creates another energy level above the valence band called the *acceptor level*.

Stage/Step/ Content/Estimated Time	**Teaching and Learning Activity**		**Main Ideas**
	Teacher Activity	**Student Activity**	
	2. Describe the conduction process in intrinsic semiconductors. 3. Explain the doping process of semiconductors. 4. Describe the types of extrinsic semiconductors.		

Assignment:

1. Describe the conduction process in intrinsic semiconductors.
2. Read on P-N junction for our next lesson.