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Enhancing Grade 10 Students Conceptual Understanding and Engagement in Electrochemistry through Technology-Mediated þÿTeam Pair Solo Learning: A Design-Based Research in Focus

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BAHIR DAR UNIVERSITY

COLLEGE OF EDUCATION

SCHOOL OF TEACHER EDUCATION

DEPARTMENT OF SCIENCE AND MATHEMATICS EDUCATION

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science Education in Focused of Chemistry

Major Advisor- Derejaw Yesgat (PhD, Asst Professor)

JUNE, 2026

BAHIR DAR, ETHIOPIA

DECLARATION

I, the undersigned, declare that this dissertation work, entitled "Enhancing Grade 10 Students Conceptual Understanding and Engagement in Electrochemistry through Technology-Mediated Team–Pair–Solo Learning: A Design-Based Research in focus" submitted in partial fulfillment of the requirements for a Master of education in Science focused in Chemistry, is a record of original work completed by me and has never been submitted to this or any other institution to receive any other degree or certificate.

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APPROVAL OF DISSERTATION FOR DEFENSE

We hereby certify that we have supervised, read, and evaluated this thesis entitled **"Enhancing Grade 10 Students Conceptual Understanding and Engagement in Electrochemistry through Technology-Mediated Team–Pair–Solo Learning: A Design-Based Research in Focus"** prepared under my guidance. I recommended the Thesis be submitted to oral defense.

Approval of thesis for defense

Derejaw Yesgat (PhD, Asst. Prof.)	______________________	June, 2026
Major Advisor's name	Signature	Date
Adem Mohammed (PhD, Assi. Prof.)	______________________	June, 2026
Department head's name	Signature	Date

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APPROVAL OF DISSERTATION FOR DEFENSE RESULT

As members of the head of examination, we examined the dissertation entitled "**Enhancing Grade 10 Students Conceptual Understanding and Engagement in Electrochemistry through Technology-Mediated Team–Pair–Solo Learning: A Design-Based Research in Focus**" by Mulugeta G/Mariam. We hereby certify that the dissertation is accepted for fulfilling the requirements for the award of the "Master of Education in Science focused in Chemistry".

Board of Examiners

____________________________	____________________	June, 2026
External Evaluator's name	Signature	Date
____________________________	____________________	June, 2026
Internal Evaluator's name	Signature	Date
____________________________	____________________	June, 2026
Chair Person's Name	Signature	Date

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Table of Contents

List of figures

List of Tables

ABSTRACT

The aim of this design-based-research study was to develop students' conceptual understanding and engagement of electrochemistry course using an integration of technology mediated instruction Team-Pair-Solo method in Fitawirari Habtemariam Secondary school. The participants in this study were grade 10 students' and they were chosen purposively. The data were gathered through classroom observation, pretest, posttest, classroom activities, interviews and focus group discussion and questionnaires. The students' responses on the pretest, first cycle posttest and second cycle posttest were analyzed both quantitatively and qualitatively. The quantitative paired sample t-test showed that students' were performed better in the second cycle posttest than the previous tests. A paired-sample t-test revealed that students' scored significantly higher at the first cycle post-test (M= 13.37, SD= 2.35) compared to pre-test (M=7.93, SD=2.22), t (39) =11.103, p<0.01. Moreover, the second cycle paired-sample t-test revealed that students' scored significantly higher at the second post-test (M=16.25, SD= 1.72) compared to the first cycle post-test (M= 13.37, SD= 2.35), t (39) = 6.57, p<0.01 indicating an improvement from cycles. The engagement questionnaire result revealed that students' were highly engaged in the second cycle (M=3.35, SD=0.182) compared to the first cycle intervention (M=2.882, SD=0.22), t (39) =9.838, p<0.01 indicating the re-designed cycle helped them to engage more on electrochemistry. The qualitative result from the open ended response and the focus group discussion indicated that students were able to understand the concept of electrochemistry conceptually as they were correctly wrote and tell the concept of electrochemistry specifically electrical conductivity, oxidation-reduction reaction, and galvanic cell. They were able to relate what they are learning in the class with the day to day activities. In addition, the students' were working passionately during the intervention that incorporates team-pair-solo strategy for dealing electrochemistry contents both in the first and second cycle of the intervention. At the second cycle, there was conceptual change texts incorporated at each stage of the team-pair-solo approach integrating it with technology. The re-designed context of the second cycle resulted both conceptual development and engagement on students' learning moreover than the first cycle. The researcher concluded that Team-Pair-Solo co-operative learning strategy will develop students' conceptual understanding and engagement if it is integrated with technology and to some extent conceptual change texts (CCTs). Therefore, the researcher recommended that electrochemistry topics such as electrical conductivity, redox reactions, and galvanic cell should be taught and learnt using the integration of technology in Team-Pair-Solo approach of cooperative learning with CCTs.

Key words: *Electrochemistry, Design Based Research, Team-Pair-Solo, Technology integration, Conceptual understanding*

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

Among the fields of natural science, chemistry is known for its enormous role in the societal applications of human beings. Chemistry is a branch of natural science that studies about the composition and structure of matter and the energy changes that matter undergoes (Myers, 2004). The concept of chemistry is versatile in all day to day activities of human societies. It deals with the production of soap and detergents, drugs, cosmetics, water treatment, material development, environmental monitoring, forensic science, consumer products and energy production. This highlights the importance of chemistry education at all educational levels that is in our primary, secondary, preparatory and university institutions. A chemistry student who cannot able to understand the wisdom of chemistry will not perform well in real life situations and in the world of work.

From the branches of chemistry, a physical chemistry deals about the structure of matter and how energy affects matter(Myers, 2004). A subdivision of physical chemistry that deals with the interaction of electrical energy and chemical energy is called an electrochemistry. Electrochemistry is concerned with the chemistry and physics of systems in which chemical reactions can produce an electrical current or, conversely, an external electrical potential is applied to provoke the reaction of species (Orozco et al., 2023). Electrochemistry is applied in different situations or activities in our daily life.

There are some application of electrochemistry concepts in the industrial relevance such as battery and electroplating (Wiyarsi et al., 2020). Electrochemical technology contributes in many ways to a cleaner environment and covers a very broad range of technology (Janssen & Koene, 2002). It includes production of energy using new batteries and fuel cells, purposive production of organic chemicals, removal of impurities from process liquids etc. Electrochemistry is also involved in the explanation of how a chemical energy is converted to an electrical energy using batteries by an electrochemical reaction Gibbs energy reduction (Schmidt-Rohr, 2018).Wear resistant, low friction and corrosion resistant materials can be produced as coatings on cheap and tough steel surfaces using an electrochemical deposition which is the concept of electrochemistry.

From the above evidences, an electrochemistry concept is a core and sensitive topic for students who are learning at secondary schools and higher institutions such as colleges and universities. Despite its importance in practical utility of the society and workers, the concept of electrochemistry is very difficult to understand it very well by students. Since the concepts are most abstract such as conductivity, oxidation-reduction, electrode potential, galvanic and electrolytic cells, students as well as teachers are confusing while learning and teaching it respectively.

According to Akram et al., (2014), students have a difficulty on understanding conduction of electrolysis by ions, mechanisms of electrolysis and its practical application, redox reactions and the product gotten at anode and cathode. A study conducted in South Africa also reveals that students tend to focus more on algorithmic problem-solving than conceptual understanding of electrochemistry(Amponsah, 2020). Note only the conceptual difficulty of students in electrochemistry is observed, but also there are misconceptions developed while learning it in classroom, textbooks or else. Students have a misconceptions regarding galvanic and electrolytic cells. They are confusing on the identification of the anode and the cathode of galvanic and electrolytic cells (Sanger & Greenbowe, 1997b). Sanger and Greenbowe's study which was conducted in 1997 is also congruent with the study of Dorsah and Yaayin conducted in 2019.

In Ethiopia, chemistry is delivered to students' in a conventional, teacher centered way and teacher centered explanation without dynamic visual representations. According to the study done in Dire Dawa, Ethiopia at three schools, 90% of the students replied in the interview that their teachers are just telling the theoretical part of electrochemistry without offering a practical and technology assisted instruction (Woldeamanueal & Goshu, 2020). This mode of delivery of electrochemistry course makes it one of the most difficult portions of chemistry for students to understand it very well. The students were also full of misconceptions while learning electrochemistry when it is delivered alone in didactic teacher centered way and forget the concepts behind the subject (Woldeamanueal & Goshu, 2020). There should be a conceptual understanding of electrochemistry for students to better know it practically. So as to improve students' better involvement in the concept, rote memorization of ideas should be improved and learning the topics through problem solving should be emphasized. Meaningful learning and long term retention is achieved while students are actively engage in the teaching-learning process. According to Iyamuremye et al.(2023), students have a positive experience and engage in chemistry practical works by doing activities. This study also revealed that, engagement can increases students' academic performance(Iyamuremye et al., 2023).

Team-Pair-Solo method of instruction can increase students' achievement as it focuses on peer learning, participation, and understanding level. Although there is a limited amount of research regarding this technique, It is a recommended technique so as to teach a chemistry topics Ogunleye (2011). In Team-Pair-Solo type of cooperative learning, students learn and work together in a group first before solving similar problems individually. While they are learning in group, students can help each other, coach themselves and share previous information's they know (W. Wibisono, 2018). In the pair phase, students work in couple building what they learnt in the team stage this makes them to explore the topic further and lastly in the solo phase students work alone so as to accommodate their understanding (Etukakpan et al., 2025).

Design Based Research (DBR) is a methodology designed by and for educators that seeks to increase the impact, transfer, and translation of education research into improved practice (Anderson & Shattuck, 2012). DBR is a recent field of research seeks to answer educational problems in natural setting after carefully identifying happened problems in the classroom to propose a possible solution, implement it and evaluate its effectiveness again and again until the appropriate understanding is achieved. DBR is an essential technique so as to empower students' conceptual understanding in science educations such as chemistry, biology or physics courses as well as others. According to Juuti (2006), Design based research is a research for education rather research about education as its objective is to improve the teaching- learning process.

This study aims to solve an educational problem in electrochemistry using the recent flexible approach of design based research by incorporating technology mediated instruction with team-pair-solo method as an intervention.

1.2 Statement of the problem

Electrochemistry is a basic course in secondary school chemistry (grade 9-12) since it provides the fundamental understanding for oxidation-reduction reactions, batteries, electricity, industrial products such as phones, car batteries, wrist watch batteries etc. Although electrochemistry is essential for students' to understand the real life, it is consistently identified as one of the most difficult and abstract topics for students to learn and for teacher to teach. According to different researches done on electrochemistry, students often experience difficulties in understanding the movement of ions and electrons, as well as galvanic and electrolytic cells (Schmidt et al., 2007 ; Akram et al., 2014). As a result, many students' develop misconceptions that persist even after instruction and hinder their achievement in chemistry in general and in electrochemistry course in particular.

According to John stone's model of chemical representation, meaningful understanding in chemistry requires students' to coordinate macroscopic, microscopic, and symbolic representations simultaneously (Johnstone, 2000 ; Taber, 2013). However, students' are relying on rote memorization of rules and procedures other than developing a deep conceptual understanding of electrochemical processes. The reason for this rote memorization of learning in students is happened due to their passive role in the learning process. In teacher-centered method of instruction, students' receive information from teachers with limited opportunities for discussion, collaboration, and also conceptual investigation. Such type of instructional practices may not adequately address students' misconceptions and hence hinder their meaningful conceptual learning (Sukarmin et al., 2020).

So as to increase students' conceptual understanding while learning, different educational researchers give emphasis on the importance of active learning approaches in classroom. Among the active learning strategies, cooperative learning strategies have been found to enhance conceptual understanding by allowing students' to share and exchange ideas, justify their reasoning's and also construct knowledge collaboratively. According to Johnson & Johnson (2009), they recommended that cooperative learning promotes higher academic achievement, greater retention of knowledge, and also improve problem solving skills. This makes students' to interact in peer and engage in collaborative discussion that paves a way for them to construct their knowledge. In addition to cooperative learning, technology-enhanced instruction has emerged a good approach for addressing conceptual difficulties in chemistry. Visual representations, animations and simulations can help students' visualize abstract electrochemical processes in macroscopic aspect. According to Lin & Wu (2021), technology-supported learning environments can facilitate students' understanding of electrochemical concepts and also assist teachers in identifying and addressing misconceptions. It also provides interactive learning experiences that support students' conceptual development and engagement.

Among cooperative learning strategies, the Team-Pair-Solo strategy offers a structured sequence of learning experiences in which students' initially solve and discuss on problems as a team, then they will be arranged in to pair and work in pair, and finally they will perform tasks independently. This method of learning reveals what Vygotsky's said in his theory of learning. Students' or learners' can achieve higher levels of understanding when support is gradually reduced as competence develops (Cole & Scribner, 2016). Based on this perspective, the Team-Pair-Solo strategy has the potential to enhance students' conceptual understanding while simultaneously fostering independent learning skills.

Though there studies done on cooperative learning and technology-integrated instruction, studies that are aimed to investigate the integration of the cooperative learning strategy known as Team-Pair-Solo with a computer-assisted learning is still insufficient. Only few studies in chemistry, biology and physics integrated the above combination (Team-Pair-Solo with Technology mediated) in their research and found a positive result, but research done specifically on electrochemistry is hardly found. Mostly English and Mathematics courses are researched using a Team-Pair-Solo method of instruction (Sojinu & Sanni, 2025; B. W. Wibisono, 2019) and announced us to use them. On electrochemistry, it is difficult to find study on the combination of Team- Pair-Solo (TPS) with technology assisted instruction.

Even though previous studies have documented students' misconceptions in electrochemistry and highlighted the benefits of cooperative learning and technology integration, it is difficult to find studies done using a Design-Based-Research (DBR) approach. Most studies tell us about misconceptions in electrochemistry only rather than examining how these approaches can be systematically designed, implemented, and refined within a Design-Based-Research framework.

Design-Based-Research emphasizes iterative cycles of analysis, design, implementation, evaluation, as well as re-designs to address real educational problems(Lewis et al., 2020). Despite its growing application in science education, relatively few studies have employed DBR to develop and refine technology-integrated cooperative learning interventions specifically aimed at improving secondary school students' understanding of electrochemistry.

Specifically, in Ethiopia there lacks studies done on electrochemistry using a design based approach as most of them rely on quasi-experimental research design without re-design the method. Moreover, in Ethiopia students are just memorizing the concepts behind an electrochemistry course because of lack of understanding the basic underpinnings behind it. There are so many reasons for the poor achievement in the topic of electrochemistry. One reason is the abstract nature of the course as it is being described above. The other reason for the poor performance of students is the way electrochemistry concepts are delivered to students. This focuses on the instructional methodologies that the teachers are using. In secondary schools and in fact in universities, teachers are using a conventional methodology for sharing their ideas without using teaching aids (Woldeamanueal & Goshu, 2020).

Most teachers are not equipped with the concept of a dynamic visualization such as simulation and animations for clearly describe an electrochemistry concept so that eliminating any misconceptions happened in students. Due to lack of such pedagogical methodology, students' motivation towards learning an electrochemistry concept is declining and performs a low grade in tests.

Moreover, most studies, in Ethiopia, on chemistry in general and electrochemistry in particular focus on the experimental designs and quasi-experimental that mostly relays on the effect of variables on students' result. However, they are not identifying a real problem in the classroom, do not designing a possible remedial strategy to solve it and evaluate its effectiveness. This study tries to cover the above gaps found in the literature and in the classroom by designing an effective and applicable way to teach an electrochemistry course using the recent research approach the so called design based research (DBR).

Therefore, the present study seeks to design, implement, and refine a technology-integrated Team-Pair-Solo instructional intervention through a Design-Based-Research approach to enhance students' understanding of electrochemistry. By addressing identified learning difficulties and misconceptions, the study aims to contribute to both the improvements of classroom practice and the advancement of knowledge regarding effective chemistry instruction.

1.3 Objectives of the study

This research has the following general and specific objectives.

1.3.1 The general objective of the study is:-

- To design an effective teaching methodology so as to teach the concept of electrochemistry using a technology- mediated instruction with team-pair-solo learning in Fitawirari Habtemariam secondary school.

1.3.2 The specific objectives of the study are stated below:-

- To increase students' conceptual understanding on electrochemistry using technology- mediated instruction with team-pair-solo method of cooperative learning.
- To develop engagement towards learning of electrochemistry concept using a technology assisted instruction cooperative Team-pair-Solo method of learning.
- To increase students discourse of electrochemistry concepts by eliminating misconceptions towards electrochemistry concept.

1.4 The research questions of the study

The study has the following basic research questions:-

- To what extent can technology- mediated instruction improve students' conceptual understanding in electrochemistry concepts in Fitawirari Habtemariam general secondary school and preparatory?

- How does a Team-Pair-Solo method of cooperative learning enhance students' engagement in electrochemistry concepts in Fitawirari Habtemariam general secondary and preparatory school?
- To what extent the integration of technology mediated instruction with team-pair-solo learning eliminates misconception and learning difficulty in electrochemistry concepts in Fitawirari Habtemariam general secondary school?

1.5 The Significance of the study

The findings of this design based research (DBR) will add important information on the existing literatures that is being done on an electrochemistry concept with technology mediated instruction. Moreover, it will help chemistry teachers', teacher educators', chemistry trainers' and chemistry learners' or students' so as to gain the basic pedagogical underpinnings behind learning and teaching an electrochemistry concepts.

Curriculum developers' will have also an insight about the teaching methodologies of electrochemistry concepts and incorporate important points in the text book. Although static visualization of electrochemistry, like graphs or diagrams are essential in the teaching material, it does not assure the conceptual understanding of all the concepts present in the abstract nature of electrochemistry. Therefore, curriculum developers and text book writers will be beneficial after reading such a research finding in order to incorporate a dynamic visualization method of teaching in electrochemistry concepts.

The study also gives information for classroom teachers' while they are teaching an electrochemistry course. They will gain instructional richness for delivering a given abstract concept of electrochemistry and improving their teaching methods and hence increasing their students' outcome. For students', the research finding gives an alarm for their learning as it describes the difficulty nature of electrochemistry that they should be carefully learn this most abstract course and be aware the misconceptions occurred behind it. However, it also suggests a possible remedial solution for the difficult nature of learning and teaching of electrochemistry concepts like oxidation-reduction reactions, metallic conductivity, electrolytic conductivity, Galvanic cell.

1.6 Delimitation of the study

This study is delimited both geographically and content coverage. Geographically, the study was conducted in Bahirdar, Amhara regional state, Ethiopia. It was conducted in Fitawirari Habtemariam secondary and preparatory school at grade 10 students'. Based on the revised Ethiopian General Education Curriculum in 2022, the concepts about an electrochemistry starts at the second semester of the academic year at chapter four in grade 10. This chapter has been given a name as "Energy changes and Electrochemistry".

The study focuses only on the second portion of the chapter known as the "Electrochemistry" part as it is the most abstract concept for chemistry learners' and teachers' to understand. This electrochemistry section encompasses other subsections such as electrical conductivity, electrolyte and non- electrolyte, galvanic cell and electrolytic cells. The electrical conductivity section also includes a metallic and electrolytic conductivity as a subsection. There is also a subsection under the section of galvanic cell. These are primary and secondary cells. As the researcher uses a design based research, the researcher taught the topics of conductivity (metallic and electrolytic conductivity), oxidation-reduction reaction, and galvanic cell (Primary and Secondary).The teaching and learning was carefully taken place until there was a satisfactory student conceptual understanding was observed and hence their increase in outcome. The topics regarding the above electrochemistry concepts were treated in to two cycles, cycle one and cycle two.

1.7 Operational definition of terms

Team-Pair-Solo- Team-Pair-Solo is a cooperative learning strategy where students first work together in a small team, then they will be break in to pairs and of triples, and finally they will complete a given task individually. It is aimed to build confidence and mastery by scaffolding learning from collaborative support to independent work.

Conceptual Understanding- It means grasping the deep, underlying principles and relationships between ideas, not just memorizing facts or procedures. In this study, conceptual understanding is about understanding the 'Why' and seeing the big picture, connecting different concepts of chemistry to build a coherent, transferable knowledge base that is in reality.

Engagement- It is the deep involvement, attention, motivation, and emotional investment learners' show in an educational process in general and in this study in particular.

Motivation- In this research motivation means the eagerness of students towards learning electrochemistry concepts in a co-operative learning.

Technology Mediated Instruction- In this study, technology mediated instruction refers to the application of different instruments such as videos, animations and simulations towards teaching electrochemistry concepts.

CHAPTER TWO

2. REVIEW OF THE RELATED LITERATURE

2.1 Introduction

Electrochemistry is a branch of chemistry concerned with the relationship between electrical energy and chemical reactions. It deals with processes involving electron transfer, oxidation-reduction reactions, galvanic cells, electrolytic cells, and conductivity phenomena. Electrochemical principles have numerous applications in modern society, including batteries, corrosion prevention, electroplating, fuel cells, and industrial chemical production. Consequently, electrochemistry occupies a central position in secondary and higher chemistry education.

Although electrochemistry is significant, it is widely recognized as one of the most difficult topics in chemistry education. Numerous studies have reported that students experience substantial challenges in understanding electrochemical concepts because these concepts involve abstract microscopic processes that are not directly observable (Marohn & Harrison, 2007). Unlike many chemical phenomena that can be observed directly, electrochemical processes require learners to simultaneously understand macroscopic observations, symbolic representations, and submicroscopic particle interactions (Li & Arshad, 2014).

Students are required to understand invisible processes such as electron transfer, ion migration, oxidation-reduction reactions, and electrochemical potentials while simultaneously coordinating macroscopic observations, symbolic representations, and submicroscopic explanations. Consequently, many learners experience difficulties in developing scientifically accurate conceptions of electrochemical phenomena (Wolfson et al., 2014). Recent studies indicate that misconceptions related to electron flow, galvanic cells, electrolysis, and oxidation-reduction processes remain prevalent among students across different educational contexts(Woldeamanueal & Goshu, 2020). Furthermore, researchers argue that the abstract nature of electrochemistry stems from the fact that many of its fundamental processes are not directly observable, requiring learners to rely heavily on mental models, visualizations, and symbolic representations(Lin & Wu, 2021). Therefore, innovative instructional approaches that support visualization, active engagement, and conceptual change are essential for meaningful learning in electrochemistry.

2.2 The Theoretical Complexity of Electrochemistry

Among the different branches of chemistry, electrochemistry is a course that needs conceptual demanding while learning it in the classroom and doing it in the laboratory activities. This is because electrochemistry integrates chemical reactions, electron transfer, energy conversion, and other topics (Akram et al., 2014). Students are expected to understand invisible particle interactions while interpreting symbolic equations and observable experimental phenomena (Taber, 2020). Consequently, many learners develop misconceptions and misunderstandings of electrochemical concepts such as oxidation-reduction reactions, galvanic cells, electrolytic cells, conductivity, and other electrochemical processes.

Electrochemistry is sophisticated because many of its core processes cannot be directly visible to our naked eye. Unlike some areas of science where learners can visually observe phenomena, electrochemical processes mainly occur at the microscopic level through the movement of electrons and ions. This abstractness creates significant learning dissatisfaction towards learners. This makes students often to rely on everyday experiences reasoning other than the correct scientific explanations (Sanger & Greenbowe, 1997b).According to Suprapto (2020),Everyone can experience misconception, not only students experience it, but it also is experienced by adults, including teachers, lecturers, and even professors. A misconception is a misunderstanding in connecting a concept with other concepts, between new concepts and old concepts that are already in the minds of students, so that the wrong concepts are formed.

One type of misconception is conceptual misunderstanding that arises when students relate to expert opinions in a way that does not cause students to resolve paradoxes or conflicts due to the presumption of initial concepts and unscientific beliefs. Students end learning with a feeling of dissatisfaction and not being able to explain what they have learned. As a result, these students build wrong models that limit the educational process in the future (Suprapto, 2020). For instance, many students incorrectly believe that electrons move through electrolytic solutions in the same way they move through metallic wires. And others believed that ions remain stationary during electrolysis or misunderstand the directions of electron flow in galvanic cells (Sanger &Greenbowe, 1997b). This all misconceptions arise because electrochemical processes involve invisible interactions that basically require visualization.

So as to reduce conceptual difficulties in the learning of chemistry in general and electrochemistry in particular, the concept of John Stone's triangle should be given emphasis while learning chemistry courses. According to Johnstone (2000), he believed that the nature of chemistry is connected with the three corners of triangles and each are complement with each other. The first chemistry triangle is the macroscopic and the tangible aspect that refers what we observe with our naked eyes and touch with our hands. Next to this the second corner of the triangle is the submicroscopic aspect which explains what is inside the macroscopic world and deals about atoms, molecules, ions and structures. The third corner of John stone's triangle deals about the symbolic aspect that represents the macroscopic learning using graphs, equations, symbols, or formula (Johnstone, 2000).

Using the application John Stone's triangle, the concept of electrochemistry can be remediated as it can be taught in macroscopic, microscopic and symbolic aspect. For example, in galvanic cell, lighting a bulb will be a macroscopic representation and the transfer of electrons will be the explanation for the lighting of the bulb that defines the microscopic aspect and the oxidation-reduction reaction equation will be the symbolic representation. Therefore, to be effective in students learning, the instruction should integrate multiple representations and promote conceptual understanding through visualization, conceptual change strategies and active learning approaches.

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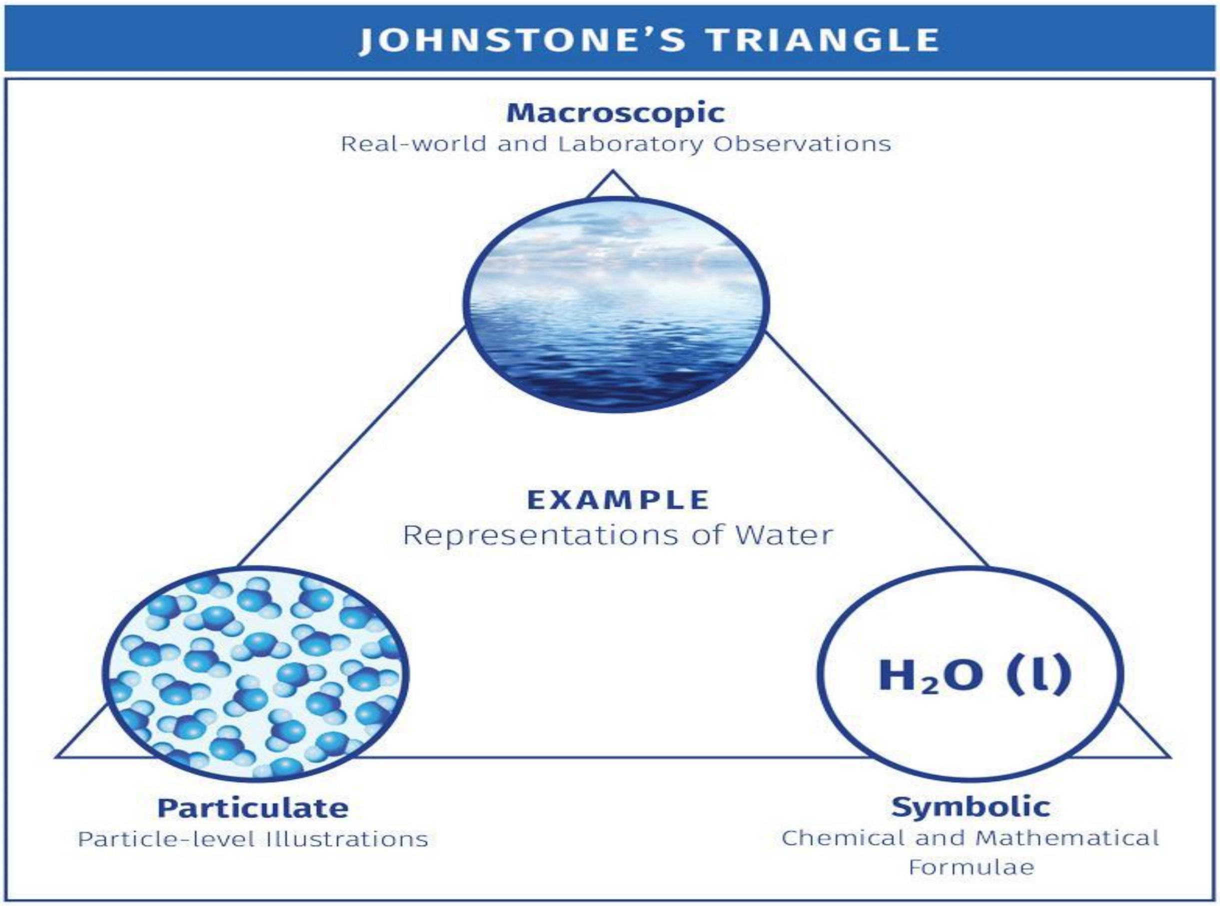


Figure 1 Johnston's Triangle of water in the three aspects

2.3 Theoretical Framework of the Study

The present study is grounded in a combination of learning theories and instructional design principles that collectively explain how students learn complex chemistry concepts and how teaching interventions can enhance both conceptual understanding and engagement.

According the review of Ali et al.,(2022), Electrochemistry is widely recognized as one of the most abstract and conceptually demanding topics in secondary chemistry curricula. Students often struggle with invisible processes such as electron transfer, oxidation–reduction reactions, and electrochemical cell operations. Therefore, this study adopts a theoretical framework that emphasizes active knowledge construction**,** social interaction**,** and technology-supported visualization to address these learning challenges.

2.3.1 Cooperative Learning

Cooperative has become one of the most influential student centered instructional approach in chemistry education as it promotes active students participation, peer two way interaction, critical thinking and in fact increasing a conceptual understanding. Cooperative learning involves students working together in small groups to achieve shared academic goals while supporting one another's learning unlike a traditional lecture based instruction (Johnson & Johnson, 2009)**.**

The major principles of cooperative learning include positive interdependence, individual accountability, face-to-face interaction, collaborative skills and also a group processing(Johnson & Johnson, 2009). Peer interaction is one the most important components of cooperative learning since it helps students' explain concepts to one another, ask questions, pose arguments and debate about different scientific topics. According to Gillies (2019), explaining ideas verbally strengthens conceptual understanding because it helps students to reorganize and refine their thinking while communicating with their peers.

This study basically grounded on the Vygotsky's socio cultural theory by applying it with a Team-pair-solo learning strategy. Below are the justifications of this learning theory with targeted intervention of the study team-pair-solo learning.

2.3.2 Social Constructivist Theory

The primary theoretical foundation of this study is social constructivist theory**,** as proposed by (Marginson et al., 2015). Social constructivism posits that learning is fundamentally a social process**,** where knowledge is constructed through interaction with others and mediated by language, tools, and cultural context. According to this theory, cognitive development occurs first at the social level and is later internalized by the individual learner (Novita et al., 2020).

The Team–Pair–Solo instructional strategy directly reflects the core assumptions of social constructivism. During the team and pair phases, students collaboratively discuss electrochemical concepts, share ideas, negotiate meaning, and challenge misconceptions. These interactions provide opportunities for learners to operate within their Zone of Proximal Development (ZPD)**,** where more capable peers and instructional supports help learners achieve higher levels of understanding than they could independently. The solophase then allows learners to internalize the socially constructed knowledge and demonstrate individual conceptual understanding (Novita et al., 2020).

In the context of this research on electrochemistry, social constructivism supports the idea that students can better grasp abstract processes such as ion movement and electron flow as well as oxidation- reduction reaction when they engage in guided discussions and collaborative problem-solving activities. Thus, the social constructivist perspective provides a strong justification for the cooperative nature of the TPS method used in this study. Within the Team–Pair–Solo structure, constructivist learning is reinforced as students first explore concepts collaboratively and then independently try to solve problems according to their understanding in the first phase which is a team phase and the second phase which is the pair stage discussion activity. This progression supports deep conceptual learning, particularly in complex chemistry topics that require visualization and abstract reasoning. Therefore, constructivist learning theory provides a cognitive explanation for how technology mediated instruction and TPS can promote meaningful learning in electrochemistry.

2.3.3 Social Interdependence Theory

The cooperative dimension of the Team–Pair–Solo method is further explained by social interdependence theory, developed by (Johnson & Johnson, 2009). This theory asserts that the way in which goals are structured determines how individuals interact, which in turn affects learning outcomes. Positive interdependence occurs when learners perceive that they can achieve their goals only if other group members also succeed.

In the TPS method, positive interdependence is established during the team and pair phases, where students rely on one another to understand concepts and solve problems related to electrochemistry. At the same time, individual accountability is ensured through the solo phase, where each student must independently demonstrate understanding. This balance between cooperation and individual responsibility is essential for effective cooperative learning.

Social interdependence theory thus explains how the TPS method enhances both conceptual understanding and student engagement, as learners are motivated to participate actively, support peers, and take ownership of their learning. This theoretical perspective is particularly relevant in our country’s secondary classrooms, where collaborative learning can help address large class sizes and diverse learner abilities.

2.4 Technology Mediated Learning Instruction in Chemistry

So as to reduce the abstract, microscopic and difficult nature of chemistry for students, technology integrated instruction has a paramount effect on the conceptual understanding of students learning electrochemistry. As the traditional or lecture based teaching-learning process limits students understanding of intangible chemical process like electron transfer, ionic transfer, chemical bonding and molecular interaction, educational technologies should be incorporated to resolve such problems. According to Nduati (2015), he recommended the integration of computer assisted learning (CAL) in the teaching-learning process of chemistry. In his study, done in Kenya, students exposed to technology mediated instruction perform better compared to those students who were thought using a traditional lecture based method. This reveals that the integration of technology mediated instruction should be given an emphasis on the teaching-learning process. Technology mediated instruction also helps reduce abstraction in chemistry learning. Most chemistry concepts are difficult since learners are not directly observing the process being discussed. Animations, Simulations, and you tube experimental videos can reduce students cognitive load toward the concept of learning electrochemistry.

Animation videos can help students to reduce conceptual difficulty regarding the movement of electrons in galvanic oxidation and reduction reactions. It can enable students to observe the migration of ions in conductivity and in reaction mechanisms. Different studies reveal that educational animation videos help students to connect what they saw in the macroscopic aspect with the explanations inside it as well as the symbolic representation of the phenomenon(Chen et al., 2024). This strengthens the concept of what we called chemistry triangle in the John stone’s theory. When we come to electrochemistry, animation videos will play a significant role for demonstrating the microscopic aspect of the concept. It has a power to visualize charged particle movements in electrolytes and oxidation-reduction reactions in addition to the electron movement in an external circuit.

An electrochemistry concept can be thought using a Team-Pair-Solo strategy with the combination of a technological integration, for example simulation learning. A simulation is an imitation or replication from the real thing and represents a real environment within which students interact (Atabhotor & Kofoworola, 2020). Simulation can easily represent difficult topics with dynamically visual representations unlike the static visualization of the textbooks. Computer simulation approach integrates synchronized pictures, sound, and motion, creating immersive learning experiences that bridge theoretical knowledge with practical application (Etukakpan et al., 2025). Simulations can have an ability to encourage an active learning by allowing pupils' to ask and inquiry scientific concept as well as it engages students in scientific reasoning. Electrochemistry, a most abstract concept, can be delivered using simulation method of teaching as the topics of electrochemistry are more intangible and possible sources of misconceptions. Using simulation, topics like salt bridge, Galvanic cell and Electrolytic cell, Electrical conductivity can be delivered well since they can be represented with dynamic visualization.

2.5 Previous empirical studies on electrochemistry

The first reviewed study was conducted at De Britto College Senior High School, Yogyakarta, Indonesia Setyowati (2026). She investigated students' misconceptions in electrochemistry using a classroom action research design implemented in iterative cycles. The study was carried out in a single classroom without a control group, as the primary purpose was instructional improvement rather than group comparison.

The aim of the study was to improve students' learning competency throughout cycles; cycle one and cycle two rather than comparing with the control group since comparison of two groups was not her objective (Setyowati, 2026). When we look carefully this study, this study shows DBR-like characteristics such as iterative cycles although there is a difference between an action research and a design based research. Design based research (DBR) is a methodology designed by and for educators that seeks to increase the impact, transfer, and translation of education research into improved practice (Anderson & Shattuck, 2012). According to this definition, the researcher was slightly implementing a design based research because she was implementing her methodological intervention in cycles or phases until the conceptual understanding of the students' was improved satisfactorily. Cyclical or iterative process is one characteristics of a design based research (Lewis et al., 2020).

The researcher identified several learning challenges prior to the intervention, including low student participation in discussions, difficulty relating electrochemistry concepts to real-life situations, and a dominance of teacher-centered instruction. Additionally, over 40% of students failed to meet the Minimum Completion Criteria (KKM = 80), indicating significant conceptual difficulties, particularly in electrolysis.

To address these challenges, a problem-based learning approach was implemented through two iterative cycles. The findings showed progressive improvement in students' performance. The average pre-test score was 70.57, with only 33.33% of students meeting the competency benchmark. After Cycle I, the mean score increased to 79.57, with 63.33% achievement. In Cycle II, further refinement of instruction—including improved group organization, clearer instructions, contextualized problems, and scaffolding through guiding questions—resulted in a mean score of 85.16 and 80% student achievement.

Although the study was framed as action research, its cyclical refinement, data-informed redesign, and focus on improving instructional practice reflect key characteristics of Design-Based Research (DBR), which emphasizes iterative development of educational interventions in authentic classroom settings (Anderson & Shattuck, 2012; Lewis et al., 2020). However, the study did not explicitly develop transferable design principles beyond the immediate classroom context.

This research is more or less related with design based research because her target was not to compare the result of the experimental group with that of the control group rather she designed another best methodology for the improvement of her one class room students.

According to Dorsah & Yaayin (2019), out of ten students only two of them correctly understand the anode and cathode of a galvanic cell. Moreover, they also found a misconception regarding functions of salt bridge and direction of flow of ions or charges in electrochemical cell. In the study of Dorsah & Yaayin (2019), they found misconceptions about function of the salt bridge, the anode, anions and oxidation. According to Dorsah & Yaayin (2019) , students' were assuming the function of the salt bridge is to conduct electrons; the anode is always on the left; anions move from the anode to the cathode; oxidation occurs at the cathode. The results showed that students' misconceptions were centered on identifying cathode and anode in galvanic cells, understanding the functions of the salt bridge, understanding charge of the cathode and anode, identifying cathode and anode in electrolytic cells and understanding current flow in galvanic and electrolytic cells. These researchers were found that students in both the experimental and control groups had some misconceptions about electrochemistry. Also, for both experimental and control groups no student had sound understanding of the electrochemistry concepts tested. This suggests that students had difficulties in understanding the concepts in electrochemistry. They found that conceptual change approaches can be a remedial solution for teaching some electrochemistry concepts. Conceptual change texts helped students to change their pre-existing conceptions or misconceptions for scientifically correct ones.

According to Sukarmin et al (2020), students' have a misconceptions developed from textbook diagrams as they believed that the anode is always on the left. Moreover, the positions of electrons are memorized instead of conceptually understood. The researchers recommended using teachers a remediation through guided conceptual change strategies tailored to students' learning styles. This is similar with the recommendation of the researches of Dorsah & Yaayin (2019). In the review of Ali et al (2022), students were unable to explain how a drift of anions come to the negatively charged anode electrode because of their common assumptions that anode is negatively charged. Similarly, those students who believed anode is a positively charged specious were not have ample understanding to explain the flow of electrons from the anode to the cathode to undergo a reduction reaction (Ali et al., 2022).

The study of Turner et al(2024) reveals that students commonly confuse ionic conduction with electronic conduction and misunderstand the polarity of electrodes in galvanic and electrolytic cells. Many believe electrons move through the solution like ions or assume the negative pole is always the cathode, showing that they over generalize concepts without understanding that electrode identity depends on oxidation and reduction and differs between cell types. These misconceptions arise from inconsistent textbooks, unclear explanations, and teachers limited confidence in teaching complex electrochemistry. Students also misinterpret diagrams that suggest electrons move inside the electrolyte.

To address this, Turner and his colleagues recommended improving teaching models, explicitly distinguishing between electron flow in metals and ion movement in solutions, and using accurate analogies supported by clear clarification. They also emphasize the importance of teacher training and the use of digital media such as animations that show electrons moving only in the wire while ions maintain internal charge balance. Strengthening curriculum design, integrating physics and chemistry concepts properly, and supporting teachers with better pedagogical tools can greatly reduce misconceptions and improve students understanding of electrochemical processes.

An article that was published in January 2025, deals about the remedial solutions about how we can teach an electrochemistry course in secondary school. The title of the research says “The impact of virtual laboratory integration on electrochemistry education at Enessie secondary school” (Enchalew, 2025).This study was conducted in East Gojjam at HuletEjuEnessie District, Ethiopia and focuses on studying the conceptual understanding of electrochemistry concept using virtual laboratory settings. By incorporating animations and simulations into the learning process, particularly for abstract topics, students can become active participants in their own education. This interactive approach allows students to construct and comprehend complex concepts more readily (Atabhotor & Kofoworola, 2020). Moreover, simulations and applications tailored to specific content can significantly accelerate learning by enabling students to express their understanding in real-time.

The experimental group was exposed to a blended learning approach, integrating traditional hands-on experiments with computer simulations and animations and the control group was learnt using traditional conventional methods of teaching. The results of the study show that the conceptual understanding of students who are exposed to virtual laboratory instruction was improved from pre-test to post test results. In this study, it was observed that the mean score of the control group students increased from 11.40 to 30.34, while the mean score of experimental group students increased from 11.18 to 38.42. Moreover, Students paired samples test showed that the greatest increase was shown in the experimental group. This implied that learning of electrochemistry using an animation and simulation integration enhances students’ conceptual understanding than learning it theoretically in traditional way. This result is consist with the studies of (Plass et al., 2012).

The study also dealt about the engagement and motivation of students while learning an electrochemistry concept and found that there was a positive interdependence between electrochemistry concept and virtual laboratory. In relation to this more than 90% of experimental group respondents agreed virtual laboratory increased their interest to learn the content knowledge. According to the students questionnaire result, 90% of them responded as the lesson shown in the classroom motivated them to learn an electrochemical cells and they also develop a motivation again for learning electrochemical cells using animation visual way. Another finding in this study is that 94% of the students had developed an interest to learn an electrolysis concept of electrochemistry since the teacher was explaining the topic using virtual lab way. This result is consistent with the ideas of Sharifi et al studies. Among the advantages pointed out by Sharifi and his colleagues about simulation and animation is that it increases students' interest and motivation in the topic being studied ; It makes the material more realistic and relevant when compared to the traditional approach to education; Students can experiment with ideas without having to worry about actual consequences with receiving receive immediate feedback so that they can change their course of action (Sharifi et al., 2017).

Regarding movement of electrons, students responded as the virtual laboratory helps them to understand easily the movement of electrons in the electrolytic cell from one electrode to another in the external circuit. 92% of students who were exposed to virtual lab gained a conceptual understanding regarding where electrons move in electrolytic cell. This makes the virtual laboratory simulation based teaching to have a powerful effect on reducing student conceptual difficulties in electrochemistry concepts. The confusion regarding the movement of electrons in electrochemistry is also the case for an organic chemistry. According to (Issa I. Salamea,*, Sagar Patela, 2019), students have a greater difficulty about responding where electrons to move and where to move electrons to. Therefore, the case of electron movement can be illustrated using a virtual laboratory assistant teaching.

This study also revealed us that the integration of technology assisted learning can correct students' misunderstandings about electrochemistry course as 88 % of students have improved their learning by eliminating their misconceptions about electrochemical cells.

2.6 Cooperative Learning in Chemistry Education

Cooperative learning has been widely investigated in chemistry education as an effective pedagogical approach for improving students' academic achievement, conceptual understanding, and engagement in science learning. According to Abdulwahab et al (2016), they recommended that teachers' should use of cooperative instructional strategy as it enhance students' achievement in chemistry especially with low and medium scoring students.

In classroom-based studies, cooperative learning models such as Student Teams Achievement Division (STAD), Think–Pair–Share (TPS), and group-based inquiry approaches have consistently demonstrated improved student outcomes. For example, Karaçöp (2016), investigated the effect of STAD cooperative learning with conceptual models on students' understanding of electrochemical cells. The results showed that students in the cooperative learning groups significantly outperformed those in traditional instruction, particularly in understanding abstract electrochemical concepts such as electron transfer and electrode processes.

According to Ifeoma & Drummond (2025), the co-operative learning strategy think-pair-solo fosters the teaching and learning of chemistry. Moreover, they added that if think-pair-share strategy effectively implemented, it can improve understanding and also cultivate critical thinking skills.

Across these studies, cooperative learning consistently demonstrates several educational benefits, including improved academic achievement, enhanced conceptual understanding, increased student engagement, and better retention of knowledge (Felder & Brent, 2007). These improvements are particularly significant in chemistry topics that involve abstract and microscopic processes such as electrochemistry, where students often struggle to connect macroscopic observations with submicroscopic explanations.

However, despite the effectiveness of cooperative learning, most existing studies apply it in isolation, without integrating it with technology-mediated instruction or iterative design-based refinement processes. Additionally, limited research has explored structured cooperative learning models such as Team–Pair–Solo in combination with digital tools and conceptual change strategies within a Design-Based Research framework.

2.7 Design Based Research and Its Principles

Design- Based Research (DBR) is a systematic research methodology that targets to design, develop, implement, and refine educational interventions in real-world learning environments while it simultaneously generating theoretical knowledge about teaching and learning. It focuses on understanding how and why an intervention works through iterative cycles of design, implementation, analysis and revision. According to Sandoval (2014), DBR has three major goals. The first one is designing an innovative learning environments or interventions. The second one understands how those interventions work in real educational settings and the last one is based on the previous observations, developing or refining theories about teaching and learning will be established.

Educational Design Research (EDR) is a flexible, non-linear research approach that requires researchers to adapt their methods to the specific problem, context, and circumstances of the study rather than following a fixed sequence of steps (McKenney S. & Reeves 2011). Because of this DBR is not a one shot investigation rather it requires careful follow up of students' progress at each contact time. As DBR focuses on the process of learning rather than product or end of learning, students' way of thinking and responding during the intervention is the main part of the designing process. This makes teachers' or researchers' to identify specific problems happened during the learning process and help them to plan for solving the problem.

Educational settings are complex and can be influenced by many contextual factors as a result DBR generates design principles that are directly applicable to educational contexts. According to Wang & Hannafin (2005), DBR has nine principles that are basic in educational settings. These principles are tabulated below with their descriptions.

Table 1 The nine principles of DBR (Wang & Hannafin, 2005)

No	Principle	Description
1	Support Design with Research from the Beginning	Review relevant literature, previous studies, and theoretical frameworks before designing the intervention.
2	Set Practical Goals and Develop an Initial Plan	Clearly define the educational problem, research objectives, and theory-development goals. Develop a flexible plan that can evolve during implementation.
3	Conduct Research in Real-World Settings	Implement and study the intervention in authentic learning environments such as classrooms.
4	Collaborate closely with participants	Engage teachers, students, and other stakeholders throughout the research process.
5	Use research methods systematically	Employ multiple data collection methods such as observations, interviews, surveys, assessments, and document analysis.
6	Analyze Data Continuously	Conduct data analysis throughout the research process rather than waiting until the end of the study.
7	Refine the Design Iteratively	Modify and improve the intervention based on evidence gathered during implementation.
8	Document Contextual Influences and Design Principles	Record contextual factors affecting implementation and develop design principles based on findings.
9	Validate Generalizability	Examine whether the developed design principles can be applied in contexts beyond the original setting.

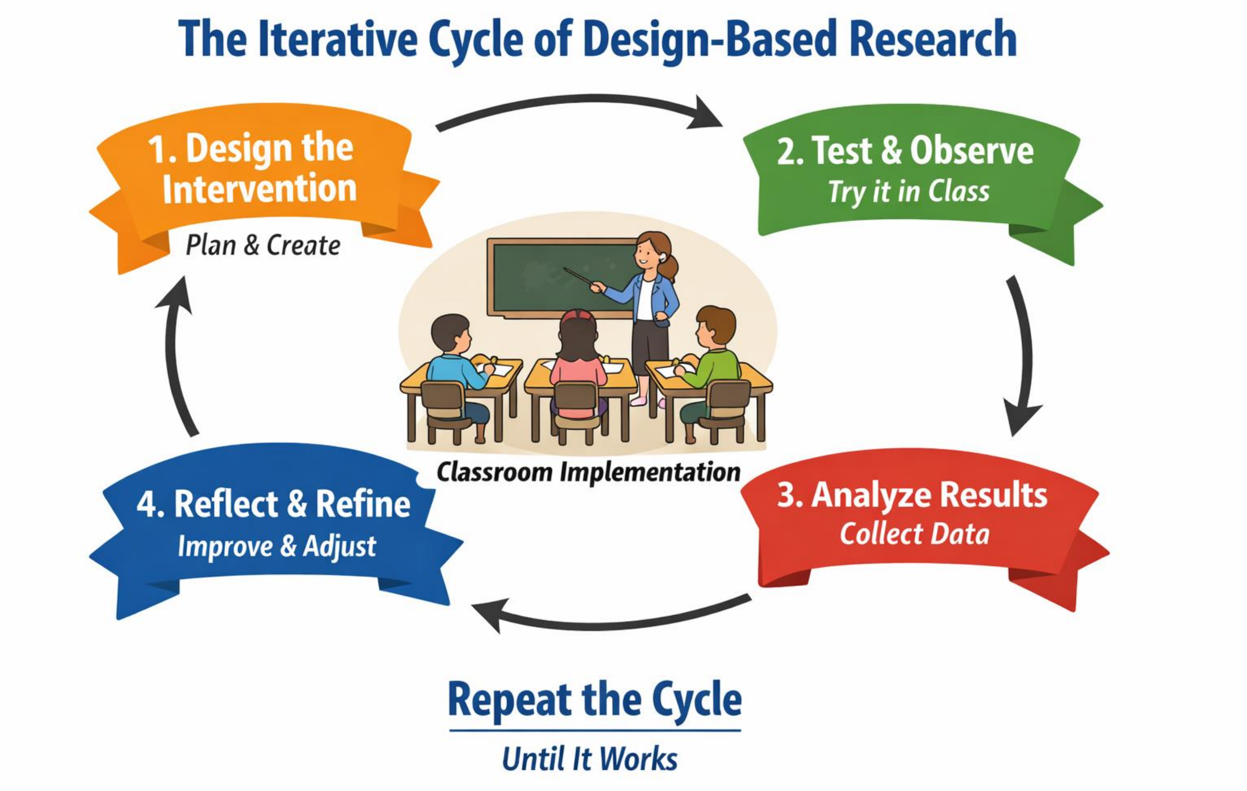


Figure 2 the cyclic nature of Design Based Research

2.8 Research Gaps from the Empirical Review

From the perspective of the researcher, there are some research gaps that the researcher pointed out after a deep investigation of vast literature review.

Firstly, most existing studies on chemistry in general and electrochemistry in particular relies on either experimental or quasi-experimental research design. Moreover, the above reviewed studies involve pre-test and post-test designs so as to measure the effectiveness of the planed intervention method. That means they are just for the purpose of testing a methodology rather than refining and designing an ongoing intervention structure. Their final goal is to compare the pretest result with that of the post test result by ignoring the process of learning environment. Therefore, this impedes to redesign and adapt new instructional methodologies based up on the real classroom setting, students' opinion and observed misconceptions during the teaching-learning process. Therefore, one research gap is research design gap that means there is hardly to find a paper done on a design based research on electrochemistry.

Secondly, most studies focus on the cooperative learning strategy alone without an integration of technology mediated instruction. Or most relies on an integration of technology mediated instruction without a cooperative learning strategy. To our surprise, there is hardly to find a research done on the cooperative learning strategy Team-Pair-Solo method integrated with technology mediated instruction in a design based approach.

Thirdly, most studies recommended conceptual change texts as a remedial solution to reduce misconception however they were often implemented without collaborative and interactive environment. There lacks an integration of conceptual change strategies in Team-Pair-and-Solo strategies in each phase with the help of technology mediated instruction.

Fourthly, when we come to the Ethiopian context, most researched studies primarily focuses on measuring the effectiveness of a given teaching methodology over the traditional lecture based method. In addition, the research focuses on the identifications of misconceptions rather than taking an immediate redesigned intervention process. There is lack of studies that considers a cooperative learning Team-Pair-Solo strategy with the integration of technology mediated instruction by refining the process of learning.

Fifthly, most studies done in Ethiopia used quasi-experimental research design which has an experimental and a control group for the investigation process. Rather than relying on a single section, the researchers did a comparison between the two groups and report it. There lacks a research done by design based focused on a single classroom so as to improve students learning competency.

Based on the above research gaps identified, this study tries to fulfill students' conceptual difficulties of learning electrochemistry. It is designed a cooperative learning strategy Team-Pair-Solo with an integration of technology mediated instruction, and conceptual change texts as a refine method. This intervention is all work based on a Design-Based-Research approach.

CHAPTER THREE

3 Methodology of the Study

3.1 Research Design and approach

This study was guided by the pragmatic research paradigm. This research paradigm is particularly suitable for the teacher researcher's design-based research study as it focuses on developing and refining educational interventions in real-world contexts while generating both practical and theoretical knowledge. In this study, pragmatism guided the iterative design, implementation, evaluation, and refinement of a technology-mediated team-pair-solo learning intervention targeted on enhancing students' conceptual understanding and engagement in electrochemistry topics.

The study follows a design-based research (DBR) approach. As DBR strives to change students' conceptual understanding using a cyclical process (Juuti, 2006), the researcher applied such approach for teaching grade 10 students to teach electrochemistry. From many directions of investigation, the researcher wanted to address such design method to measure and improve students conceptual understanding using a cooperative (TPS) student centered learning strategy. This DBR approach study was conducted on a single class of grade 10 students of Fitawirari Habtemariam secondary and preparatory school.

Moreover, the study incorporated both a quantitative and a qualitative approach for identifying possible problems of learning and find solutions to them. The Mixed method approach was chosen for this study for collecting data from students.

3.2 The research setting and condition

This study was conducted on a governmental school found in Bahir Dar, a capital city of Amhara Regional state, Ethiopia. Most governmental schools in Ethiopian lack adequate infrastructure, teaching aids like books, laboratory equipment, technological advancements (Hunduma & Mekuria, 2023), and innovative teaching methodologies such as active learning methods. The learning environment in this school is mostly a teacher centered chalk- board methodology. This research was conducted in such school environment and its conditions.

3.3 Sources of Data

The source of the data in this study was both a primary and a secondary data. As a primary data the researcher conducted interview for students' and teacher's at Fitawirari Habtemariam governmental school found in Bahir Dar city, a capital city of Amhara regional state, Ethiopia. These students were learning in Fitawirari Habtemariam secondary school at grade 10 class. Another source of data in this research was the respected chemistry teachers in Fitawirari Habtemariam secondary school. The researcher plans to interview them about the subject chemistry in the general and electrochemistry in particular so as to identify learning difficulties of students'.

The researcher wanted to know how chemistry teachers were teaching an electrochemistry and aimed to ask teachers about students' behavior so that helping their students' learning. As the researcher believed that the teacher is the basic source of data for identifying students' misconceptions, the researcher collected information from teachers to know students difficulty throughout the semester that are related with the research area.

Another source of data that the researcher collected information is from secondary sources that are from literature reviews, articles and journals about the problem observed in the natural setting of the classroom while the teacher is teaching and the students are learning an electrochemistry concept. These secondary sources helped the researcher to redesign an effective intervention method for students to overcome learning difficulty in the second cycle of the study. By investigating the sources of the observed problems when the researcher teaches students', the researcher reviewed another studies existing in the time of the researchers work. This made the researcher to go through a research based teaching approach (Sriprakash, 2012).

The third sources of data in this research was a grade 10 chemistry text book that was published in 2022 by the Federal Democratic Republic of Ethiopia, Ministry of education, under General Education Quality Improvement Program for Equity (GEQIP-E). The chemistry text book is the major teaching material for students and teachers as they are relied on the topics presented in the book. The text book incorporates the topic “Energy change and Electrochemistry” on chapter 4 where the focus area of the research was grounded. The text book was the base for the researcher so as to design an effective teaching strategy. It was also used to know if there is possible wrong representation of ideas diagrammatically or non- diagrammatically.

3.4 Population, Sample Size, and Sampling Technique

The study was conducted in Fitawirari Habtemariam secondary and preparatory school found in Bahirdar city. The school was chosen because in this school chemistry subject is delivered 3 times a week and among the three periods the two periods are programed consecutively in one day. This made the researcher to implement the team-pair-solo learning method as it requires time to implement it. The population of the study was students’ who were attending to learn at this school at grade 10. The researcher aimed to study the intervention method on a single class among the five grade 10 sections. Since the researchers design approach is Design Based Research, it was aimed to conduct the study on a single class. Because of this the researcher chose a single class and the sampling technique was purposive sampling. The sample size is 40 students.

The researcher used purposive sampling as the teachers who were teaching the five sections of the grade 10 were not equally reach at the topic of research. Only the teacher who was teaching section 10^{th} E was teaching based on the lesson plan scheduled. The other two teachers were not reaching the topic of the research to be studied.

3.5 Data Gathering Instruments

The data collection method in this study was both a quantitative data gathering method as well as a qualitative data gathering method. As the study adopts a design based research that follows a mixed approach, the data collection method was the blended of quantitative and qualitative one. The qualitative method was chosen so as to investigate students existing understanding about an electrochemistry concept. Moreover, the qualitative method was aimed to know their prior experience or knowledge about the course deeply using interview questions and to some extent focus group discussions. The interview was focused on the collecting of information about students' prior and existing knowledge. Classroom observation was also another method of qualitative data collecting method in this study.

The quantitative method was also included under this study to measure students' knowledge quantitatively through a predetermined pretest before an intervention was going to be applied as this gives information for the researcher about students' learning difficulties. Moreover, a questionnaire was another data gathering instrument in this study. The questionnaire was aimed to collect data that reveals how much students' are engaged and motivated in the activities done while learning the concept. The questionnaire was grounded by different theories and students' engagement in electrochemistry content was measured using a researcher- developed questionnaire. The instrument was theoretically grounded in the multidimensional model of student engagement, encompassing behavioral, cognitive, emotional, and socio-cultural dimensions (Fredricks et al., 2004). Moreover, co-operative learning theory (Johnson & Johnson, 2009)& (Novita et al., 2020) and technology-mediated learning principles (Koehler, 2006) informed the researcher for the construction of items related to peer interactions and technology use respectively.

The researcher also conducted a post-test for students so as to measure students' conceptual change quantitatively at the end of the first cycle of the study. The post test questions were the same as the pretest one which contains both in open ended questions and multitier multiple choice tests. In the second cycle of the study, the researcher employed a redesign intervention process and prepares another related test that is aimed to know the change and the effect of the redesigned method. Similarly, as it is done in the first cycle, the researcher conducted an interview for students about the changes they made in the second cycle after learnt in the redesigned method of intervention. A questionnaire was also given for students' at the end of the second cycle of the research. Therefore, this study used both a qualitative and quantitative data gathering instruments to collect basic references to act for students benefit.

3.6 Data collection procedures and Designing Process

3.6.1 Before Intervention Method

Initially the researcher understands the teaching environment after entering the classroom compound and Communicates with students and the respected teacher so as to form friendship and partnership with students and the classroom teacher. After doing this, the researcher entered the class and attentively follows students' progress in each day while the teacher was delivering the concept of electrochemistry. The reason for the attentive follow up of students in their learning was so as to identify any misconceptions and learning difficulty happened to them. The researcher attended continuous class room observation sitting on the middle of students' and observe unclear or vague ideas created by a student or students'. The researcher attended and section of grade 10 students' chemistry period in different days as this helps the researcher to identify different learning difficulties and personal misconceptions of students' using the predetermined prepared observation checklist.

Moreover, a pretest had been given before the researcher was going to prepare an intervention plan for students' difficulty. This pretest results was being recorded and carefully interpreted as it was ground information for the researcher's intervention plan. From the researcher's classroom observations of continuous periods and the interviews that the researcher conducted for students' and teacher, the researcher organized those several misconceptions and learning difficulties in to manageable way so as to conduct a literature review.

From the point of literature review investigation, the researcher designed a technology assisted team-pair-solo method of teaching electrochemistry as an intervention plan for teaching students' at grade10. However, this was being modified after looking students' behavior in relation to the concepts about electrochemistry and the effective of the designed intervention in the cycle one.

3.6.2 Cycle one of the intervention plan

In cycle one, the researcher aimed to fulfill the gap of students' knowledge found in the pre-test and in the observation process. In this cycle, the researcher designed an intervention method that was implemented in the natural setting of the school. The intervention method was blending a technology mediated instruction with a co-operative learning strategy the so called Team-Pair-Solo approach while learning an electrochemistry concept. The processes in cycle one is listed below.

3.6.2.1 Implementing the intervention

The researcher scheduled a lesson plan for delivering the electrochemistry lesson by incorporating computer assisted instruction as a teaching aid. At this stage, the researcher implemented the intervention method which was teaching electrochemistry concepts using a computer assisted methodology. Here, the students' attended the class first by taking notes from the board given by the researcher and listen attentively about the written topic. After that the researcher was displayed a video or animation that explains the process of the concept giving students' to understand the invisible aspect visible.

Then, the students' was being assigned in team and pair/triple to discuss about what they wrote on their note book with the opened animation or video that talks about the concept. In the first stage, Team stage, the researcher gave students' an activity which aimed to know their prior knowledge and discuss electrochemistry concept within the group. At this time, the researcher was observing the students' engagement process using his observation checklist format which is put at the appendix section of this paper.

After giving students a chance to discuss in team, that contains a maximum of 6 students, the researcher arranged the students', again, in pair/triple. In the pair/triple stage, the researcher gave them discussion questions that are basically related with what they discussed on the team stage. Then, again the researcher followed the students' discussion attentively and identifies possible impediments for their discussion. Then lastly, the researcher arranged students' individually and again gave them discussion questions but at this time a student was discussing it with his own assumptions. At the third stage, students wrote what is in their mind after they discuss with their partners in the team and pair/triple stage.

The researcher filled his observation checklist format by looking students' progress in the discussion part. After implementing such technology mediated instruction with a Team- pair-Solo approach of co-operative learning for consecutive classes, the researcher gave them a cycle one of post-test so as to know how much students are progressing using the implemented approach. Therefore, the researcher prepared a post-test for students so as to measure their learning progress both academically and conceptually. The post-test was focused on measuring the conceptual understanding of the students as a result the post-test was open ended questions and multitier multiple choice questions as it was given in the pretest. Then, the researcher recorded the result of the post- test section of cycle one and analysis it.

3.6.2.2 Retrospective Analysis of Intervention Process and Result of Cycle One

In this stage, the researcher reviewed the students' actual learning progress in the present by comparing it with their behavior before the beginning of the intervention. Having the observation checklist before and after the intervention process, the researcher performed a qualitative analysis of the students' engagement before and after the intervention.

Moreover, the researcher conducted an analysis on the pre-test of the students' score with the post-test of the cycle one. Since the two tests, pre-test and post-test, have the same questions, the researcher would have a comparison aspect of each students' progress. The pre-test result of a given student was compared with the post –test result of his own response. A paired sample t-test was conducted. By this, the researcher identified how much students' have got the true concept and how much of them are also still struggling after carefully analyze the students' both pre-test and post-test responses and made another decision to redesign the way the intervention method could be delivered.

3.7 Critical Reflection on the first cycle

Based on the first cycle overall process, the researcher observed several advantages as well as observed problems on students' learning. Since it is the very important aspect of Design Based Research, the research carefully identified the benefit and the existed problem of the implemented method of intervention. The researcher attempts to present the improvements as well as the observed problems of the implemented intervention.

3.7.1 The benefits of the implemented intervention

According to the post test result of the students', the researcher forwarded that the intervention was effective. However, the researcher thinks beyond the quantitative aspect and tells about the process of learning and the observed benefits. During the intervention which was Team-Pair-Solo co-operative learning, almost all of the students' were discussing passionately about metallic and electrolytic conductivity, galvanic cell and redox reactions. They were discussed in team that contains a maximum of 6 students'. At this stage, students' were not only sharing ideas about the concept but also they were arguing about some critical points. For instance, students' were discussing about the great Ethiopian renaissance dam and how it can produce electricity as well as the way electricity is coming towards towns and villages.

They argue about electrolytic conductivity and metallic conductivity related to above issue. Some students thought that electrolytic conductivity can be exhausted and its power of conductivity is low compared to metallic conductivity. So, if the Ethiopian great renaissance dam produces electricity in an electrolytic conductivity way, it will be exhausted and the dam will no longer give service. Therefore, there are metals such as Copper and Aluminum to carry charges for transmitting electricity to towns and village as well as different institutions. By using these metals, the electrons will be move from the place of high voltage to that of low voltage. This discussion of students' revealed the researcher how much they can think if they will be given a chance to discuss co-operatively. What the researcher want to say is that, the intervention opens a way to think students' about the real life and discuss it with what they have been learnt in the classroom.

Moreover, the technology that the researcher used gives students' to understand the invisible aspect of electrochemistry visible. There were so many educational videos on web sites that help students' to develop conceptual understanding. Besides, it fosters discussion while students' were in the team and pair/triple stage of the implementation process. The videos that they were watching also helped them to do the tasks that the researcher gave them at each stage of the implementation. The videos that the researcher used for the first cycle are sited at reference section of thesis paper.

At the solo stage, students' were look confident for doing their individual task using what they were seeing in the video. This stage is the critical stage for the researcher as his main objective was so as to upgrade each student's conceptual understanding regarding electrochemistry concepts. According to the evidence both in process of learning and posttest response, students' were to some extent gradually increased their way of knowing and understanding of electrochemistry concepts. They were able to response something about conductivity, redox reaction or galvanic cell after the administration of the posttest unlike the pretest.

Although the researcher saw the above improvements' on students' learning, there were some problems while implementing the designed intervention method in the classroom. These drawbacks that the researcher identified in this cycle are reported below in the second section.

3.7.2 The observed problems in the first cycle

Even though students' were performing well both conceptually and academically, the researcher critically identified the problems happened during the implementation of the first cycle. These problems are the cause for the researcher to re-design the previous intervention method and implement it again on the same class which was 10^{th} E of Fitawirari Habtemariam secondary and preparatory school. These observed problems were clearly stated below:-

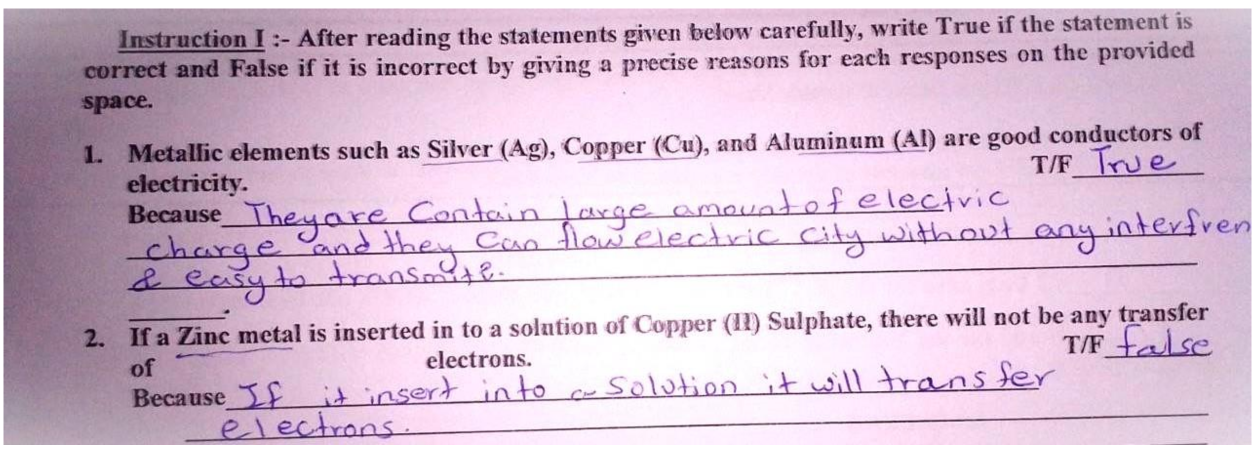
The first problem that the researcher identified was the imbalance of group arrangement while in the team and pair stages. The groups in this cycle were arranged randomly without considering students' ability. Since the intervention uses the principle of scaffolding which states that the more knowledgeable will help the less knowledgeable (van de Pol et al., 2010) & Reiser, 2018), the group arrangement should be considered based on students' content ability. Therefore, due to this improper arrangement of students', some students' were not discussing passionately or some groups of students' were silent at all as they were lack hint about the concept to discuss. As a result, they choose to be silent and shy to tell about what they think in mind.

The second observed problem was critical as it was the main cause for students' learning difficulty and low understanding. The problem was persistent misconception on different contents of electrochemistry concepts. Students' showed a persistent misconception on the concept of metallic and electrolytic conductivity, primary and secondary galvanic cell. They, not all students, still believe that:-

- ✓ The charge carriers for metallic and electrolytic conductivity is electrons
- ✓ Connecting redox reactions with ionic and covalent bond theory as most students' believed that metals cannot transfer electrons to other metals rather transfer to non-metals. Some others also still connect with the concept of octet rule.
- ✓ Most students' believed that the concept of electronegativity is the main reason for the conductivity of different materials but this is not scientific understanding.

- ✓ Many of them considered wet cell as secondary and dry cell as primary. They did not connect primary and secondary galvanic cell with the concept of rechargeable concept.

The above misconceptions or lack of understanding were observed on most students' even after the implementation of the designed intervention method. They still believe that metals conduct electricity because they have positive charge and have low electronegativity value. They also replied that because metals contain large amount of electric charge, they can conduct electricity. The above stated reasons of students have some sort of misunderstanding since they connected metallic conductivity with unrelated concept. The basic reason for the conductivity nature of metals is due to free or delocalized electrons they have in their crystalline structure. Therefore, although students' showed an improvement on the understanding level, some of them have persistent misunderstanding about the correct concept of metallic conductivity. Some students' written work is presented below.


Instruction I :- After reading the statements given below carefully, write True if the statement is correct and False if it is incorrect by giving a precise reasons for each responses on the provided space.

1. Metallic elements such as Silver (Ag), Copper (Cu), and Aluminum (Al) are good conductors of electricity. T/F True
   Because They are Contain large amount of electric charge and they Can flow electric city without any interfren & easy to transmite.
2. If a Zinc metal is inserted in to a solution of Copper (II) Sulphate, there will not be any transfer of electrons. T/F false
   Because If it insert into a solution it will transfer electrons.

Figure 3 Student's posttest explanation for the open ended questions

The third observed problem was the scarcity of time to implement the intervention method. Most students' were not able to finish the activities on time as a result they give back for the researcher without attempting the questions. This was the scarcity of the time and also the number of questions they were being asked was not balanced to the existing time schedule. There were at least four activity questions per stage though they were allowed to do it only within 10-15 minutes. These impede the students' to do the forwarded task on time hence letting other questions left. These was observed in some students' not in all of students'

The fourth observed problem was the amount of the video they were watching. Students' were allowed to see a 3 to 4 minutes video so as to help them and integrate their concept with reality. However, the video time was somewhat long and made them to discuss with in a few minutes. Therefore, the video time impedes the three stages the team-pair-and solo stage as it was talking their discussion time since all the activities should be completed within 40 minutes.

The last observed problem was the role of the teacher researcher towards helping students' understand what they were being asked. The teacher researcher was mostly observing students' discussion and talks little about the concept they were discussing about. Some students' were not also understood what really they were being asked. The teacher researcher was actually facilitating the learning process by providing discussion questions to students' but not actually elaborating the meaning and the idea about they were being asked.

3.8 Cycle two of the intervention Plan

In cycle two, the researcher conducted a modified version of cycle one so as to get satisfactory result on students' conceptual understanding of students' learning of electrochemistry. In this cycle, the researcher aimed to improve the teaching- learning strategy best fit for students'. After carefully identifying students learning difficulties and impediments happened in cycle one, the researcher re-designed the way the intervention method was delivered in cycle one and observed students' progress in it.

3.8.1 Re- Design the intervention method

After having a strong data from cycle one, the researcher designed the intervention method again. The re-designed process includes redesigning the students' pair arrangement using researcher's criteria, re-designing the group arrangement, re-design the types of questions to be discussed, re-design the computer mediated instruction such as displaying simple experiments, showing more simplified animation videos, giving diagrammatic pictures about electrochemistry concept to discuss, allow them to reflect their understanding for their peers in the classroom and also using conceptual change texts as a facilitator.

This re-designed plan was implemented later when students' would be observed by the researcher. The researcher observed the implementation of the re-designed intervention method using his own observation checklist that contains knowing students' engagement level.

After implementing the re-designed intervention method, the researcher employed another post-test for students' which was almost similar but minor modification from the first cycle posttest. The second cycle post test questions were formulated based on the learning and experience students' got in the second cycle. The post-test result of the students' was collected and analyzed quantitatively and qualitatively. The post-test result of the students' in cycle two was compared with the post-test result of students' in cycle one so as to know the change of students' in cycle two. Moreover, students' engagement level was also measured using a second cycle questionnaire that contains the re-designed intervention which was a conceptual change text. Finally, students were being interviewed in focus group discussion (FGD) about the whole process of their learning both in cycle one as well as in cycle two and it was transcribed.

Based on the observed problems that were arranged in the first cycle, the researcher re-designed the intervention method for the second cycle and implemented it in the same class. The following are the re-designed strategies that were implemented on the second cycle.

1. Based on the principle of scaffolding, the groups were arranged based on the first semester chemistry course result of the students'. The arrangement was aimed to create a heterogeneous group arrangement so that students' would gain an opportunity to help each other. As a result, students' who scored above 75 out of 100 were arranged in each team. There were 6 students' who scored beyond 75 in their first semester chemistry course grade.
2. The researcher re-designed the intervention by adding conceptual change texts in the team-pair-solo method of co-operative learning. According to a study done in Ghana, conceptual change texts helped students to change their preexisting conceptions or misconceptions in electrochemistry (Dorsah & Yaayin, 2019). Here, the researcher added conceptual change texts (CCTs) on the activities that the students' were trying to answer. These conceptual change texts were provided with some questions that students' were doing after reading the conceptual change text (CCT) with in the team- pair and solo stage of the intervention.

3. The researcher minimized the video time and also the number of questions they were being asked as time constraint matters the effectiveness of the intervention.
4. The role of the teacher-researcher in this cycle was also increased at the different stages of the intervention. The teacher-researcher was trying to give hints and also tried to explain the conceptual change text (CCT) they had in their language. This makes the researcher to give students' confident about what they were dealing about in the team-pair and solo stage of the intervention.

3.8.2 Retrospective Analysis in Cycle Two

After collecting all the information, while conducting a re-designed intervention plan, the research conducted a retrospective analysis at this stage. This retrospective analysis focuses on reviewing students' conceptual understanding in cycle one with the improved aspects of conceptual understanding and academic performance in cycle two. The researcher analyzed students' progress both qualitatively and quantitatively. Qualitatively, the researcher elaborated the saying of students in cycle one with that of cycle two and knows how much they grow conceptually in cycle two compared to that of cycle one. Quantitatively, the researcher analyzed how much students' are responding the questions correctly. From the pre-test before the implementation to the post-test of the second cycle, students' quantitative result was being carefully looked and analyzed. The researcher reported how much the second cycle improved students' conceptual understanding and academic performance well.

3.9 Conceptual Framework of the study

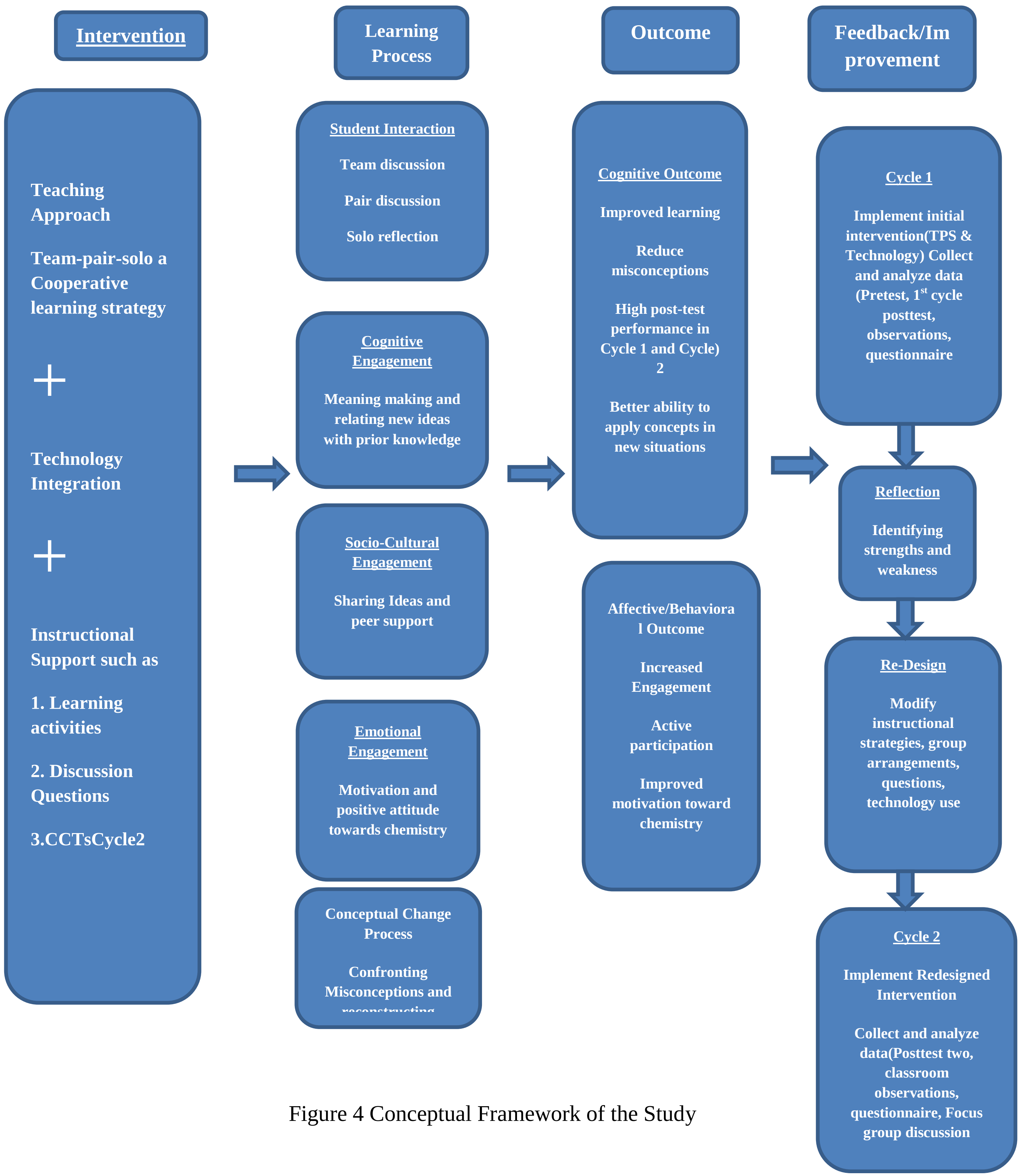


Figure 4 Conceptual Framework of the Study

3.10 Data Analysis Technique

In this study the researcher used both a quantitative and qualitative data analysis method as the researcher used a mixed method approach.

3.10.1 Quantitative Data Analysis

For the quantitative data obtained from students pre-test and post-test (both 1st and 2nd cycle), the researcher used a statistical tool for analyzing their result. SPSS was used for the quantitative analysis of students result. Additionally, for the questionnaire item both in the first and second cycle, the researcher again used an SPSS statistical tool for analyzing their response according to the Likert scale in the questionnaire items.

The analysis was takes placed in three categories. The first category is analyzing students' True/false item answers with their reasoning. In this category, students' result was coded using the researcher's scoring rubric. Scoring rubrics will help researchers and teachers to be consistent in scoring students' activities and also helps to improve students understanding of chemistry subject (Nsabayezu et al., 2022). As a result the researcher used the scoring rubrics for analyzing the students' pretest and posttest results. The scoring rubric has three points as indicated below:-

0 = no understanding or misconception

1= partial understanding

2= sound understanding

The above scoring rubric has also implications for each question's. For instance, if a student got the correct answer but did not explain the reason or wrong explanation, it was coded as 1 which is partial understanding. And also if another student did not have the correct answer but had correct reasoning it was also coded as 1. But if a student did not have the correct answer and the correct reasoning, it is coded as 0 which stands for no understanding or have misconception. When the students get the correct answer with scientific explanation, it will be coded as 2 which stand for sound understanding.

The second category is analyzing for the multiple choice part. This was done using the following scoring rubric. As it is multitier questions that contain the reasons for the first choice and their confidence level, it was coded in to three sections these are sound understanding, partial understanding, misconception and guessing/no understanding.

Table 2 Scoring rubric for the multitier multiple choice questions

No	Students' Response	Scoring Rubric
1	If a student is correct for the 1st and 2ndtier but not confident for both responses, it is categorized under guessing/no understanding rubric	0
2	If a student has a correct answer for the 1st and 2ndtier but only confident for either of the questions, he is categorized under partial understanding rubric	2
3	If a student has a correct answer for the 1st and 2ndtier and also confident for both questions, he is categorized under sound understanding scoring rubric	3
4	If a student is correct for the 1sttier only or the 2ndtier only but not confident for his response, it is categorized under guessing/no understanding	0
5	If a student is correct for the 1sttier only or the 2ndtier only and also confident for both attempts, it is categorized under partial understanding	2
6	If a student is correct for the 1sttier only or the 2ndtier only with a confident response for one of them only, it is again categorized under partial understanding	2
7	If a student is incorrect for the 1st and 2ndtier but has confident for both attempts, it is categorized under misconception/misunderstanding	1
8	If a student is incorrect for the 1st and 2ndtier and confident for one of the two questions, it is categorized under misconception category again	1
9	If a student is incorrect for the 1st and 2ndtier and also does not confident for both questions, it is categorized under guessing/no understanding	0

After analyzing the multitier multiple choice results, the researcher analyzed the open- ended essay questions result using students' response in thematic analysis way by describing their response.

3.10.2 Qualitative Data Analysis

For the qualitative data obtained from the open ended-students response and class room observation, the researcher used a narrative analysis technique for explaining what they said in their responses so as to identify themes or patterns across their responses. Regarding the classroom observation, the researcher used a narrative analysis technique for explaining what was observed in the classroom while the teacher was teaching and the students were learning. Moreover, the focus group discussion (FGD) data was analyzed thematically after it was carefully recorded and listened. Students' focus group discussion (FGD) was taken placed at the classroom with five students who were willing to attend and respond what was taking place in the classroom as well as to share what they got while learning the concept using the implemented intervention method. The instrument used in this study is developed by the teacher researcher based on students' learning difficulties of the concept of electrochemistry. To assure the validity of the instruments, the test, the questionnaire and the focus group questions were validated by the use of non-statistical approach with the teacher who teach chemistry in Fitawirari Habtemariam secondary and preparatory school. Moreover, the teacher researcher's adviser also critically evaluated the instruments being prepared by the researcher.

3.11 Ethical consideration of the study

In this study ethical consideration was carefully implemented in different aspects as it is described below elaborately.

1. The researcher announced for the participants about the purpose of the study, the procedures and the possible benefits after finishing it. Moreover, the researcher asked the participants about their willing so as to attend the intervention method since the intervention was taken placed in the natural setting.
2. The researcher also asked a permission to have taking pictures and having videos while students were discussing in the classroom. The participants were voluntaries and freely discuss in their learning and also allowed the researcher to record audios in the interview and focus group discussion session.
3. In this study, the intervention did not affect students' normal day to day learning process. As the researchers' study focuses on the Design Based Research (DBR), the researcher took the teacher's classroom and taught them for three weeks without diving students in to two classes and did not made them in to stress.
4. In this research, the researcher allowed participants to express their opinions or responses in their own language. The participants were told to be free to write answers in Amharic language in the open ended response as well as in the class activity.

CHAPTER FOUR

4. DATA ANALYSIS AND FINDING OF THE STUDY

In this chapter the researcher tried to present what was found before the intervention, during the intervention and after the intervention. Before the intervention, the researcher conducted a classroom observation and teachers' interview. This part of the research was analyzed first below. During the intervention, the researcher presented what were students' activities that were being discussed in the Team stage then Pair stage and lastly Solo stage. This data was presented because it was the basic and the most important part of the intervention as Design Based Research relies on the ongoing process of learning rather than a one shot method(Lewis et al., 2020). Then, the data found after the implementation of the intervention were analyzed. At this time first cycle post-test result and first cycle students' questionnaire were being analyzed. This process of analyzing data in the first cycle of the intervention method was being repeated in the analyzing process of the second cycle data as design based researcher requires an iterative and cyclical process that are basically required a revised and an improved interventions (Anderson & Shattuck, 2012).

4.1 Baseline data before the intervention

4.1.1 Classroom observation before the intervention

Before the implementation of the intervention method, the researcher observed the classroom climate using a predetermined observation checklist put at the appendix section. This observation checklist format incorporates the general teaching methods of the teacher, students' interaction with their teachers, students' interaction with their peers, any learning difficulties happened, the prevalence of technology integration and related issues. This base line data are analyzed below based on the observation checklist which contained yes/ no option and an open ended reflection notes from the observers point of view.

To begin with teachers' teaching method, the researcher wanted to analyze his approach of delivering the topic for his students. From the beginning the teacher was not clearly stating the lesson objectives that he was going to teach. The topic of the lesson was about electrochemistry which was the second portion of the chapter after he thought about energy changes which was the first section of the chapter. As I stated above, the teacher forgot stating the beginning of the discussion of the topic with stating the lesson objectives.

Moreover, the teaching methodology of the teacher was more teachers centered or conventional that many students were not actively and attentively following his lecture. Since the topic of the lesson was about electrochemistry that requires students' active involvement in the process, the researcher was expecting higher order thinking questions such as Why/How questions from the side of the teacher. But, the teacher was not asking students' a higher order thinking questions as his target was so as to finish the portion of the subject in time.

According to his word to the researcher, he would be fast to finish the portion of the book before the closing of the school as a result he was very running on the topics of the chapter. Although we are talking about student centered teaching methodology in higher levels, it will not be achievable if there is a bulk of contents printed on the book. Another issue that the researcher observed during the teaching process was lack of technology integrated instruction in his topic.

The other observed issue in the classroom observation was the absence of integrating the electrochemistry lesson with the day to day activities of the students'. Electrochemistry has so many applications in the real life of the day to day activities of human beings such as in the electric system, in mobile phones, in vehicles and soon. The teacher was teaching the concepts just by telling what was written on the book and give explanation what he wrote on the board rather than connecting the topic with the day today activities of the students'.

Regarding to students' learning process, during the teaching-learning process, most students' were not actively following the teacher's lecture and there was no two way communication between the teacher and the students'. Students' were not remain on task during the lesson of the subject and were not actively engaged in discussion by allowing them to have a freedom to talk what they know about the lesson.

The topic of the lesson was metallic and electrolytic conductivity and they were not participating actively to talk about what they have on their mind as a pre-requisite knowledge. As the teacher's teaching methodology was dominated by a lecture method, students' were not allowed to tell about conductivity to their teacher and as well as to their peers'. This predominantly inferred the researcher that there was a huge gap between the interaction of teacher-students' and student-student interaction as well as students'-students' interaction. This made most students' not to ask questions related to the lesson of the content and pushed them to be silent at the teaching-learning process that made them to have a learning difficulty and misconceptions' related to an electrochemistry concept. As a result, there was no classroom discussion on the topic what they were being learnt.

There are some misconceptions that the researcher observed during his time of observation in classroom while the teacher was teaching and the students were learning. These are some students' responded to the teacher about the conductivity of metals and solutions. Both in metallic and electrolytic conductivity the subatomic particle the so called electrons are responsible for conductivity. This was learning misconception that the students' had at the beginning of the lesson during the teacher's explanation.

Moreover, some students' were confused about oxidation and reduction reaction. Students' believed that reducing agent is a substance that contains a substance that is being reduced and oxidizing agent is a substance that contains a substance that is being oxidized. Regarding metallic conductivity, most students' believed that all metals conduct electricity equally and forget that acid and bases can conduct electricity. This misconceptions and learning confusions were being observed by the researcher before the administration of the pretest which was prepared to know students' conceptual understanding about the topic of the lesson.

4.1.2 Pre- test results and analysis

This section presents the students' pretest result and its analysis. The pretest questions contained three instructions; true/false with reasoning section, three tier multiple choice items and open ended questions. The average result of the students is calculated and also the overall students' responses were coded to the four scoring rubric values stated in the data analysis techniques of chapter three of the paper.

The following Table describes the average performance of the students' based on the teacher researcher's scoring rubric of the true/false and multitier multiple choice section of the pretest. Generally, the scoring rubric is three types which are no understanding/misconception, partial understanding and sound understanding.

Table 3 The average pretest result of students (out of 20)

Total pretest		
Mean	N	Std. Deviation
7.9250	40	2.22327

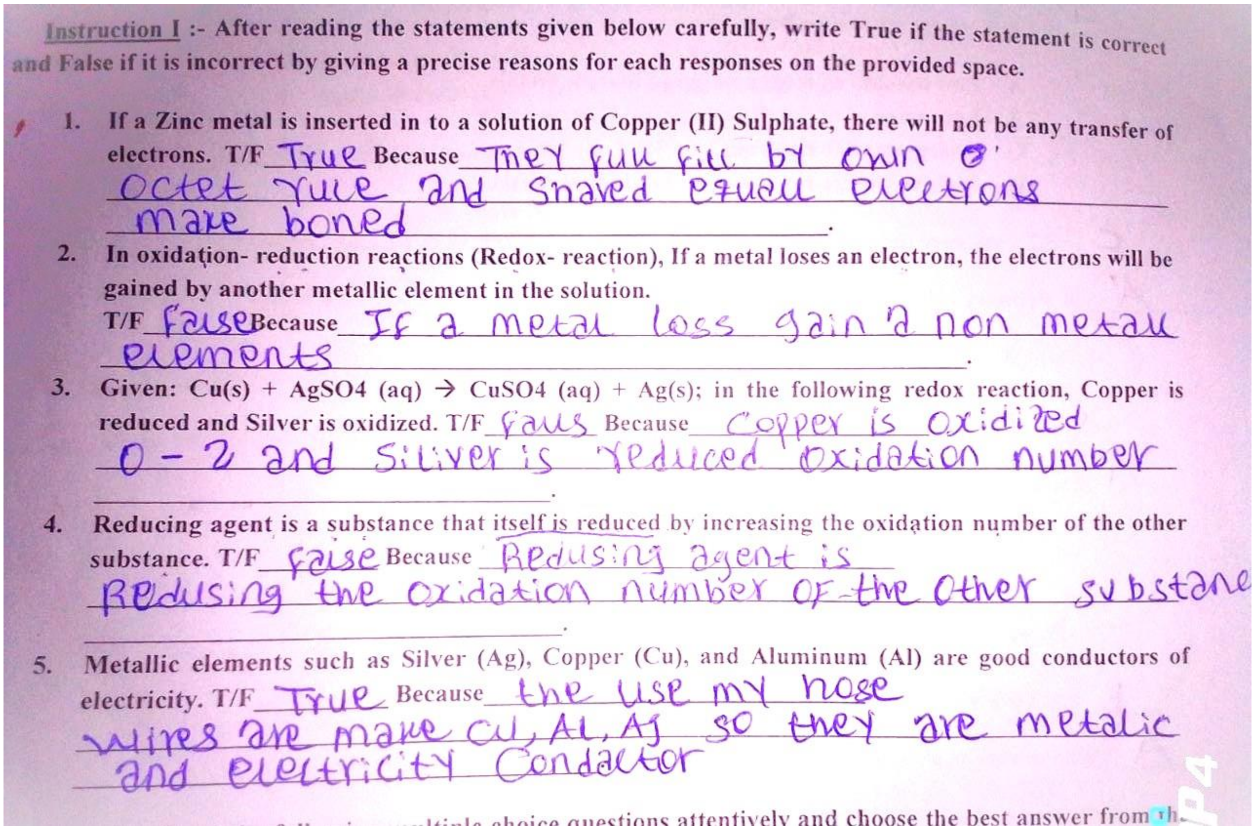
As the above Table 3 revealed that students' scored below the mean expected value which was 10 for the pretest. The average score of the students' was 7.925 that shows there is learning difficulties for the topics they were being examined. They scored below 10 that shows there should be an intervention. Moreover, students' conceptual understanding level is not adequate. The conceptual understanding level of the students' is tabulated below.

Table 4 Pretest conceptual understanding levels

Conceptual understanding level	Average students	Percentage (%)
No understanding/misconception	22.375	55.93
Partial understanding	12.375	30.93
Sound understanding	5.25	13.125

As the above Table 5 depicted that only 13 % of the students' were found in sound understanding category. However, 55% of the students' were not have enough understanding about the topics they were being tested. They did not understand metallic conductivity, oxidation-reduction reaction, and galvanic cell concepts appropriately.

Based on students' explanations, most students connected oxidation-reduction reaction with the concept of non-metals. As metals loss electrons, non-metals are known by their gain of electrons. Although they are correct that non-metal gain electron, but they misconnected this concept with oxidation-reduction reaction. In oxidation reaction, metal with metal or metal with non-metals as well as non-metals with non-metals can transfer electrons according to their degree of reactivity. Therefore, student responses indicated a belief that metals do not accept electrons; rather, only non-metals gain, leading them to mark the item as False.



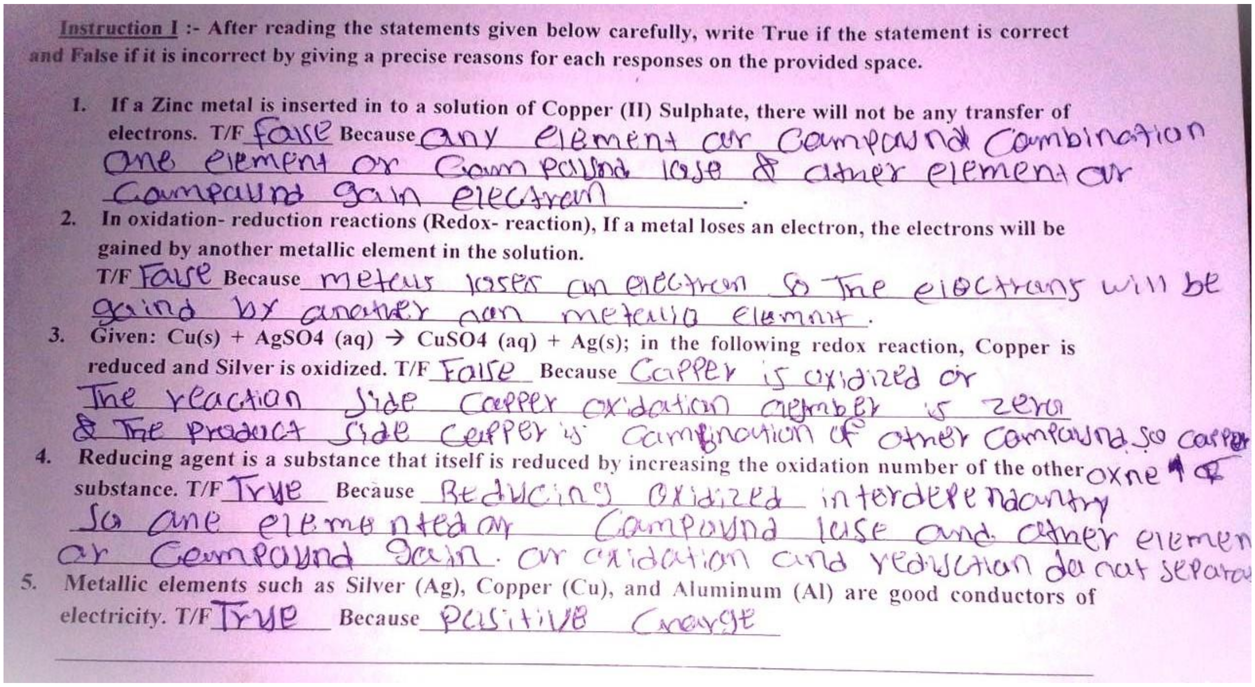
Instruction I :- After reading the statements given below carefully, write True if the statement is correct and False if it is incorrect by giving a precise reasons for each responses on the provided space.

1. If a Zinc metal is inserted in to a solution of Copper (II) Sulphate, there will not be any transfer of electrons. T/F True Because They full fill by own octet rule and shared equell electrons make boned.
2. In oxidation- reduction reactions (Redox- reaction), If a metal loses an electron, the electrons will be gained by another metallic element in the solution. T/F false Because If a metal loss gain a non metall elements.
3. Given: Cu(s) + AgSO4 (aq) → CuSO4 (aq) + Ag(s); in the following redox reaction, Copper is reduced and Silver is oxidized. T/F falls Because Copper is oxidized 0 - 2 and Silver is reduced oxidation number.
4. Reducing agent is a substance that itself is reduced by increasing the oxidation number of the other substance. T/F false Because Redusing agent is Redusing the oxidation number of the other substane.
5. Metallic elements such as Silver (Ag), Copper (Cu), and Aluminum (Al) are good conductors of electricity. T/F True Because the use my hose wires are make Cu, Al, Aj so they are metalic and electricity Condactor

Figure 5 sample of student's open ended justification

Moreover, students' had huge conceptual misunderstanding about the concept of metallic conductivity. Metals are good conductors of electricity as they have delocalized electrons that can move throughout the lattice. These electrons are responsible for the production of electricity. Metals are also found mostly in solid state that they can transfer electricity without used up. This was the true concept behind the question. However most student replied that:-

1. Metals have the lowest electric attractive force.
2. Metals have positive charge.
3. Metals found in our home electric wires.
4. Metals have low ionization energy then low ionization energy is less electric conductor.


Instruction I :- After reading the statements given below carefully, write True if the statement is correct and False if it is incorrect by giving a precise reasons for each responses on the provided space.

1. If a Zinc metal is inserted in to a solution of Copper (II) Sulphate, there will not be any transfer of electrons. T/F false Because any element or compound combination one element or compound lose & other element or compound gain electron.
2. In oxidation- reduction reactions (Redox- reaction), If a metal loses an electron, the electrons will be gained by another metallic element in the solution. T/F False Because metals loses an electron so The electrons will be gaind by another non metallic elemnt.
3. Given: Cu(s) + AgSO4 (aq) → CuSO4 (aq) + Ag(s); in the following redox reaction, Copper is reduced and Silver is oxidized. T/F False Because Copper is oxidized or The reaction side copper oxidation number is zero & The product side copper is combination of other compound so copper oxne
4. Reducing agent is a substance that itself is reduced by increasing the oxidation number of the other substance. T/F True Because Reducing oxidized interdependancy so one element or compound lose and other element or compound gain. or oxidation and reduction do not separa
5. Metallic elements such as Silver (Ag), Copper (Cu), and Aluminum (Al) are good conductors of electricity. T/F True Because positive charge

Figure 6 A student’s response for the true/false multitier open ended tier.

Regarding redox reactions, students’ had not fully understood the concept scientifically. For the question that asks about the transfer of electrons between metals, 32.5 % of the students’ were categorized under the scoring rubric of partial understanding. Though they were correct for the answer, they were not scientifically explaining the reason. They replied that:-

1. False because Zinc is non-metal.
2. False because Zinc metal is good conductor of electricity.
3. False because metal transfer electrons and non-metals accept it.

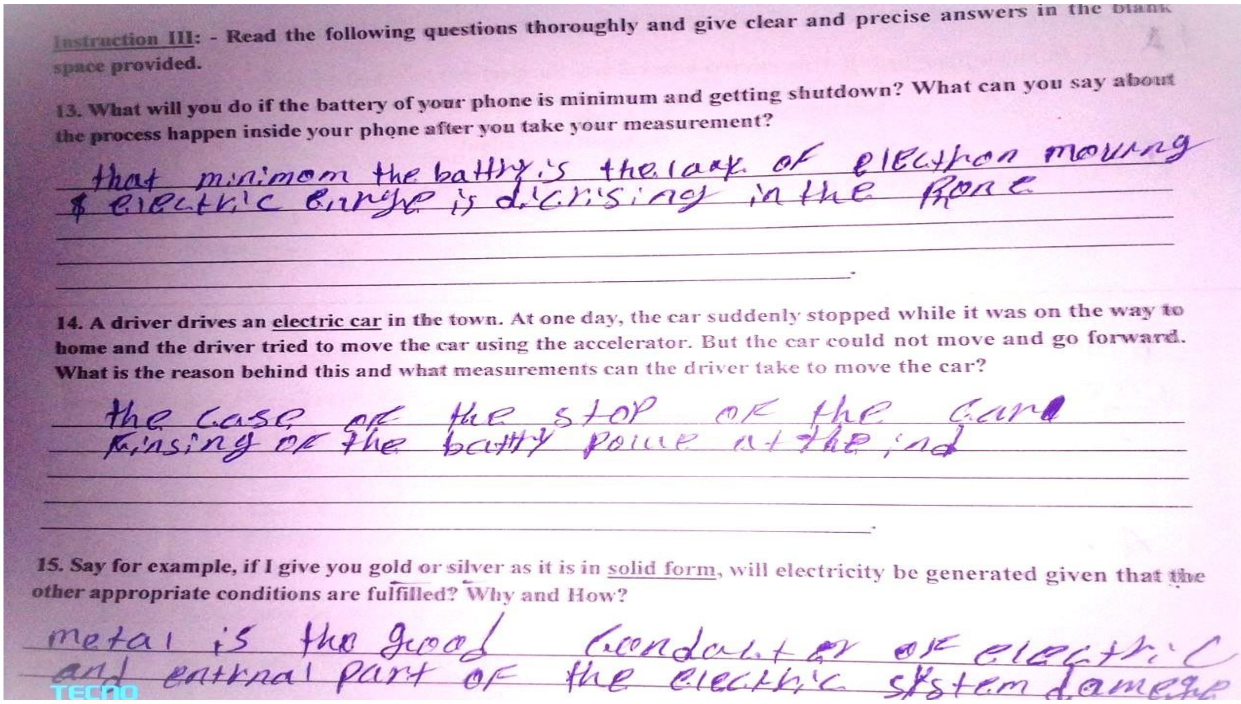
Moreover, 57.5% of the students’ were not correct the answer and their explanation. From the 40 students’, 23 of them had a deep conceptual difficulty regarding the question. Most did not respond the explanation part. However, some students' tried to explain what they have in their mind regarding the question and replied that:-

1. True because this solution is metallic solution then metallic element is low ionization energy and low electric conduction.
2. True because the solution cannot transfer any electrons.
3. True because they are full filled by the octet rule.
4. True because they full fill by own octet rule and shared equal electrons make bond.

The above students' responses all are misconceptions and mismatching prior knowledge in to unrelated concept. Students' were thinking to connect redox reactions with the concept of metal and non-metal interaction only. They believed that metals loss an electron and non-metals gain an electron. Although they are correct, they misrelated the concept with that of redox reaction and electrochemical cells.

The open ended essay questions basically prepared so as to know how much students' are understand the real life application of electrochemistry concept. The open ended essay questions predominantly asked about primary and secondary galvanic cell as well as the concept of metallic conductivity. These questions are prepared by the teacher researcher for the purpose of identifying students' understanding of the connection of chemistry with their real life. However, most of them were not integrating the concept of electrochemistry with the day to day activities of their life.

Students' have lack of knowledge about what is happening inside our cell phones when it is shutdown. The basic concept is that cell phones are secondary galvanic cells that can be recharged after their battery is used up once. Since their batteries are rechargeable, it is possible to plug the phone in to an electric source so that it can collect energy for the later use. From the 40 students' only 6 students' were trying to give their own assumption about the question based on their understanding. Some of students' response is attached below.


Instruction III: - Read the following questions thoroughly and give clear and precise answers in the blank space provided.

13. What will you do if the battery of your phone is minimum and getting shutdown? What can you say about the process happen inside your phone after you take your measurement?

that minimom the battry is the lack of electron moving
& electric energe is dicrising in the phone

14. A driver drives an electric car in the town. At one day, the car suddenly stopped while it was on the way to home and the driver tried to move the car using the accelerator. But the car could not move and go forward. What is the reason behind this and what measurements can the driver take to move the car?

the case of the stop of the car
finsing of the batty powe at the ind

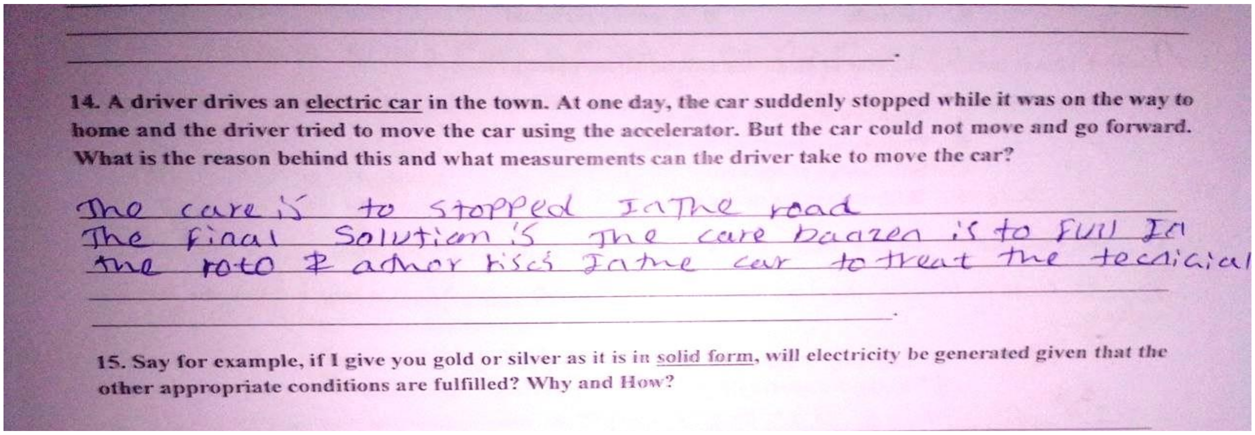
15. Say for example, if I give you gold or silver as it is in solid form, will electricity be generated given that the other appropriate conditions are fulfilled? Why and How?

metal is the good conductor of electric
and extrnal part of the electric system damage

Figure 7 Student A’s response about conductivity and galvanic cell

In the above picture of the student’s work, The other student also replied that the reason for the minimum battery happening is due to lack of electron moving as a result the electric energy is decreasing in the phone. Although electric energy decreases in the phone when the battery becomes low, the students’ assumption that there is lack of moving electrons is not fully accurate. The correct idea is that electrons do not disappear or become absent rather the chemical reactants inside the battery become depleted as a result the battery can no longer produce enough electric energy. Moreover, some students’ also responded the question by relating it with an external electric connector.

In addition, some students’ had also misunderstanding regarding what electric car is and how it works. This is a basic concept that is grounded under the concept of electrochemistry, specifically secondary galvanic cell. However, students’ had knowledge gap and low conceptual understanding to relate electrochemistry with the real life. The electric car is an example of secondary galvanic cell that can be recharged when its battery is shutdown or minimum. The basic concept behind this question is when the car’s battery shutdown, the car cannot move as the chemical reactants’ inside the battery are so much exhausted. Therefore, the driver should recharge the car’s battery properly. The researcher expected students’ to have this concept although so many of them did not respond it well and understand it differently. Some of the students' ideas regarding this concept are put below in their original hand writing.

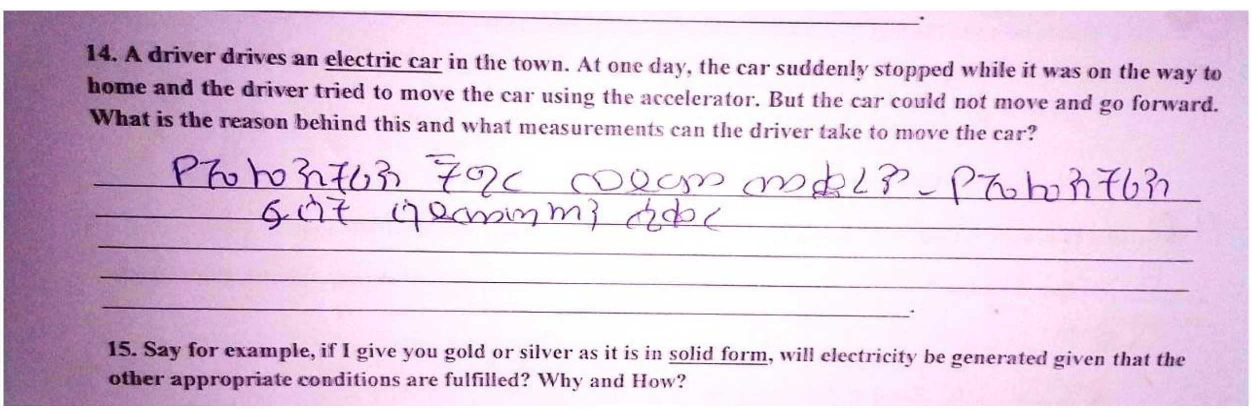

14. A driver drives an electric car in the town. At one day, the car suddenly stopped while it was on the way to home and the driver tried to move the car using the accelerator. But the car could not move and go forward. What is the reason behind this and what measurements can the driver take to move the car?

The care is to stopped In the road
The final Solution is the care baazen is to full In the roto ₽ ather risci In the car to treat the tecnicial

15. Say for example, if I give you gold or silver as it is in solid form, will electricity be generated given that the other appropriate conditions are fulfilled? Why and How?

Figure 8 Student B's idea about the application of secondary galvanic cell

From the above picture of student's work, students' were connecting the problem with their experience and forwarded several opinions. Some believed the cause for the sudden stop of the car is due to scarcity of the natural gas benzene in the car's engine and others' also replied that it is due to imbalance of the flow of electricity in the car. These thought was purely revealed that students' have lack of understanding about what is the concept of galvanic cell specifically secondary galvanic cell.


14. A driver drives an electric car in the town. At one day, the car suddenly stopped while it was on the way to home and the driver tried to move the car using the accelerator. But the car could not move and go forward. What is the reason behind this and what measurements can the driver take to move the car?

[illegible]

15. Say for example, if I give you gold or silver as it is in solid form, will electricity be generated given that the other appropriate conditions are fulfilled? Why and How?

Figure 9 Student C's concept regarding the application of galvanic cell

The above results of the students' work clearly show that there should be an intervention so that students' conceptual understanding will be improved. Because of the above observed learning difficulties and misconceptions and also minimum score, the researcher implemented the intervention method in the classroom which was technology mediated instruction with Team-Pair-Solo co-operative learning.

4.2 Conceptual Learning Development in Electrochemistry

From the above analysis of students result in different instruction, it showed that there was a huge conceptual learning difficulty on the side of students'. Students' were thinking electrochemistry differently and also did not understand relate the subject with their day to day activities.

Since design based research (DBR) is a process oriented approach (Wang & Hannafin, 2005), the researcher analyzed students' learning process during the implementation of the intervention method. The researcher analyzed how much students' were discussing in their team for the questions given to them followed by their pair/triple discussion. Then, lastly the researcher attentively followed each student's progress by giving related task that they were discussed in the team and pair stage of the intervention.

4.2.1 The Learning Process in Cycle One

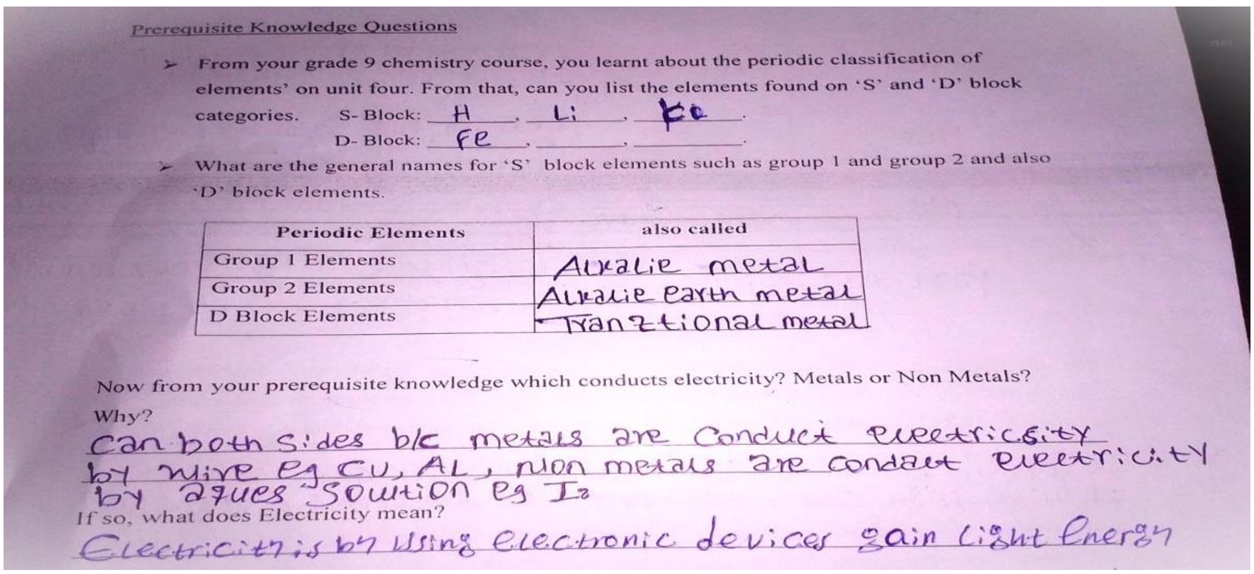
In this section, the researcher presents how the students' were learning the content of electrochemistry in the classroom based on the designed intervention method. In this cycle, students' were learning about metallic conductivity, electrolytic conductivity, oxidation and reduction reaction, primary galvanic cell as well as secondary galvanic cell. The instructional methodology was team-pair-solo cooperative learning with the integration of technology such as animation videos etc. The activities given for the team, the pair and the solo stage are different but conceptually related.

4.2.1.1 Task Design for Electrical Conductivity

On the topic of electrical conductivity, the researcher developed different tasks that were provided on the three stages during the intervention. The three stages were being takes placed with different but related activities.

A. The team stage activity for Electrical Conductivity

In this stage the researcher designed an activity that was aimed to be worked in group. This activity started by asking students' prior knowledge about periodic table elements that are found in S and D block category. The purpose of this question was so as to know how much students' understand where metals are found in the periodic table. Moreover, the question also asked students' about which one conduct electricity, metal or non-metal. Since they were being asked in the team stage, almost the entire group forwarded their ideas although they have misunderstanding. The role of the teacher researcher at this stage was facilitating the discussion of students' by giving discussion questions on the basis of what they were watching in the video.



Prerequisite Knowledge Questions

- From your grade 9 chemistry course, you learnt about the periodic classification of elements' on unit four. From that, can you list the elements found on 'S' and 'D' block categories. S- Block: H, Li, K
D- Block: Fe, _____, _____.
- What are the general names for 'S' block elements such as group 1 and group 2 and also 'D' block elements.

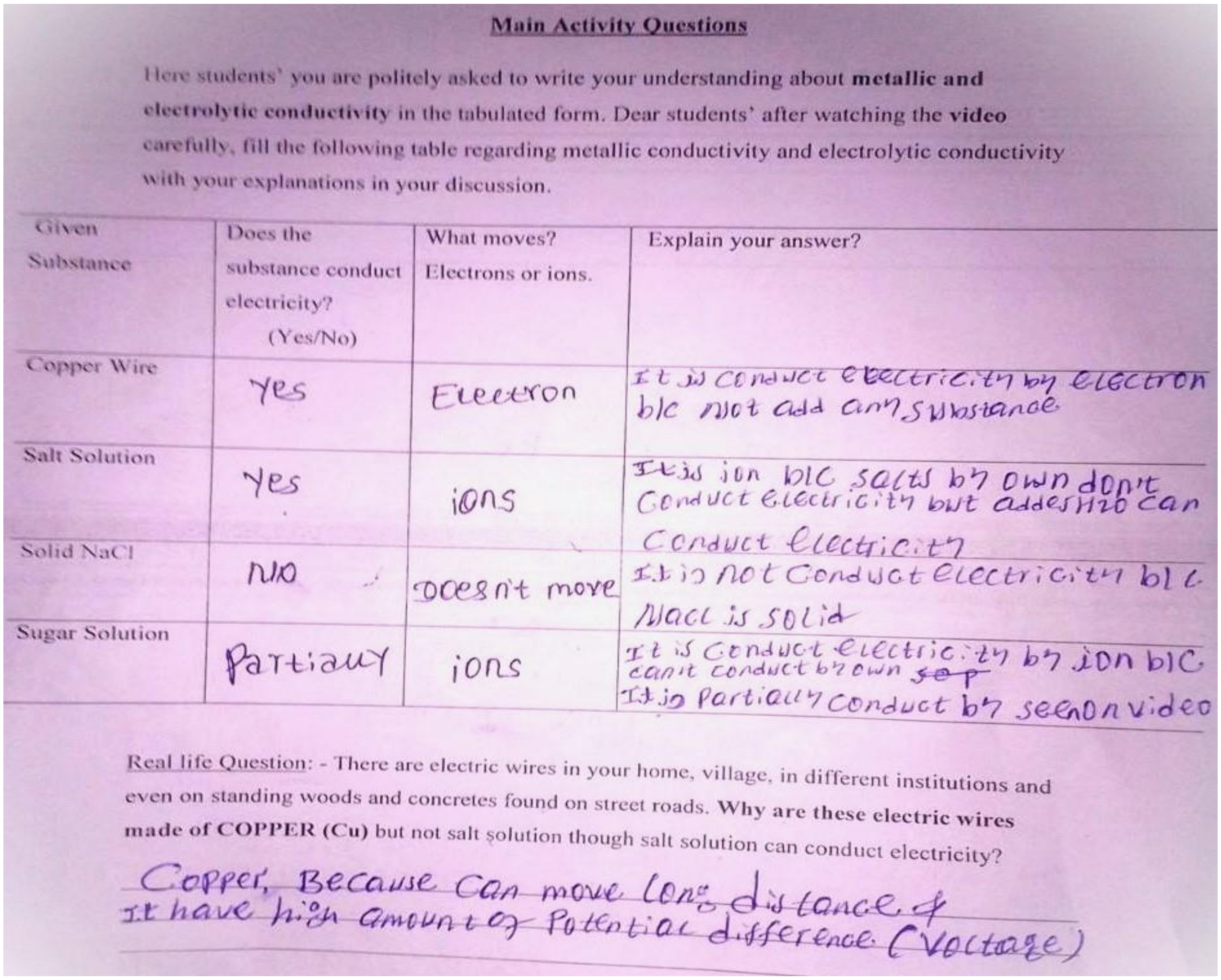
Periodic Elements	also called
Group 1 Elements	Alkalie metal
Group 2 Elements	Alkalie earth metal
D Block Elements	Tranztional metal

Now from your prerequisite knowledge which conducts electricity? Metals or Non Metals?
Why?
can both sides b/c metals are conduct electricity by wire eg CU, AL, non metals are condact electricity by aques soution eg I_2
If so, what does Electricity mean?
Electricity is by using electronic devices gain light energy

Figure 10 Students' prerequisite understanding about metals and non-metals

The response of students' revealed that the students' have some misunderstanding prerequisite knowledge regarding conductivity as they replied that non-metals can conduct electricity in aqueous solution such as Iodine. However, since Iodine does not strongly ionize in water, it is considered as poor conductor of electricity.

The main task that the students' worked on was on electronic conductivity which has two type, metallic and electrolytic conductivity. This task was given based on the videos they were allowed to see in group about conductivity. Most groups were tried to get the correct understanding by filling the table they asked and the real life question.



Main Activity Questions

Here students' you are politely asked to write your understanding about **metallic and electrolytic conductivity** in the tabulated form. Dear students' after watching the **video** carefully, fill the following table regarding metallic conductivity and electrolytic conductivity with your explanations in your discussion.

Given Substance	Does the substance conduct electricity? (Yes/No)	What moves? Electrons or ions.	Explain your answer?
Copper Wire	Yes	Electron	It is conduct electricity by electron b/c not add any substance
Salt Solution	Yes	ions	It is ion b/c salts by own don't conduct electricity but added H2O can conduct electricity
Solid NaCl	No	Doesn't move	It is not conduct electricity b/c Nacl is solid
Sugar Solution	Partially	ions	It is conduct electricity by ion b/c can't conduct by own sep It is partially conduct by seen on video

Real life Question: - There are electric wires in your home, village, in different institutions and even on standing woods and concretes found on street roads. **Why are these electric wires made of COPPER (Cu)** but not salt solution though salt solution can conduct electricity?

Copper, Because can move long distance & It have high amount of Potential difference (Voltage)

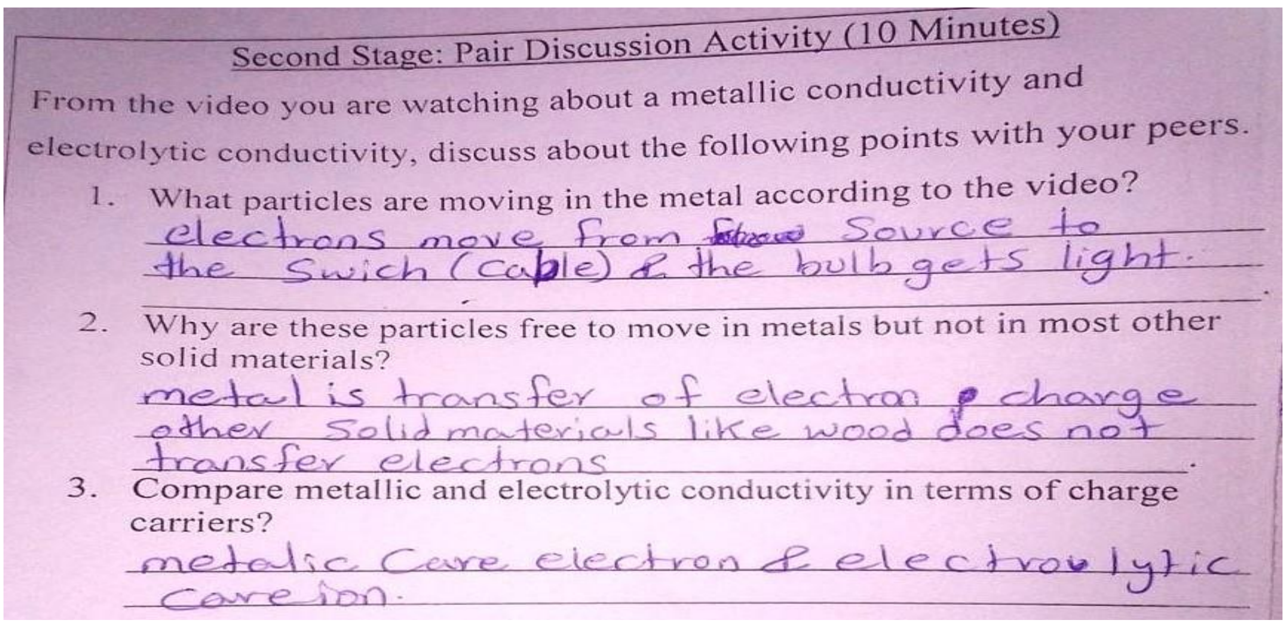
Figure 11 Team discussion activities on electrical conductivity and students' response

According to the above works of students' explanation, students' were able to tell the charge carriers for different substances and they tried to explain about metallic and electrolytic conductivity.

The above picture revealed that students' were able to give explanation when they were supported by technology integrated instruction. They replied that copper and salt solution conduct electricity since they do have electrons and ions that move in the system. Moreover, they were collectively discussed and forwarded their idea which is correct to the scientific understanding.

B. The pair stage activity for Electrical Conductivity

In this stage of the intervention, the researcher gave for the paired/ tripled students' another task that was related with what they were have been discussed in the first stage which was a team stage. In this pair/triple stage, the researcher also used technology for the purpose of showing students' some videos that were talking about metallic and electrolytic conductivity. Some of their written responses are attached below



Second Stage: Pair Discussion Activity (10 Minutes)

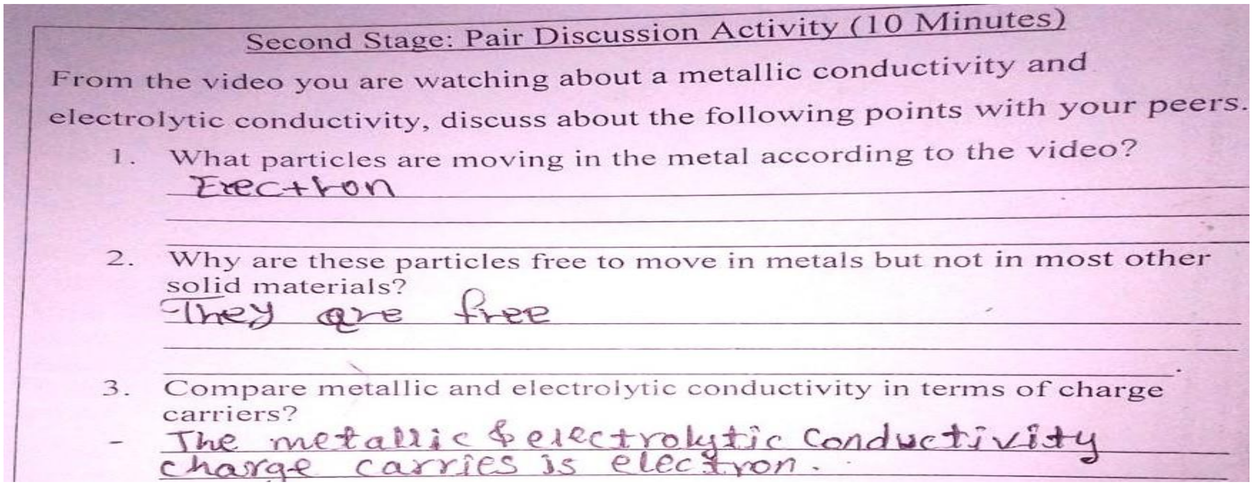
From the video you are watching about a metallic conductivity and electrolytic conductivity, discuss about the following points with your peers.

1. What particles are moving in the metal according to the video?
electrons move from ~~[illegible]~~ Source to the Swich (cable) & the bulb gets light.
2. Why are these particles free to move in metals but not in most other solid materials?
metal is transfer of electron & charge other Solid materials like wood does not transfer electrons.
3. Compare metallic and electrolytic conductivity in terms of charge carriers?
metalic Care electron & electrolytic Care ion.

Figure 12 Students' pair activity work on electrical conductivity

The above students' pair work revealed that, the students' responded that electrons move from source to the switch and the bulb gets light. They tried to connect the concept with metallic conductivity and clearly explained that electrons are the cause for metallic conductivity but they are not charge carriers for electrolytic conductivity.

However, as samples of students' paired/tripled classroom task depicted below shows that students' explained electronic conductivity differently. Some paired students' had the concept and understand what metallic and electrolytic conductivity with the help of the videos they were watching. The students' below reflected that electrons are the cause for metallic and electrolytic conductivity.


Second Stage: Pair Discussion Activity (10 Minutes)

From the video you are watching about a metallic conductivity and electrolytic conductivity, discuss about the following points with your peers.

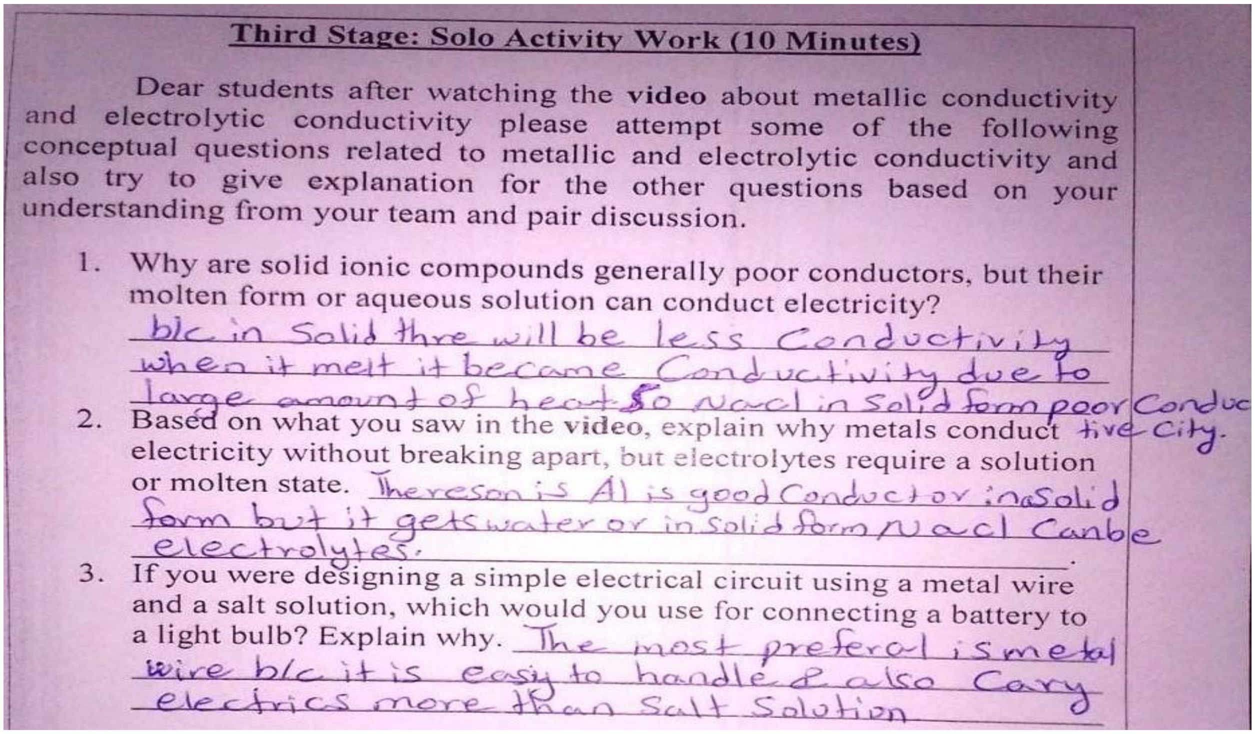
1. What particles are moving in the metal according to the video?
   Erectron
2. Why are these particles free to move in metals but not in most other solid materials?
   They are free
3. Compare metallic and electrolytic conductivity in terms of charge carriers?
   - The metallic & electrolytic conductivity charge carries is electron.

Figure 13 Students' pair activity work for electrical conductivity

The above picture tells us that the paired students' understands electrons as charge carriers for both metallic and electrolytic conductivity. They replied that the metallic and electrolytic conductivity charge carriers are electrons.

C. The solo stage activity for Electrical Conductivity

At this stage, the researcher provided another task which was basically grounded on the questions of the team and the pair stage activities. At this stage, the aim of the provided question was so as to evaluate the effectiveness of the discussion that the students' did in the team and pair stage. For this reason the researcher delivered an activity for each student's and collected some individual insights from students. Given below are some of students' responses about the forwarded questions.



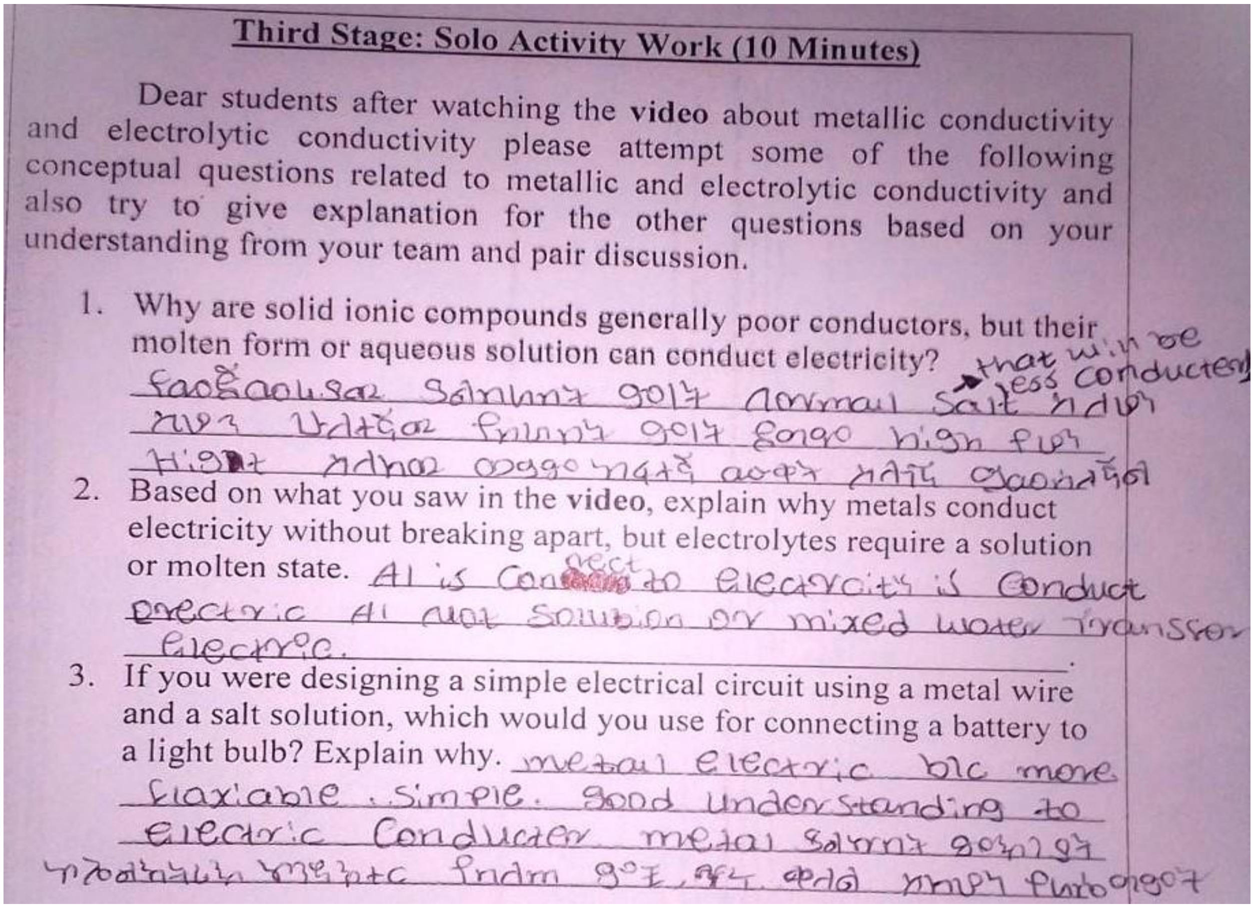
Third Stage: Solo Activity Work (10 Minutes)

Dear students after watching the **video** about metallic conductivity and electrolytic conductivity please attempt some of the following conceptual questions related to metallic and electrolytic conductivity and also try to give explanation for the other questions based on your understanding from your team and pair discussion.

1. Why are solid ionic compounds generally poor conductors, but their molten form or aqueous solution can conduct electricity? b/c in Solid thre will be less Conductivity when it melt it became Conductivity due to large amount of heat So Nacl in Solid form poor Conductive City.
2. Based on what you saw in the **video**, explain why metals conduct electricity without breaking apart, but electrolytes require a solution or molten state. Thereson is Al is good Conductor in Solid form but it gets water or in Solid form Nacl Canbe electrolytes.
3. If you were designing a simple electrical circuit using a metal wire and a salt solution, which would you use for connecting a battery to a light bulb? Explain why. The most preferal is metal wire b/c it is easy to handle & also Cary electrics more than Salt Solution

Figure 14 Student A's explanation for electrical conductivity

Based on the solo activity work, most students' replied that metals conduct electricity because of their delocalized electrons whereas electrolytes conduct electricity when they are in molten state or aqueous solution. Students' explanation on the solo stage revealed that their team and pair discussion activity strengths their understanding about metallic and electrolytic conductivity. Since the third stage was also supported by technology which was video that focus on the conductivity, most other students' were also initiated to give explanation even in their own mother tongue language. Their understanding is attached below in pictures and it is translated by the researcher.



Third Stage: Solo Activity Work (10 Minutes)

Dear students after watching the **video** about metallic conductivity and electrolytic conductivity please attempt some of the following conceptual questions related to metallic and electrolytic conductivity and also try to give explanation for the other questions based on your understanding from your team and pair discussion.

1. Why are solid ionic compounds generally poor conductors, but their molten form or aqueous solution can conduct electricity? that will be less conducted

   [illegible] normal salt [illegible] high [illegible]

2. Based on what you saw in the **video**, explain why metals conduct electricity without breaking apart, but electrolytes require a solution or molten state. Al is conduct to electricity is conduct electric Al not solution or mixed water transfer electric.

3. If you were designing a simple electrical circuit using a metal wire and a salt solution, which would you use for connecting a battery to a light bulb? Explain why. metal electric b/c more flaxiable. simple. good understanding to electric conducter metal [illegible]

Figure 15 Student C’s explanation for electrical conductivity

According to student C’ response that was written in Amharic, they suggested that high amount of heat makes the salt to conduct electricity as this makes the salt to be in molten state. But, the basic concept behind this question was that when solid ionic compounds are changed in to molten state, the ions found in the solid will become mobile and free to move so that conduct electricity. In a solid ionic compound, there are ions that are fixed in a crystal lattice and cannot move freely as a result there will not be the flow of electricity. However, when the compound becomes in liquid state/molten state, the ions become free to move that will allow them to conduct electricity. Therefore, students’ had some conceptual misunderstanding about electrical conductivity although students’ had tried to explain based on their views.

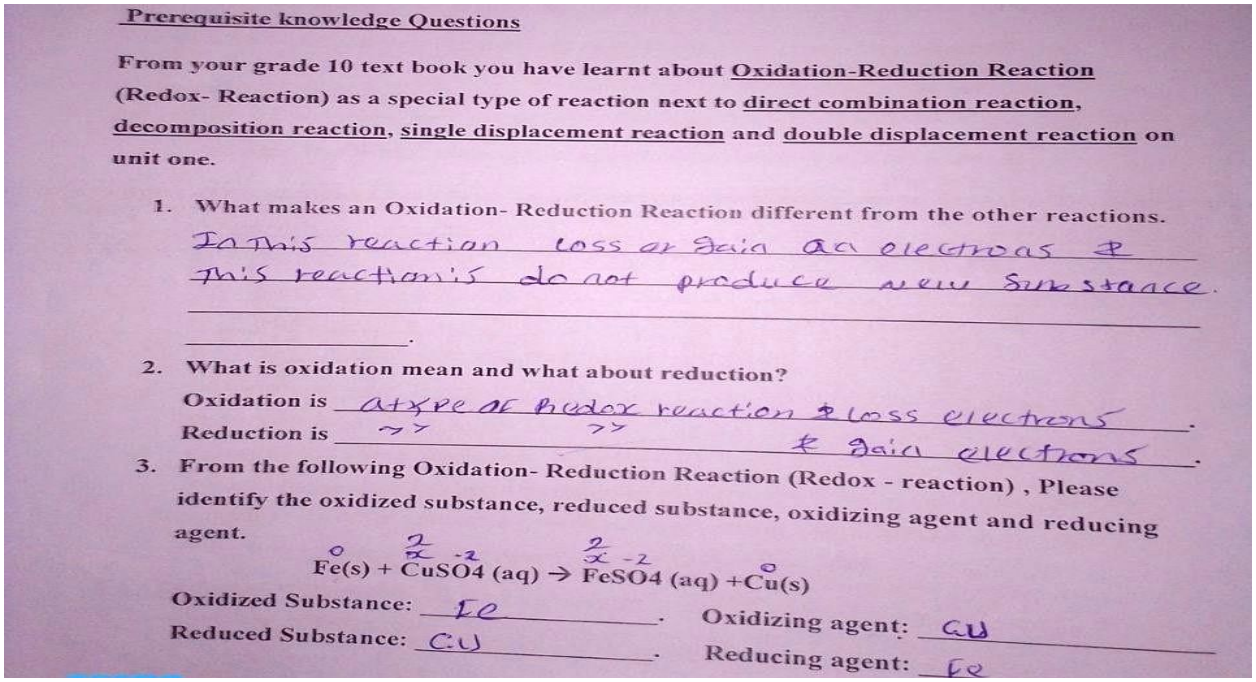
4.2.1.2 Task design for Redox reaction and Galvanic cell topic

Again in this topic, the researcher prepared different activities that were being asked to students' in the three phases, the team-pair-solo stage. The teacher researcher's role in this task design intervention process was facilitating students' group and pair discussion rather than just lecturing throughout the period. The researcher opened some related videos that focus on redox and galvanic cell and the researcher was observing students' participation and engagement level.

A. The team stage activity for Redox and Galvanic Cell lesson

In this topic the team stage activity given to students' were focusing on the prerequisite knowledge they have on redox reaction. Most groups had defined the rote definition of what oxidation-reduction reaction mean by stating that oxidation is the loss of electrons and reduction is the gain of electrons. However, some groups had understand that oxidation-reduction reaction differ from the other types of reactions such as synthesis reaction, decomposition reaction and displacement reaction in that it do not produce new substance.

Moreover, the other group suggested that oxidation-reaction reaction occur simultaneously but the rest types of reactions occur spontaneously. From this thoughts of students' we can infer that they related oxidation-reduction reaction with that of physical reaction and that can occur non-spontaneously with the help of other external force.



Prerequisite knowledge Questions

From your grade 10 text book you have learnt about Oxidation-Reduction Reaction (Redox- Reaction) as a special type of reaction next to direct combination reaction, decomposition reaction, single displacement reaction and double displacement reaction on unit one.

1. **What makes an Oxidation- Reduction Reaction different from the other reactions.**
In this reaction loss or gain an electrons & this reaction's do not produce new substance.
2. **What is oxidation mean and what about reduction?**
Oxidation is a type of redox reaction & loss electrons.
Reduction is " " " " & gain electrons.
3. **From the following Oxidation- Reduction Reaction (Redox - reaction) , Please identify the oxidized substance, reduced substance, oxidizing agent and reducing agent.**

$$\overset{0}{Fe}(s) + \overset{2}{Cu}S\overset{-2}{O}4\ (aq) \rightarrow \overset{2}{Fe}S\overset{-2}{O}4\ (aq) + \overset{0}{Cu}(s)$$

Oxidized Substance: Fe. **Oxidizing agent:** Cu
Reduced Substance: Cu. **Reducing agent:** Fe

Figure 16 Students' team prerequisite knowledge about redox reaction

Compared to their prerequisite knowledge, students' understanding of electrochemistry concept was increased while they were learning it using a technology mediated instruction such as incorporating some electrochemistry videos. At the main activity, students' were allowed to observe the video and discuss on the questions based on the videos. The researcher found that they were able to explain electrochemistry concepts. The students' replied that the reaction that they were watching was a redox reaction because there is a transfer of electron from one substance in to the other substance..

The prerequisite knowledge questions were also followed by the main activity that was aimed to show students' some videos about oxidation and reduction reaction so as to discuss it in group as well as in the pair/triple way. The team discussion activity response showed that students' gradually understood the concept of oxidation-reduction reaction with the help of technology mediated instruction. Some of the students' responses on this stage are attached below in their original hand writing.

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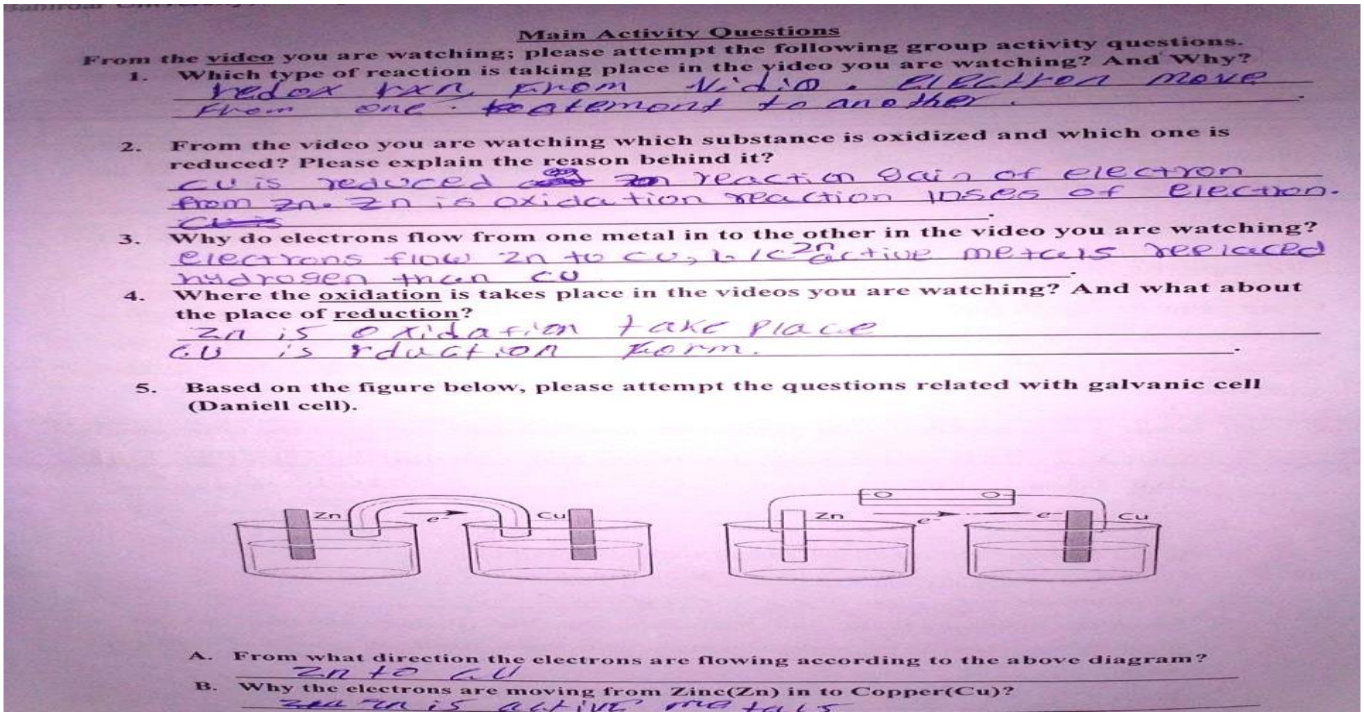


Main Activity Questions

From the video you are watching; please attempt the following group activity questions.

1. Which type of reaction is taking place in the video you are watching? And Why?
   redox rxn from vidio. electron move from one element to another.
2. From the video you are watching which substance is oxidized and which one is reduced? Please explain the reason behind it?
   Cu is reduced Zn reaction gain of electron from Zn. Zn is oxidation reaction loses of electron.
3. Why do electrons flow from one metal in to the other in the video you are watching?
   electrons flow Zn to Cu, b/c Zn active metals replaced hydrogen than Cu.
4. Where the oxidation is takes place in the videos you are watching? And what about the place of reduction?
   Zn is oxidation take place
   Cu is rduction form.
5. Based on the figure below, please attempt the questions related with galvanic cell (Daniell cell).

   A. From what direction the electrons are flowing according to the above diagram?
   Zn to Cu
   B. Why the electrons are moving from Zinc(Zn) in to Copper(Cu)?
   Zn is active metals

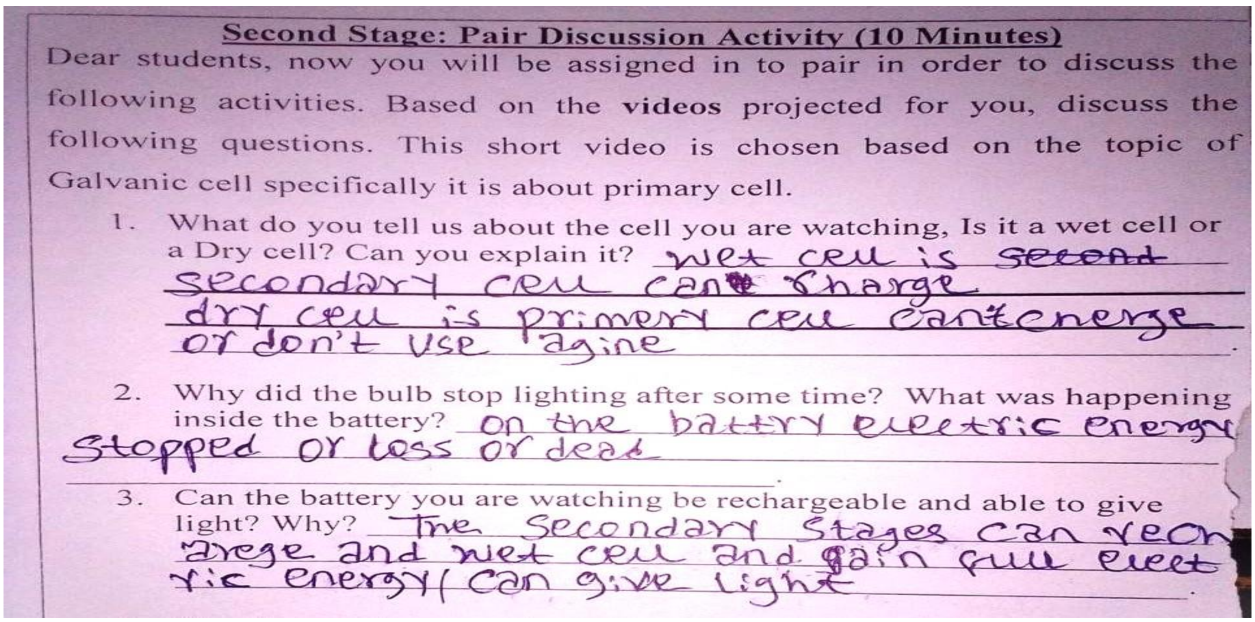
Figure 17 Students' main activity work on redox reaction

Students' prerequisite understanding was redox reaction differs from other types of reaction because it is physical reaction. But from the video they saw and some conversations that the teacher made to them, their understanding changed and thinks that redox reaction is a chemical reaction as electrons are transferred between substances. And there will be new substances formed and the chemical composition changes over time.

B. The pair stage activity for Redox and Galvanic cell Lesson

In the pair stage activity of the intervention, students were arranged in to pair/triple so that discuss about primary galvanic cell and secondary galvanic cell. The discussion questions were given to students' in a piece of paper and were expected to discuss the question based on the videos they were watching. According to their responses and the oral discussions that the teacher researcher made to them, they had some understanding about the application of galvanic cell in primary and secondary galvanic cell. Students' response revealed that the reason for the bulb to stop lighting was that because of electric charge since the electric charge on the battery stopped as a result it would not give light. There was some partial understanding for this concept although students' connect galvanic cell with that of electric charge.

The true concept behind the malfunction of the bulb was basically connected to primary galvanic cell. Primary galvanic cell is not rechargeable as their reactants are gradually consumed and the products that can be formed cannot change in to its original materials by supplying electricity. Moreover, some students' related the reason for the stop of the bulb with lack of electron. This understanding is partly correct but it was better if they said that primary galvanic cells such as dry cells becomes used up because of the chemical reactants are exhausted and can no longer continue the redox reaction effectively.



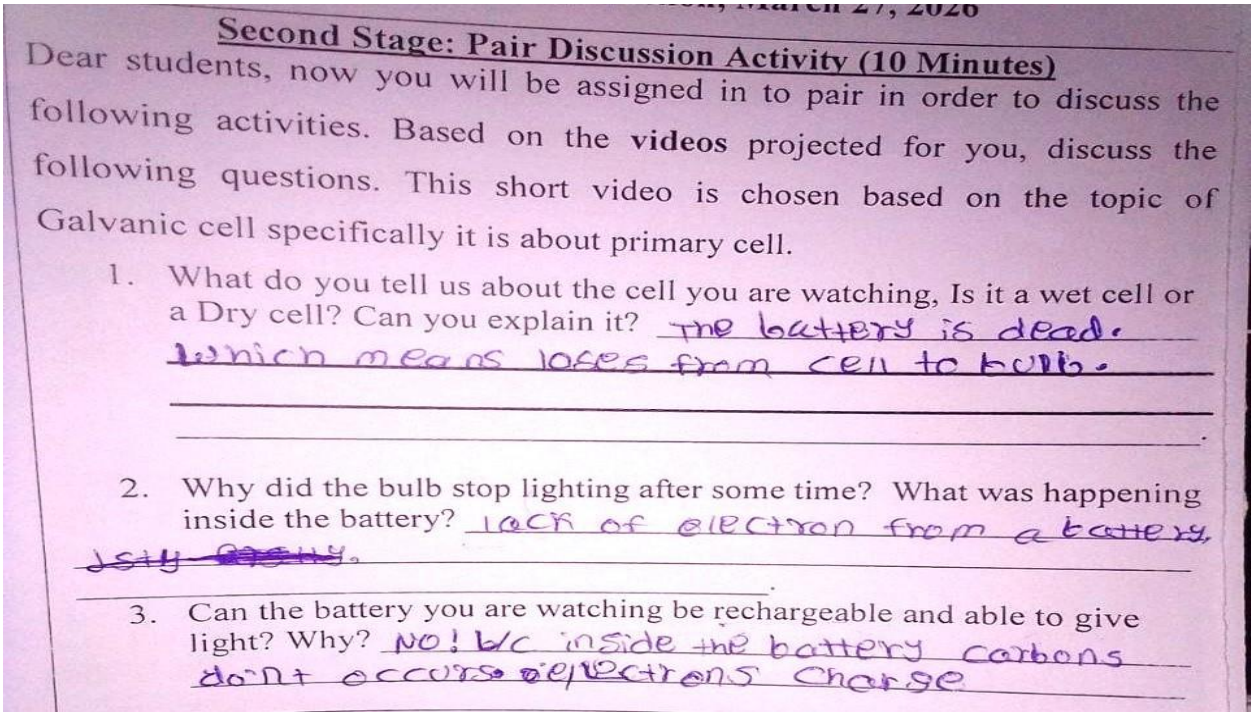
Second Stage: Pair Discussion Activity (10 Minutes)

Dear students, now you will be assigned in to pair in order to discuss the following activities. Based on the **videos** projected for you, discuss the following questions. This short video is chosen based on the topic of Galvanic cell specifically it is about primary cell.

1. What do you tell us about the cell you are watching, Is it a wet cell or a Dry cell? Can you explain it? wet cell is ~~second~~ secondary cell can charge dry cell is primery cell cantenerge or don't use agine
2. Why did the bulb stop lighting after some time? What was happening inside the battery? on the battry electric energy stopped or less or dead
3. Can the battery you are watching be rechargeable and able to give light? Why? The secondary Stages can recharege and wet cell and gain full electric energy/ can give light

Figure 18 Students' pair activity work on the application of galvanic cell

Besides, some paired students' assumed that carbon is the cause for the rechargeable nature of dry cell. As they replied that dry cells cannot be rechargeable because carbons will not occur inside the battery. This is a misconception or non-scientific understanding because the absence of carbons is not the reason for non-rechargeable nature of dry cells. Rather, the correct understanding is that because the chemical reaction in primary galvanic cell is irreversible, the reactants become consumed and completely depleted. As a result, the original chemicals cannot easily be regenerated using electricity. Therefore, students' assumption about connecting primary galvanic cell with the concept of carbon is not scientific. Some of students' written work is attached below.



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Second Stage: Pair Discussion Activity (10 Minutes)

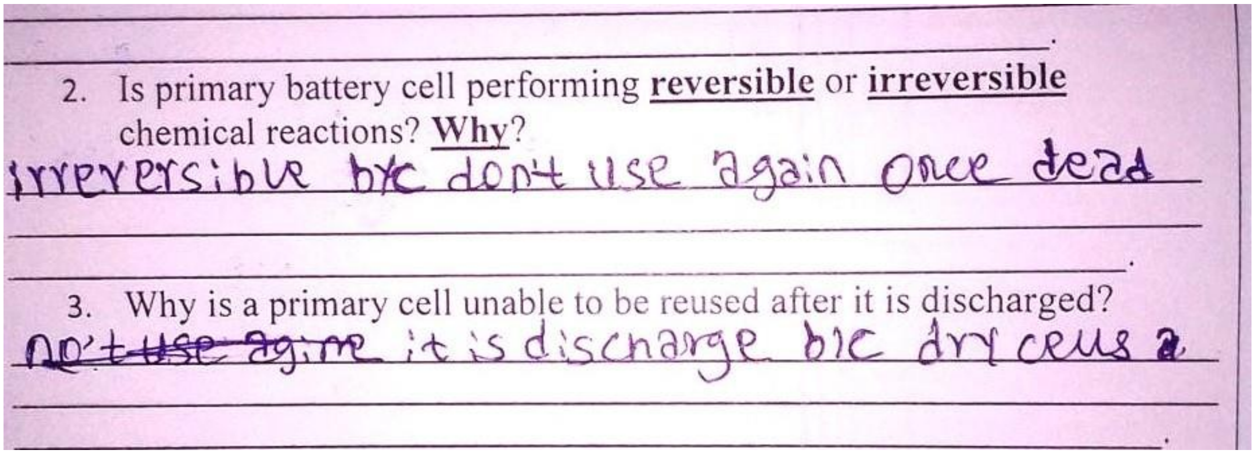
Dear students, now you will be assigned in to pair in order to discuss the following activities. Based on the **videos** projected for you, discuss the following questions. This short video is chosen based on the topic of Galvanic cell specifically it is about primary cell.

1. What do you tell us about the cell you are watching, Is it a wet cell or a Dry cell? Can you explain it? The battery is dead. which means loses from cell to bulb.
2. Why did the bulb stop lighting after some time? What was happening inside the battery? lack of electron from a battery. ~~Jsty~~ ~~[illegible]~~.
3. Can the battery you are watching be rechargeable and able to give light? Why? NO! b/c inside the battery carbons don't occurs electrons charge

Figure 19 Students' pair activity work on the application of galvanic cell

C. The solo stage activity for Redox reaction and Galvanic cell lesson

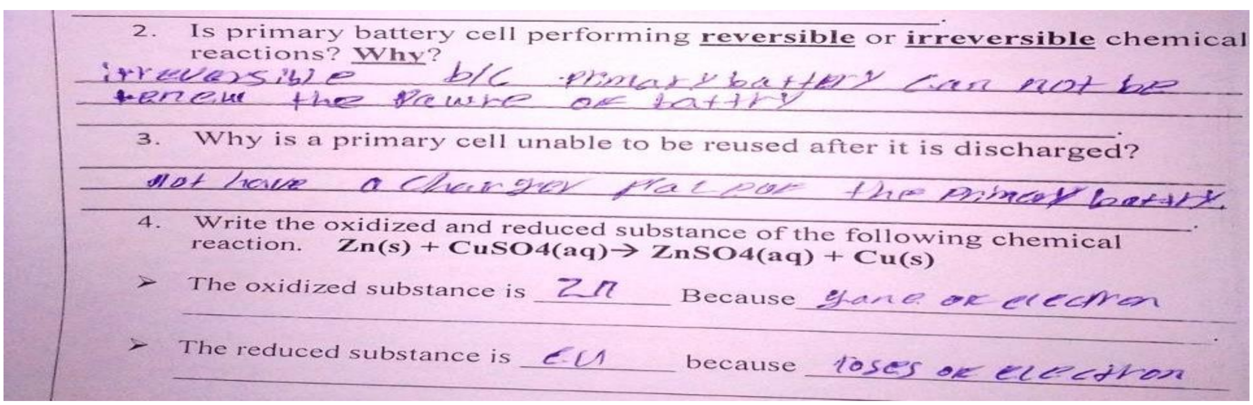
The solo stage activities for the students' were focused on comprehending what they were discussing on the team and the pair stage. As a result, it asked about primary galvanic cell and oxidation-reduction reaction so as to measure how much they understand it. Based on students' response, most students' replied that primary galvanic cell is non-rechargeable and has an irreversible chemical reaction.


2. Is primary battery cell performing **reversible** or **irreversible** chemical reactions? **Why**?
irreversible b/c don't use again once dead

3. Why is a primary cell unable to be reused after it is discharged?
~~no't use agine~~ it is discharge b/c dry cells a

Figure 20 Student A's work for the solo activity on primary galvanic cell

At this stage, students' were trying to solve problems based on information what they got on the team and pair stage discussion. Most of them correctly responded the activity although there is some degree of incomplete understanding. Some students' tried to solve the problem reasonably by stating why they said whereas some of them did the correct response without stating why they said. Some of students' responses are attached below.


2. Is primary battery cell performing **reversible** or **irreversible** chemical reactions? **Why**?
irreversible b/c primary battery can not be renew the pawre of battry

3. Why is a primary cell unable to be reused after it is discharged?
not have a charger plalpor the primary batery.

4. Write the oxidized and reduced substance of the following chemical reaction. **Zn(s) + CuSO4(aq)→ ZnSO4(aq) + Cu(s)**

➢ The oxidized substance is Zn Because gane of electron

➢ The reduced substance is Cu because loses of electron

Figure 21 Student C's work for primary galvanic cell activity

Based on the process of intervention on the first cycle, students' were discussing electrochemistry concepts in the team and pair stage that made them to grasp deep understanding about contents of electrochemistry. According to the video reflection that the teacher researcher used while discussing students' in the classroom, most of them were engaged in the team discussion activities. They were sharing different ideas such as about the real life application of electrochemistry concept like electricity on the daily activities of humans, metals and non-metals, galvanic cells, technological products etc.

Figure 22 Students’ discussion in the team stage

4.3 First cycle post test result analysis

The result of the first cycle post test revealed that there is improvement on students’ both conceptual understanding and academic achievement. Although there are consistent misconceptions and learning difficulties observed, the researcher found the result of the posttest better than that of the pretest. The posttest analysis was done in the same procedure that the researcher used to analyze the pretest.

Table 5 Posttest average score of the students (out of 20)

Total posttest		
Mean	N	Std. Deviation
13.3750	40	2.34999

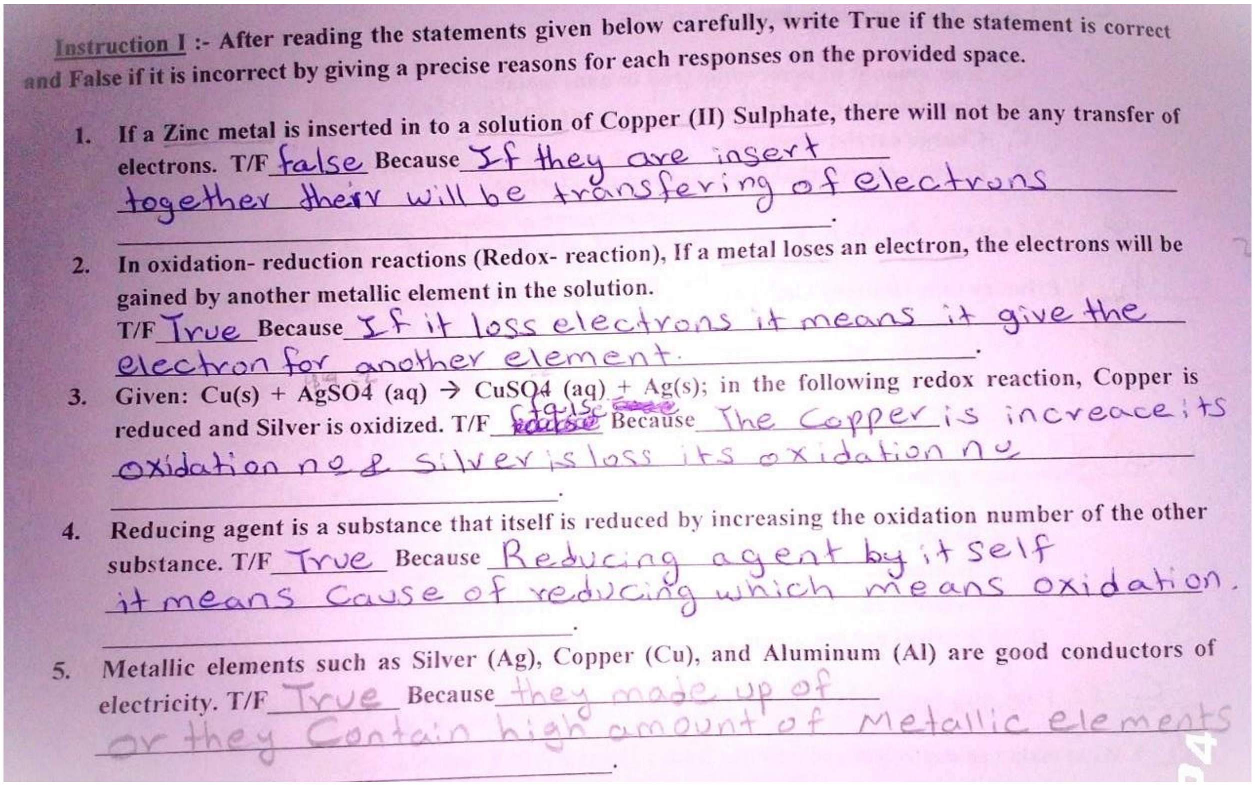
As the above Table 6 depicted that the average mean score of the students’ in the posttest is 13.37. The first cycle posttest result of the students’ shows growth in conceptual understanding level. Moreover, the conceptual understanding level of students’ for question result is tabulated below.

Table 6 Posttest average conceptual understanding levels

Conceptual understanding level	No of average students’	Percentage (%)
No understanding	8.75	21.875
Partial understanding	14.625	36.56
Sound understanding	16.625	41.56

From the above Table 7, the percentage of students’ categorized under no understanding category is 21.875%. In the pretest that was 55.93% of students’ were categorized under no understanding category and only 13.125% of the students’ were under sound understanding category. But, the posttest result clearly shows that students’ developed in each conceptual understanding category. 21.875% of the students’ is under no understanding and also 41.56% of the students’ are categorized under sound understanding category. The students’ posttest result shows that the intervention made them to develop conceptual understanding regarding metallic conductivity, oxidation-reduction reaction and galvanic cell.

According to students’ responses, most of them have clearly understood about metallic conductivity and redox reactions. Compared to the pretest, students’ in the posttest correctly answered the questions and they were able to give explanations for their answers.



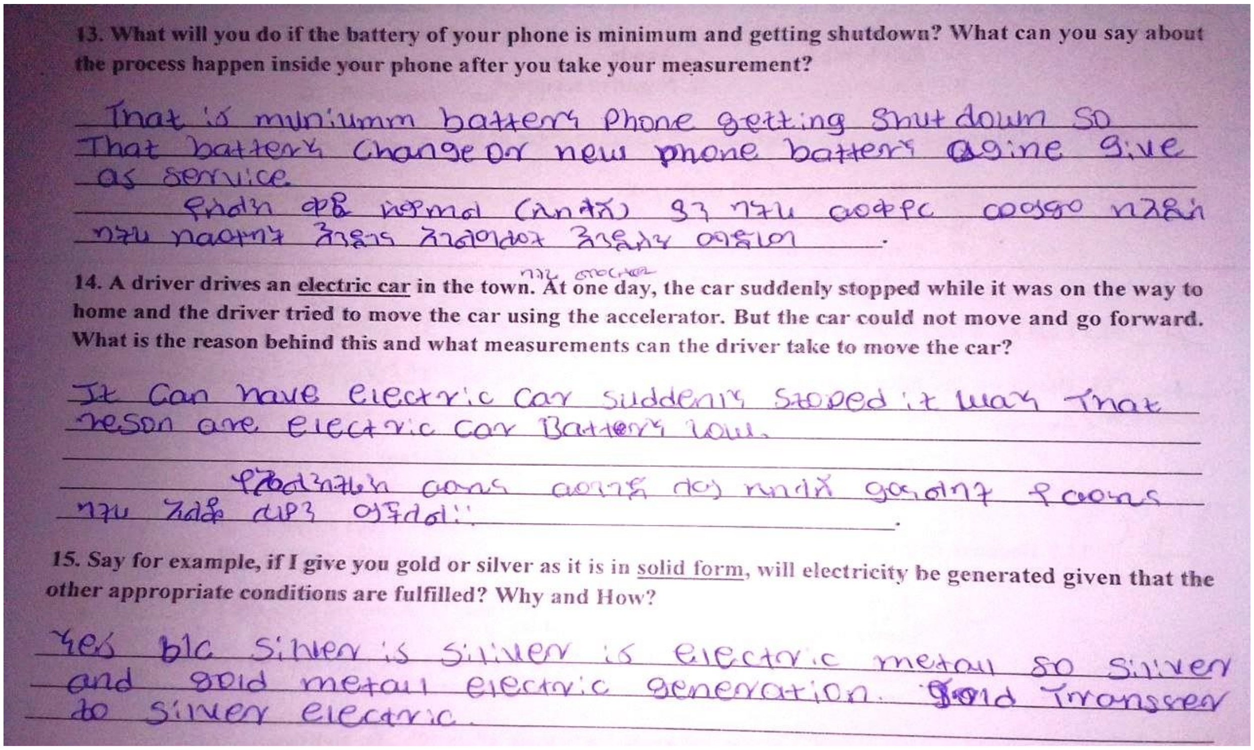
Instruction I :- After reading the statements given below carefully, write True if the statement is correct and False if it is incorrect by giving a precise reasons for each responses on the provided space.

1. If a Zinc metal is inserted in to a solution of Copper (II) Sulphate, there will not be any transfer of electrons. T/F false Because If they are insert together their will be transfering of electrons.
2. In oxidation- reduction reactions (Redox- reaction), If a metal loses an electron, the electrons will be gained by another metallic element in the solution. T/F True Because If it loss electrons it means it give the electron for another element.
3. Given: Cu(s) + AgSO4 (aq) → CuSO4 (aq) + Ag(s); in the following redox reaction, Copper is reduced and Silver is oxidized. T/F false Because The Copper is increace its oxidation no & Silver is loss its oxidation no.
4. Reducing agent is a substance that itself is reduced by increasing the oxidation number of the other substance. T/F True Because Reducing agent by it self it means Cause of reducing which means oxidation.
5. Metallic elements such as Silver (Ag), Copper (Cu), and Aluminum (Al) are good conductors of electricity. T/F True Because they made up of or they Contain high amount of Metallic elements.

Figure 23 Student's posttest explanation for the multitier Tue/False items

The above figure clearly shows that after the intervention, the students' were able to correctly answer the question and the student also give explanation that is to some extent correct. Compared to the pretest where most students' forwarded that transfer of electrons only occur between metals and non-metals, the posttest result of the students' reveals that electrons can be transferred between metals and metals also.

Moreover, students' were trying to connect the daily life activities with the concepts learnt in the classroom. The students' posttest explanation response revealed that they were trying to connect the questions with the day to day activities of their life. Compared to the pretest explanation, students' explain electrochemistry concept in understandable way. For instance, some students' connect the concept of galvanic cell with the phone we have. Moreover, students' understand the concept of secondary galvanic cell in that it can be rechargeable and if our phone or electric car is suddenly stopped, it is because of a decrease in electric charge inside the device. But, it can be rechargeable as the chemical reactants cannot be used up. Some of the students' response is presented below.



13. What will you do if the battery of your phone is minimum and getting shutdown? What can you say about the process happen inside your phone after you take your measurement?

That is muniumm battery Phone getting shut down so That battery change or new phone battery agine give as service

[illegible]

14. A driver drives an electric car in the town. At one day, the car suddenly stopped while it was on the way to home and the driver tried to move the car using the accelerator. But the car could not move and go forward. What is the reason behind this and what measurements can the driver take to move the car?

It can have electric car suddenly stoped it way That reson are electric car Battery low.

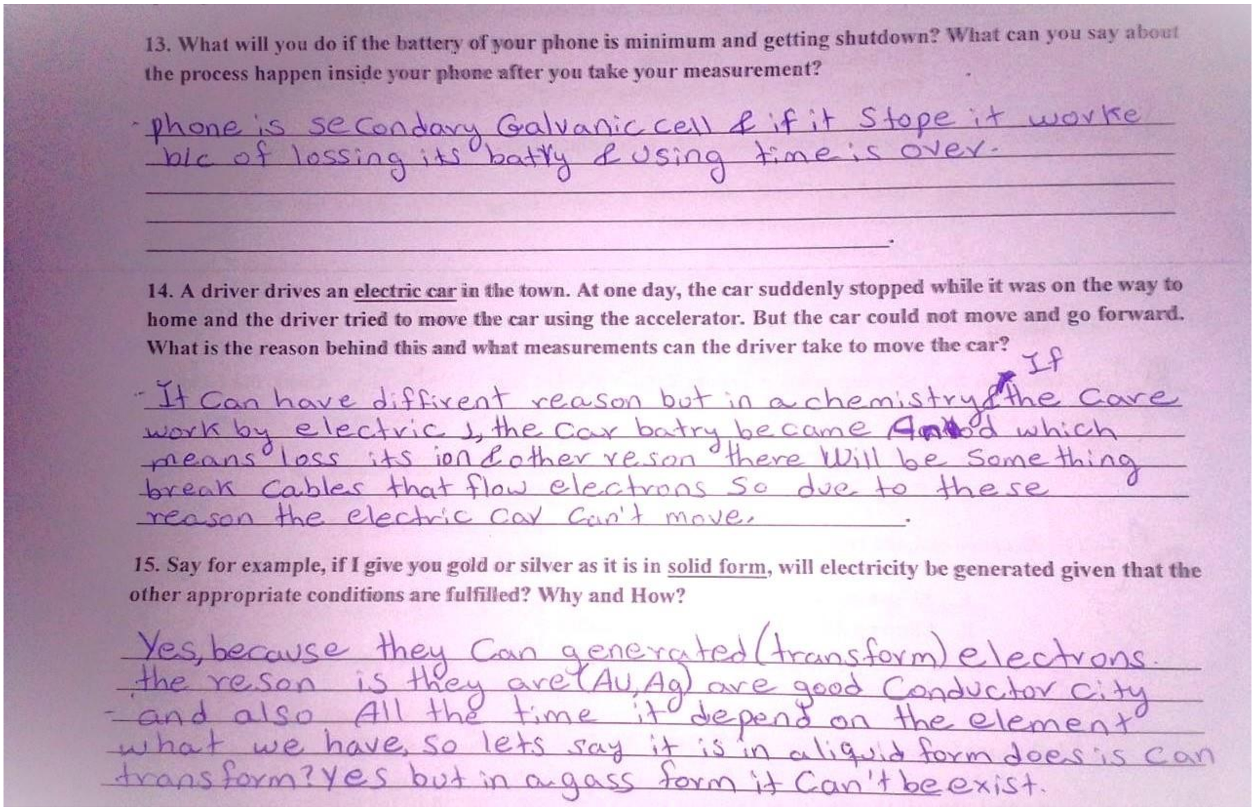
[illegible]

15. Say for example, if I give you gold or silver as it is in solid form, will electricity be generated given that the other appropriate conditions are fulfilled? Why and How?

yes b/c silver is silver is electric metal so silver and gold metal electric generation. Gold Transfer to silver electric.

Figure 24 Student’s posttest explanation for the open ended questions

Moreover, the other student deeply explains that secondary galvanic cell and the concept of metallic conductivity with accurate reasoning. The students’ tried to connect the concept with what they have learnt in classroom so as to interpret the day to day activities of humans. A sample of work is attached below.



13. What will you do if the battery of your phone is minimum and getting shutdown? What can you say about the process happen inside your phone after you take your measurement?

- phone is secondary Galvanic cell & if it Stope it worke b/c of lossing its batry & using time is over.

14. A driver drives an electric car in the town. At one day, the car suddenly stopped while it was on the way to home and the driver tried to move the car using the accelerator. But the car could not move and go forward. What is the reason behind this and what measurements can the driver take to move the car?

- It Can have diffirent reason but in a chemistry If the Care work by electric, the Car batry became ~~Anod~~ which means loss its ion & other reson there Will be Something break Cables that flow electrons So due to these reason the electric Car Can't move.

15. Say for example, if I give you gold or silver as it is in solid form, will electricity be generated given that the other appropriate conditions are fulfilled? Why and How?

Yes, because they Can generated (transform) electrons. the reson is they are (Au, Ag) are good Conductor city and also All the time it depend on the element what we have, so lets say it is in aliquid form does is Can transform? yes but in agass form it Can't be exist.

Figure 25 Student’s posttest explanation for the open ended questions

The above figure shows students’ work that best explains the concept of secondary galvanic cell. As the student replied that the phone we have is categorized under secondary galvanic cell in which it can be recharged. Therefore, the phone will stop its work because of losing its battery and usage time is over. This is a very big concept the student developed as she understands that our phone will only be effective whenever the time over is not reached. That means, the phone will be shut down after some time of usage. But, it can be recharged and used again and again since the battery in the phone is a secondary battery. This is a good understanding of the integrating technological product with the concept of electrochemistry. The student also explains much about the electric car and metallic conductivity as depicted above in the figure.

To conclude about the posttest analysis of the students, the researcher found that the designed intervention method helped students' to gain a conceptual understanding and increased their engagement while learning electrochemistry. Moreover, students were discussing about electrochemistry concepts by integrating it with the day to day activities.

4.4 Comparison of the pretest and posttest result of the first cycle

4.4.1 Comparison of the conceptual understanding level of pretest and posttest

The following table summarizes the percentage of students' who have conceptual understanding level in the pretest and posttest out of 40 students'.

Table 7 Comparison of the conceptual understanding level of students

No understanding		Partial Understanding		Sound Understanding	
Pretest	1st Posttest	Pretest	1st posttest	Pretest	1st Posttest
55.93%	21.875%	30.93%	36.56%	13.125%	41.56%

As the above Table 8 depicted that the students' conceptual understanding is increased from 13.125% of the pretest in to 41.56% of the posttest under sound understanding category. Moreover, students' who had no understanding level is diminished to 21.875% which was more than half of the students' were joined to either partial understanding or sound understanding category level.

4.4.2 Paired sample t-test comparison of the students' pretest and posttest results

The researcher conducted a comparison table using SPSS analysis technique for evaluating whether the implemented intervention method was effective or not on students' conceptual understanding level. The paired sample t-test value was calculated after the total pretest and posttest result of each student is calculated since it required changing the ordinal data in to scale.

Table 8 Mean of the students' pretest and posttest result

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Total pretest	7.9250	40	2.22327	.35153
	Total posttest	13.3750	40	2.34999	.37157

As the above Table 9 depicted that the mean of the students' score for the pretest was 7.925. However, after the implementation of the intervention, students mean score is increased to 13.375.

Table 9 Paired sample t-test for the pretest and first cycle posttest

Paired Samples Test

			95% CI of the Difference				
Paired Differences	Mean	SD	Lower	Upper	t	df	Sig. (2-tailed)
Total Posttest- Total Pretest	5.45000	3.10459	6.44290	4.45710	11.103	39	.000

As it is clearly depicted in the above Table 10, there was a significant difference between students' pretest and posttest conceptual understanding scores after the implementation of the intervention. The analysis showed a statistically significant difference between the first cycle post test scores (M=13.37, SD=2.35) and pre-test scores (M=7.93, SD=2.22), t(39)=11.10, P=.001.

4.5 The Learning Process in Cycle Two

In the second cycle, students' were learning electrochemistry concept with technology integration, Team-Pair-Solo co-operative learning and the added intervention, conceptual change text (CCT). During the implementation of the intervention method, it was observed that students' were discussing electrochemistry concepts' such as conductivity, redox reaction and galvanic cell together and also solve problems with their team and peer friends.

These conceptual change texts (CCTs) results them to have a cognitive dissonance about what they previously know. At this time, the teacher-researcher was trying to accommodate this cognitive dissonance of students' by creating balanced condition in their learning. The process of learning at this cycle is described below.

4.5.1 Task design for electrical conductivity of the second cycle

In this section, the researcher presented the learning processes happened during the implementation of the second cycle. Like the activities being given to students' in the first cycle, there were also some questions related to electrical conductivity in this second cycle though they were presented with conceptual change texts (CCTs).

A. The team stage activity for electrical conductivity

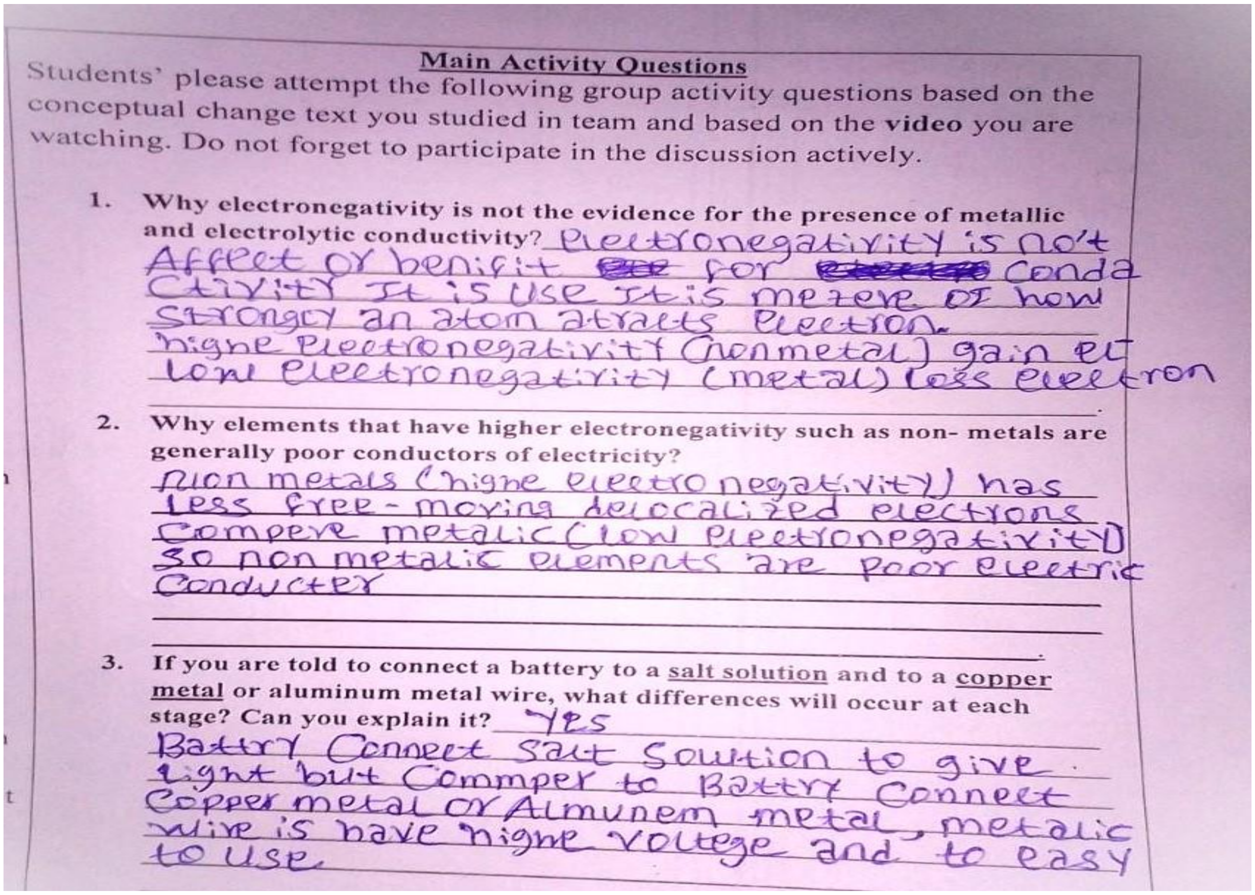
At this stage the teacher researcher presented a task for students' that basically aimed to tackle their learning difficulty on the concept of conductivity. The conceptual change text in this stage focuses on the misunderstanding or partial understanding they had on electronegativity. As students' connect conductivity with the presence of electronegativity, the conceptual change text was about the meaning of electronegativity and its relationship with chemical bond and conductivity. The conceptual change text at this stage made students' to had two ideas and argue about their previous believes. The students' were discussing while reading the conceptual change text and doing the activities after read the conceptual change text.

Compared to the first cycle, in which the students' reflect their misunderstanding about electronegativity, this stage of the second cycle improves students understanding about electronegativity and its relation with that of chemical bond and conductivity. They clearly differentiate the basic concept under the concept of electronegativity and forwarded that high electronegativity means poor conductor of electricity. Although the main reason for the conductivity of substance is their delocalized electron, the concept of electronegativity can be also raised as it is the ability of a substance to attract electron towards itself. Substances with high electronegativity values are generally poor conductors of electricity because the electrons are strongly attracted to the atoms and as a result they are not free to move easily.

Some of students’ written works about their understanding related to electronegativity are attached below. They tried to respond scientifically by forgetting their knowledge gap that they had in the first cycle as they were believed that non-metals are good conductors due to high electronegativity value. A group of students’ forwarded that electronegativity is an attraction of electrons towards itself. If electrons cannot move freely, the concept of conductivity cannot be imagined. Besides, they also replied that high electronegative substances have poor/ no conduct electricity. This revealed that the previous believes they had about electronegativity is now resolved with the help of the conceptual change text they discussed.

Additionally, students' were clearly stated that the difference between the conductivity of salt solution and metal wires such as copper and aluminum. They described that salt solutions are electrolytic conductivity that conduct electricity in liquid form whereas copper and aluminum conduct electricity in solid form.

Moreover, the other group also suggests that electronegativity cannot be the reason for the concept of conductivity rather it tells us about the attraction of electrons towards a substance. The students’ in this group also forwarded that non-metals have less free-moving delocalized electrons compared to metals. As a result they are poor electric conductor. This idea of the students’ is also scientifically correct as non-metals have high attraction power of electrons towards themselves. Because of this they perform less in electric conductivity process. The students’ written work is attached below.



Main Activity Questions

Students' please attempt the following group activity questions based on the conceptual change text you studied in team and based on the **video** you are watching. Do not forget to participate in the discussion actively.

1. **Why electronegativity is not the evidence for the presence of metallic and electrolytic conductivity?** electronegativity is no't Affect or benifit for Condactivity It is use It is mezere of how strongly an atom atracts electron. highe electronegativity (nonmetal) gain el low electronegativity (metal) less electron

2. **Why elements that have higher electronegativity such as non- metals are generally poor conductors of electricity?**
non metals (highe electronegativity) has less free-moving delocalized electrons compere metalic (low electronegativity) so non metalic elements are poor electric Conducter

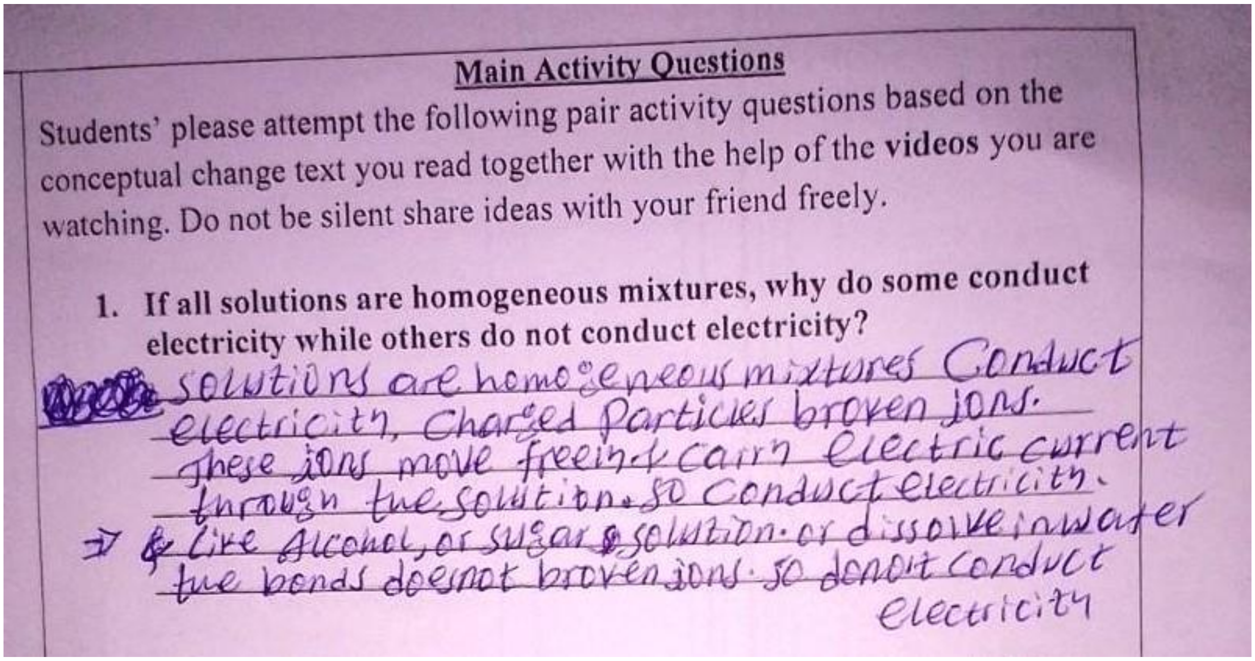
3. **If you are told to connect a battery to a salt solution and to a copper metal or aluminum metal wire, what differences will occur at each stage? Can you explain it?** Yes
Battry Connect salt solution to give light but Commper to Battry Connect Copper metal or Almunem metal, metalic wire is have highe voltege and to easy to use

Figure 26 Students' explanation about electronegativity in the second cycle team stage

B. The pair stage activity for electrical conductivity

At this stage, students' were grouped in to pair/triple so that they discussed about the concept that not all solutions conduct electricity. When we talk about electrolytic solutions, we are talking about homogenous solutions which have a uniform component throughout the substance. But, not all solutions conduct electricity. This is because there are solutions that cannot produce free-moving ions. However, some students' have misunderstanding about this concept and was unable to tell the reason behind why some solutions cannot conduct electricity in the first cycle. The researcher gave students' a conceptual change text to discuss in pair/triple and open videos that demonstrates the conductivity of solution, both electrolyte and non-electrolyte.

According to the students' written work and oral discussion, most of the paired/grouped students' were performed well and conceptually understand that the basic reason for conductivity of solutions is the presence of free moving ions. They replied that solutions that have no free moving ions such as sugar solution and alcoholic solution are generally cannot conduct electricity. Some of students' written works about electrolytic solutions are attached below.



Main Activity Questions

Students' please attempt the following pair activity questions based on the conceptual change text you read together with the help of the **videos** you are watching. Do not be silent share ideas with your friend freely.

1. **If all solutions are homogeneous mixtures, why do some conduct electricity while others do not conduct electricity?**

solutions are homogeneous mixtures Conduct electricity, Charged particles broken ions. These ions move freein & carry electric current through the solution. so conduct electricity.
& like alcohol, or sugar solution. or dissolve in water the bonds doesnot broken ions. so donot conduct electricity

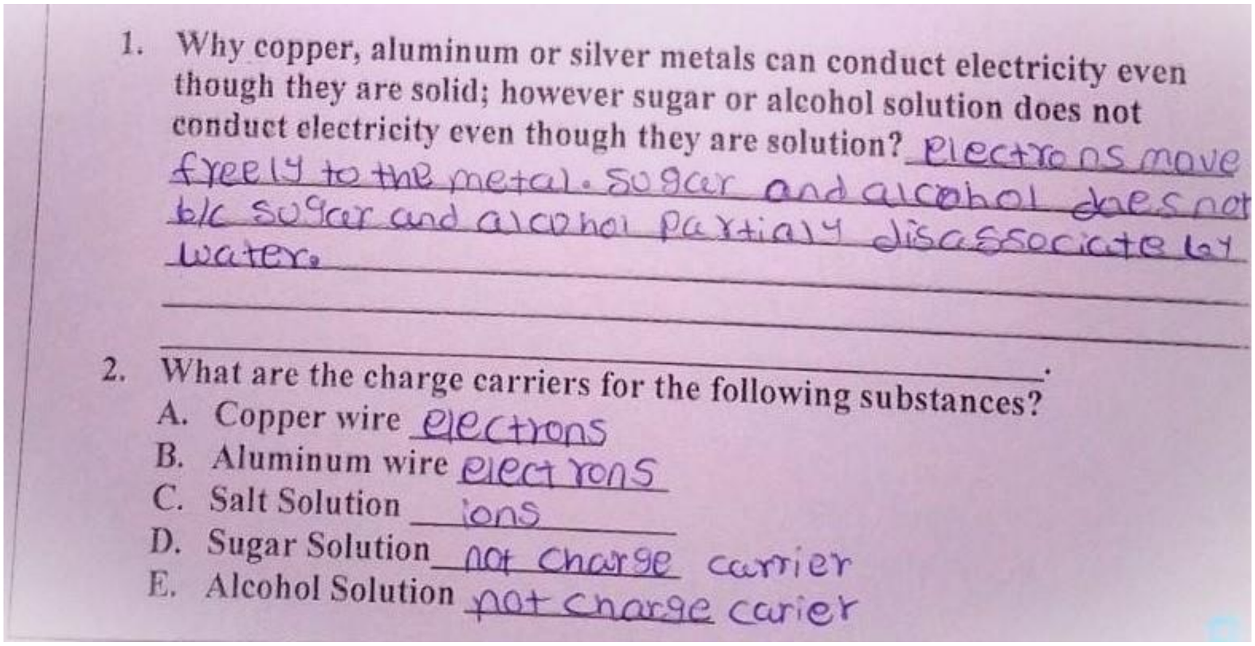
Figure 27 Paired students' explanation about conductivity in solutions

As the above paired activity response reveals, the paired students' were discussed effectively and forwarded a clear and correct scientific idea. They replied that the reason for not all solutions conduct electricity is that because some solutions like alcohol or sugar solutions have a bond that cannot be able to form ions. Therefore, if that solution cannot produce ions, it cannot conduct electricity.

The other paired students' also replied that the primary and the basic thing for the formation of conductivity are charge carrier particles. They are scientifically correct as charge carrier particles such as electrons and ions are responsible for conductivity of substances. Some of students' works are attached below.

C. The solo activity for electrical conductivity

At the solo stage of the second cycle, the students' were allowed to be alone and attempt to solve activities after reading the conceptual change text which was about metals and electrolytes. This conceptual change was prepared due to misconceptions students' had about the charge carriers for metals and solutions. Not all, but some students' were reflected that the charge carriers for metallic conductivity and electrolytic conductivity were electrons at the first cycle intervention and conversations. But, now they were allowed to read conceptual change text talks about metals and non-metals so as to give the correct understanding about the concept of conductivity. Some of the students' works are attached below.


1. Why copper, aluminum or silver metals can conduct electricity even though they are solid; however sugar or alcohol solution does not conduct electricity even though they are solution? electrons move freely to the metal. sugar and alcohol does not b/c sugar and alcohol partialy disassociate by water.

2. What are the charge carriers for the following substances?
   A. Copper wire electrons
   B. Aluminum wire electrons
   C. Salt Solution ions
   D. Sugar Solution not charge carrier
   E. Alcohol Solution not charge carier

Figure 28 the student's explanation about conductivity

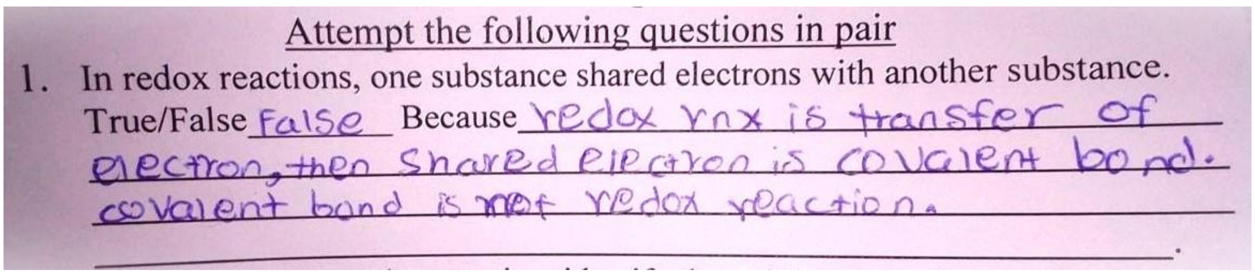
As the above picture shows us that the student correctly understands the difference between metallic and electrolytic conductivity as well as non-electrolytes. The student clearly wrote that electrons move freely in metals and they are the charge carriers for metals to conduct electricity. Moreover, the student also put that non-electrolytes such as sugar solution and alcoholic solution have no charge carrier electrons or ions as a result they cannot conduct electricity.

4.5.2 Task design for redox and galvanic cell topic of the second cycle

In this phase of task design, the researcher prepared some activities that were presented with conceptual change texts in the team-pair-and solo stages along with videos. This task design was implemented in the classroom and the researcher observed improvements on students' conceptual understanding. Some of them believed that due to full filled electrons in metals,

metals cannot transfer electron to other specious. This assumption was wrong that the students' related the concept of conductivity with sharing of electrons. However, the concept of conductivity should be judged by the transfer of electrons.

After discussing the conceptual change text with their peers, students' were trying to understand the true concept behind conductivity and redox reactions. As conductivity is related with redox reaction, students' now able to reply that redox reactions are happened due to transfer of electrons rather than sharing of electrons. Some of student works are attached below.



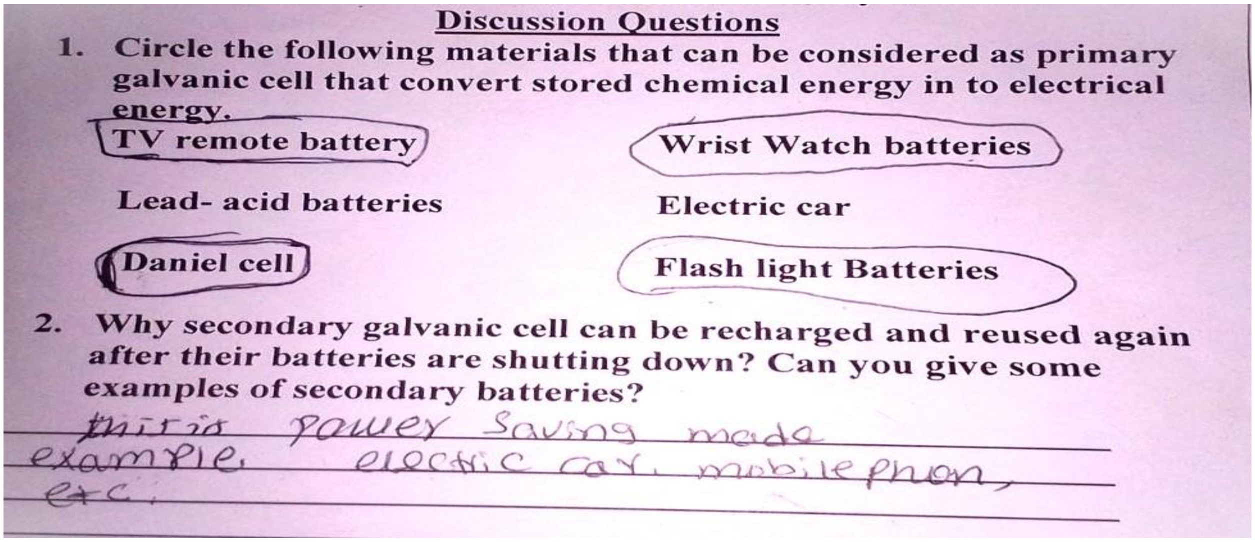
Attempt the following questions in pair

1. In redox reactions, one substance shared electrons with another substance.
True/False False Because redox rnx is transfer of electron, then shared electron is covalent bond. covalent bond is ~~mot~~ not redox reaction.

Figure 29 Paired students' explanation about oxidation-reduction reaction

Some students' were connecting redox reaction with sharing of electrons or connect it with covalent bond. However, after they discussed in pair about the conceptual change text which talks about covalent bonding and redox reaction, their assumption was improved in that they do not relate redox reaction with that of covalent bonding depicted in the above picture. Moreover, their oxidation number knowledge was also elevated while discussing in pair.

The students' were also showed improvement on the concept of primary and secondary galvanic cell. They clearly differentiated the difference between primary and secondary galvanic cell by relating it with their day to day activities. Moreover, their previous understanding that wet cells are secondary galvanic cell is now resolved and they clearly understand what wet cell is and secondary galvanic cell mean.


Discussion Questions

1. Circle the following materials that can be considered as primary galvanic cell that convert stored chemical energy in to electrical energy.

TV remote battery | Wrist Watch batteries
Lead- acid batteries | Electric car
Daniel cell | Flash light Batteries

2. Why secondary galvanic cell can be recharged and reused again after their batteries are shutting down? Can you give some examples of secondary batteries?

this is power saving mode
example. electric car. mobile phon,
etc.

Figure 30 the student's solo response for primary and secondary galvanic cell

4.6 Second cycle posttest analysis of the students' result

After the teacher researcher implemented the re-designed intervention method on the second cycle, he gave them another posttest that was the same with the pretest and first cycle posttest question items for the purpose of comparison. Here below are the analysis of the second cycle posttest results of students' and their improvements compared to the pretest and first cycle posttest results. Sample questions were chosen for the purpose of analysis of both the multitier questions and the open ended questions.

Table 10 Mean score for the second cycle posttest (out of 20)

Second posttest		
Mean	N	Std. Deviation
16.2500	40	1.72091

The above Table 11 depicted that the mean score results of the students' are 16.25. Compared to the pretest and the first cycle posttest, which was 7.9 and 13.3 respectively. Moreover, the standard deviation of the students' score is getting decreased. The pretest had a SD of 2.22 and that of the posttest is 2.34. However, the SD of the second cycle posttest is decreased to 1.72.

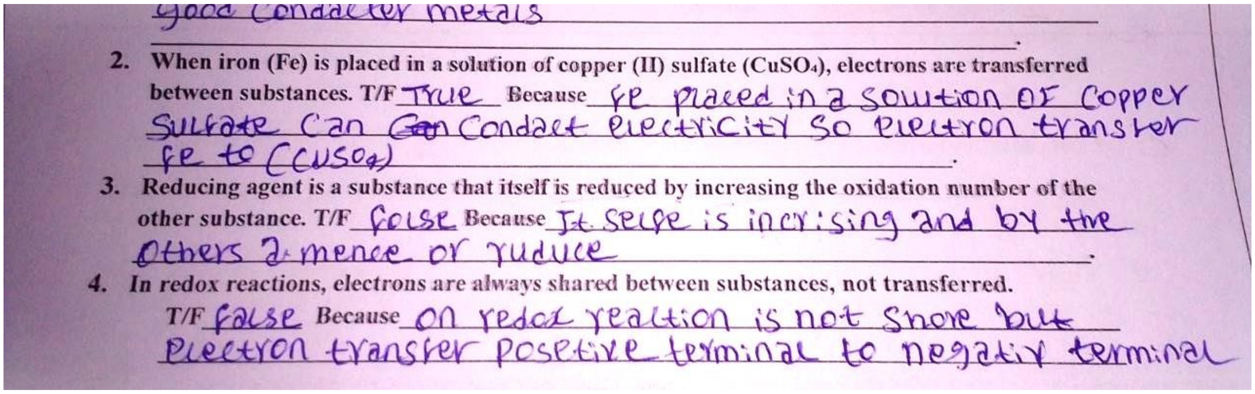
Table 11 Average Conceptual understanding levels in second post-test

Conceptual Understanding Level	Average No of students'	Percentage
No understanding/Misconception	2.75	6.87%
Partial Understanding	13.125	32.81%
Sound Understanding	24.125	60.31%

As the above Table12 depicted that the students' conceptual understanding is dramatically increased from 13.125% of the pretest to 41.56% of the first posttest and of 60.31% of the second posttest under sound understanding category. Moreover, students' who had no understanding level is now decreased to 6.87%.

The teacher researcher analyzed students' true/false with reasoning section of the posttest. Only sample questions were being analyzed qualitatively but the overall quantitative result is analyzed above.

For the following question which talks about the transfer of electrons between substances, most of the students' correctly got the answer and also they explained it better. Compared to the pretest understanding and the first cycle explanation, students' understand that electrons can be transferred between metal and metals, metals and non-metals. Previously, before the administration of the conceptual change text, students' were arguing about metals transfer to non-metals only. But now, students' understand that electrons can be transferred from metal to metallic solution. Some of students' written works for the posttest question are attached below.


good condacter metals

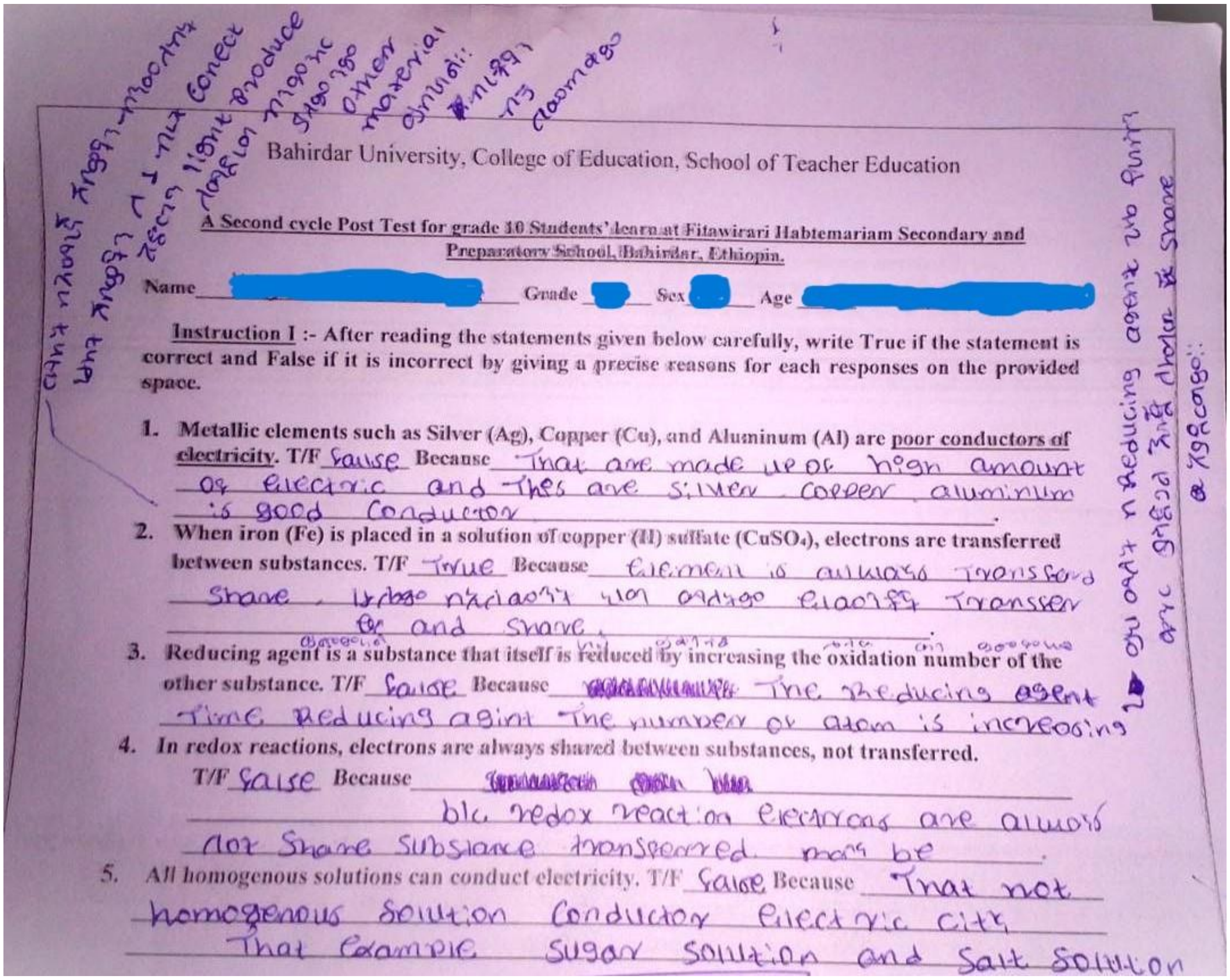
2. **When iron (Fe) is placed in a solution of copper (II) sulfate ($CuSO_4$), electrons are transferred between substances. T/F** True **Because** fe placed in a soution of copper sulfate can Can condact electricity so electron transfer fe to ($CuSO_4$).
3. **Reducing agent is a substance that itself is reduced by increasing the oxidation number of the other substance. T/F** folse **Because** It self is incrising and by the others a mence or yuduce.
4. ***In redox reactions, electrons are always shared between substances, not transferred.***

   T/F false **Because** on redox realtion is not shore but electron transfer posetive terminal to negativ terminal

Figure 31 Student's second cycle posttest explanation for the True/False multitier questions

Student's second cycle posttest explanation for the True/False multitier questions The students' were also confident to explain what they understand about the concepts even in Amharic language. Moreover, most of them got whole the answer for the question although some not clearly explain the scientific concept using the instructional language, English. But, this eagerness implicated how much they were developed conceptually after the implementation of the second cycle which was integrating conceptual change text with that of videos in team-pair and solo strategies.

In the following picture below, the student's work revealed that the student got the answers and tried to explain conceptually in Amharic and English language. The student was trying to explain the concepts in the discussion and forwarded what she understands about the question. According to the researcher's perspective, it is performed well as she tried to explain what she know based on the intervention both in the first cycle and the second cycle. This showed that the second cycle intervention helps students to be confident and try to explain concept more in understandable way.



Bahirdar University, College of Education, School of Teacher Education

A Second cycle Post Test for grade 10 Students' learn at Fitawirari Habtemariam Secondary and Preparatory School, Bahirdar, Ethiopia.

Name [redacted] Grade [redacted] Sex [redacted] Age [redacted]

Instruction I :- After reading the statements given below carefully, write True if the statement is correct and False if it is incorrect by giving a precise reasons for each responses on the provided space.

1. **Metallic elements such as Silver (Ag), Copper (Cu), and Aluminum (Al) are poor conductors of electricity.** T/F faulse Because That are made up of high amount of electric and Thes are silver copper aluminum is good conductor.
2. **When iron (Fe) is placed in a solution of copper (II) sulfate ($CuSO_4$), electrons are transferred between substances.** T/F True Because Element is allways Transford Share ... Transfer or and share.
3. **Reducing agent is a substance that itself is reduced by increasing the oxidation number of the other substance.** T/F faise Because The Reducing agent Time Reducing agint The number of atom is increasing
4. **In redox reactions, electrons are always shared between substances, not transferred.** T/F faise Because b/c redox reaction electrons are always not share substance transferred may be.
5. **All homogenous solutions can conduct electricity.** T/F faise Because That not homogenous solution conductor electric city That example sugar solution and salt solution

Figure 32 Student's response about the multitier True/False item question in second cycle

Generally, the conceptual understanding level of students' increased in the second cycle after the implementation of the intervention that contains the re-designed method CCTs. Students' were upgraded from low understanding level to the higher one on the concept of galvanic cell. They think now that metals can transfer electrons to other metals. They did not relate the transfer of metals with the concept of covalent bond which is sharing of electron and with that of non-metals. Rather, students' correctly understand that there will be a transfer of electrons between metals in redox reactions and galvanic cell concept. The result of students' understanding level is attached below in tabulated way.

4.6.1 Paired sample t-test comparison of the students' second cycle posttest and first cycle posttest results

The teacher researcher conducted a comparison table using SPSS analysis technique for evaluating whether the second implemented intervention method was effective or not on students' conceptual understanding level.

Table 12 Mean of students' second cycle posttest and first cycle posttest

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	First posttest	13.3750	40	2.34999	.37157
	Second posttest	16.2500	40	1.72091	.27210

As Table 13depicted that the mean of the students' score for the first cycle posttest was 13.37. However, after the implementation of the re-designed intervention method, the students' mean score is increased to 16.25. Besides, the standard deviation (SD) of the second posttest is decreased to 1.72 compared to the first cycle posttest which was 2.35.

Table 13 Paired sample t-test for the second cycle posttest and first cycle posttest

Paired Samples Test

Paired Differences	Mean	SD	95% CI of the Difference Lower	95% CI of the Difference Upper	t	df	Sig. (2-tailed)
Second Posttest – First Posttest	2.87500	2.76598	3.75960	1.99040	6.574	39	.000

As it is clearly depicted in the above Table 14, there was a significant difference between students' pretest and posttest conceptual understanding scores after the implementation of the intervention. The analysis showed that the mean total posttest score (M=16.25, SD=1.72) was higher than the mean total pretest score (M=13.37, SD= 2.35), implying an improvement on students' conceptual understanding after the intervention. Moreover, the mean difference between the scores was 2.87 and also $P < 0.001$. This clearly revealed that the second cycle intervention has an effect on the conceptual development of students'. Integrating technology mediated instruction with CCTs in team-pair-solo co-operative learning elevated students' conceptual and academic development.

4.7 General reflection on the implementation of the re-designed cycle

Generally, in the re-designed cycle students' were actively participated in the discussions at the team and pair stage activities. They were allowed to read conceptual change texts that were prepared by the teacher researcher based on their learning difficulties. This conceptual change texts helped students' to reason out questions and discuss cooperatively as it made them a cognitive dissonance. These conceptual change texts were supported by technological tool which was an educational video, animations and small scale experimental videos. Students' were discussing in this condition and it gave them an opportunity to understand concepts well and allowed them to make correct their misconceptions and misunderstandings. These findings imply that integrating technology with cooperative learning strategies can serve as an effective approach for addressing persistent learning difficulties in electrochemistry.

Figure 33 Students' working together at the team stage of the second cycle

4.8 Students' questionnaire result of the implementation of the intervention

The researcher administered questionnaires for students' so as to know whether the students' were engaged during the intervention. This questionnaire focuses on four perspective; these are: - behavioral engagement, cognitive engagement, emotional engagement, and socio-cultural engagement. The result of the students' questionnaire result is attached below.

Table 14 Mean score result for the engagement questionnaire items

Paired Samples Statistics

	Mean	Std. Deviation	N
Cycle 1	2.882	0.222	40
Cycle 2	3.355	0.182	40

As depicted in Table 15, the mean score for questionnaire item for cycle one is 2.882 whereas the mean score for the same questionnaire items in the second cycle is 3.355. Moreover, the standard deviation for cycle one is found to be 0.222 and for cycle two is 0.182. The mean engagement score increased from M = 2.88 in Cycle 1 to M = 3.36 in Cycle 2, indicating that the refined intervention in the second cycle was associated with more positive student engagement.

Table 15 Paired sample t-test values for cycle 1 and cycle 2 questionnaire items

Paired Samples Test

			95% CI of the Difference				
PD	Mean	SD	Lower	Upper	t	df	Sig. (2-tailed)
Cycle 2 – Cycle 1	0.473	0.304	0.376	0.048	9.838	39	.000

As depicted in Table 16, the mean difference between cycle 2 and cycle 1 engagement questionnaire items is 0.473. Moreover, the result shows that there is a statistically significant difference between students' engagement in cycle one and cycle two as the t (39) =9.838 and $p<0.001$.

Moreover, in cycle two there were five additional questionnaires that were developed because cycle was re-designed using conceptual change texts. The questionnaire items and their mean score are tabulated below.

Table 16 Engagement analysis for the CCTs of Cycle Two Intervention

No	Questionnaire Items	Mean
QP15	The texts made me think deeply about my understanding of electrochemistry concepts.	4.3
QP16	The conflict between my ideas and the text helped me learn better.	3.58
QP17	I changed my understanding after reading the conceptual change texts.	3.98
QP18	Working in groups helped me understand the conceptual change texts better.	4.18
QP19	Individual work helped me reflect on my own understanding using CCTs	4.10

As shown in Table 17, students reported positive perceptions toward the Conceptual Change Texts. The highest mean score was obtained for QP15 (M = 4.30), indicating that students strongly agreed that the conceptual change texts encouraged deep thinking about electrochemistry concepts. The lowest mean score was obtained for QP16 (M = 3.58), although students still agreed that conceptual conflict supported their learning. The overall mean score suggests a generally favorable perception of the intervention.

4.9 Focus Group Discussion (FGD) with students’

The teacher researcher conducted a focus group discussion (FGD) with students’ about the overall process of the implemented intervention. As the intervention was taken placed in two cycles, the students’ were discussing the effectiveness of the intervention method both on the first and second cycle. This focus group discussion was conducted with five students’ after the implementation of the intervention. The purpose of the discussion was to explore students’ perceptions of the overall intervention as well as so as to identify conceptual changes in their understanding of electrochemistry. The students’ opinions regarding the implementation of the intervention were analyzed using thematic analysis. Some of students’ opinions are presented below after patterns were identified and organized in to themes.

4.9.1 Development in conceptual understanding level

The FGD revealed that the students’ were shown significant improvements’ after the implementation of the designed and the re-designed intervention. Students’ were able to clearly identify what metallic and electrolytic conductivity mean as well as their charge carriers.

One of the participants said that

“ *I understand now that, metallic conductivity is happened when electrons are moving freely whereas electrolytic conductivity is happened when there is chemical reaction happened. In electrolytic solution, for example sodium chloride solution, the ions in the solution will connect with wire and produce electricity but the ions will be used up and the power of lighting will eventually decrease and will be finished as the reactants are used up.” Student B*

Based on the student B's response, it can be said that the student B is now clearly identify the difference between metallic and electrolytic conductivity. The student tried to connect the concept with chemical reaction and physical reaction which is better improvement.

And the other participant also said that for the question why solid sodium chloride cannot conduct electricity but aqueous sodium chloride does, replied that

"*Because in solid sodium chloride the ions cannot move freely but when they become in aqueous form they will be free to move. First the bond will be broken when the sodium chloride is dissolved in water which makes sodium chloride to have freely moveable ions that can conduct electricity. However, the bond cannot be broken in solid sodium chloride as a result electricity cannot be produced." Student C*

When we look carefully the student C's response, the student conceptually understand the main reason for why solid NaCl does not conduct electricity but aqueous sodium chloride does. There are ions on solid sodium chloride, the sodium ions (Na^+) and chloride ions (Cl^-), that are held tightly in a rigid crystal lattice structure. However, they cannot conduct electricity because they are fixed in position and cannot move from one place to another. Since electrical conduction requires the movement of charged particles, solid NaCl does not conduct electricity.

The other participant also forwarded about oxidation-reduction reaction by relating it with transfer of electrons other than sharing of electron. Scientifically, the fundamental idea of a redox reaction is that electrons are transferred from one species to another specious. Oxidation is the loss of electrons while reduction is the gain of electrons. The student basically understands the concept and said that:-

"*Oxidation-reduction will occur only when there will be transfer of electrons. The one substance loss electron without accept from the others. The substance will loss electrons until it have nothing to give for the other substances. But, when we say covalent bond there will be sharing of electrons to full fill the octet rule. However, when we sat transfer, the one substance gives electron to the other without anticipating the other substances electron." Student* D

4.9.2 The role of the technology and the team-pair-solo learning strategy on students' understanding

The teacher-researcher also asked the participants about the role of the technology in their learning as well as the team-pair-solo strategy while the intervention. The students' forwarded that the videos that they were watching during the intervention helped them to visualize the microscopic aspect of chemistry. Since electrons and ions cannot be visualized in reality, the animation videos supported them to understand electrical conductivity and redox reaction clearly.

One of the participants replied that:-

"The technology helped me to clearly understand the movement of electrons and ions while I was learning in electrical conductivity and redox reactions." Student E

"The technology helps me to understand about the concept of primary and secondary galvanic cell. As I understand TV remote is considered as primary but secondary galvanic cell can be recharged and be used again. For example, the phone battery we have is secondary." Student A

The other participant forwarded ideas regarding the co-operative learning strategy Team-Pair-Solo method of learning. According to the student's idea, students' should better understand well when they first be grouped with their peers as this makes them to have hint about some topic of the course. The student's response is presented below:-

"We were debating about different topics such as metallic conductivity, electrolytic conductivity, and other issues and share ideas in team and pair discussion. This is a good strategy since it enhances our engagement for discussing about the electrochemistry concept. It is better to go through simple to complex path. The team stage and the pair stage made us to have idea based on the questions we were being taken and these activities were modified at the solo stage so as to evaluate us how much we were focus on the earlier stages. Therefore, the intervention team-pair-solo method helps us to co-operatively learn the contents well." Student B

4.9.3 The Effectiveness of the re-designed strategy basically CCTs

The teacher researcher also asked the participants' about whether the conceptual change texts (CCTs) helped them or not. The participants replied differently as stated below.

According to student A, *"I was thinking that non-metals can have an ability to conduct electricity because they have high electronegative values. I did not exactly know that delocalized electrons are responsible for the concept of conductivity. But, after I read the conceptual change text that talk about electronegativity and conductivity, I understand that my previous understanding was misrelated with the current one. The conceptual change text helped me to understand the correct scientific understanding." Student A*

This revealed that the re-designed intervention method helped the student to be in the correct way. The student now correctly understands the basic concept about electronegativity and also electrical conductivity.

The other student also forwarded that:-

"Initially I was thinking that in redox reactions metals loss electrons and that electrons will be gained by another non-metal. However, using the conceptual change text I was reading, I clearly understand that in redox reaction, electrons can be transferred between metals and metals or even metals with non-metals as well as non-metals with non-metals. My previous assumption was wrong and it is now corrected using the conceptual change text I read." Student B

CHAPTER FIVE

5 DISUCUSSION, CONCLUSSION AND RECOMMENDATION

5.1 Summary of the findings

The results of this study are presented in this discussion chapter. Before the beginning of the intervention, students were learning electrochemistry concept using teacher centered instruction where the teacher was telling facts to the students. Moreover, students were not actively engaged in electrochemistry discussions rather they were being silent and some were talking in the classroom.

The pretest result of the students also clearly revealed that there were huge conceptual gaps on the side of students about electrochemistry. Some students were full of misconceptions about concepts of electrochemistry and some others have partial understanding. Most students have no understanding regarding metallic conductivity and redox reactions as their explanations revealed. The mean score of the students at the pretest was 7.925 and also 55% of the students were under no understanding category. Only 5% of them understands electrochemistry concept well. Moreover, the open ended responses revealed that most of the students have misconceptions or no understandings about metallic and electrolytic conductivity, oxidation-reduction reactions and galvanic cells.

The pretest findings are consistent with previous studies that identified electrochemistry as one of the most abstract and difficult topics in chemistry. Sanger & Greenbowe (1997) ; Akram et al. (2014), and (Dorsah & Yaayin, 2019) similarly reported that students experience misconceptions concerning conductivity, oxidation-reduction reactions, electron transfer, and galvanic cells. Therefore, the baseline findings of the present study support earlier evidence that conventional instruction often fails to promote deep conceptual understanding in electrochemistry.

Compared to the pretest, the first cycle posttest result of students showed that there were a significant improvement on students understanding and score about electrochemistry concepts. The mean value for the first cycle posttest was 13.37 and also there were several students who are now under partial or sound understanding category. The percentage of students under no understanding category is decreased to 21.875% after the implementation of the first cycle intervention. Moreover, the number of students who are under sound understanding category in the first cycle is increased to 41.56%.

The questionnaire analysis for the first cycle revealed that students' engagement in the first cycle was moderate/neutral as the total mean value for the questionnaire is 2.882. The second cycle result also showed that the conceptual understanding of the students increased due to the re-designed plans and methodological improvements. In the second cycle, students post-test result was increased to 16.25 and also the number of students who had no understanding was decreased to 6.87% while increasing the number of students' who had sound understanding to 60.31%. Moreover, students were engaged actively in the second cycle as their questionnaire result was increased to 3.35 which are interpreted as high involvement.

5.2 Interpretation of the major Findings of the study

The results of this study on Design-Based Research show that using technology to teach, working in teams and reading texts that help change the way students think about things really helped Grade 10 students understand electrochemistry better. These students were also more engaged and able to correct their mistakes. At first the students had a lot of trouble understanding some of the ideas in electrochemistry like how metals conduct electricity and what happens in oxidation and reduction reactions. They also had a time understanding galvanic cells. This was clear from the test they took at the beginning of the study, where they scored an average of 7.93. A lot of the students did not understand these ideas well and had some wrong ideas about them. This study confirms what other researchers have found, which is that electrochemistry is one of the difficult topics in chemistry to understand. This is because students have to think about what they can see, what is happening at a level and what the symbols mean, all at the same time when they are learning about electrochemistry.

The students did a lot better after the teacher researcher started using technology to teach them. This tells us that using technology to teach really helped the students understand the concepts. The students' average score went up from 7.93 before the test to 13.38 after the test. Also the number of students who really understood the material went up from 13.13 % to 41.56 %. This shows that the animations and videos the teacher researcher used really helped the students see what is going on with processes that we cannot see. The students could see the electrons moving and the ions and everything else happening. They did not just have to look at pictures in a book or listen to someone explain it. The technology really helped the students connect the dots between the picture and the small details of electrochemistry. This is like what Johnstone's triangle talks about. So, this study that using technology to help the students visualize what is going on is really important, for helping them learn about electrochemistry. It makes it a lot less confusing and helps them understand it better.

The results of this study also showed that Team-Pair-Solo cooperative learning really helped students' get more involved and participated in class during the intervention. When students worked in teams they shared ideas with each other, talked about ways to explain things, questioned each other's' thoughts and worked together to figure out tough concepts. When they worked in pair's students refined their ideas and came to an agreement with their partners. Then when they worked alone students showed what they had learned from talking with others. The result of engagement questionnaire about how engaged students were in class showed an improvement. The average score went from 2.88 at the first cycle to 3.36 by the end of the second cycle. This means students were really getting into the learning process. Students also said in group talks that they liked discussing chemistry with their friends and appreciated being able to share and explain their ideas. This shows that learning became more about the students and was more interactive and meaningful, than listening to a teacher lecture.

From a point of view the results really back up Vygotsky's Social Constructivist Theory. Students were able to learn things by talking to each other and working together. The times when they worked in teams and pairs helped them learn by giving them support, which is like a ladder to climb up to the next level. This is called the Zone of Proximal Development or ZPD, for short where their friends and teacher helped them understand things better than they could on their own. When they got to the part where they worked alone they started to get the concepts and could do them by themselves. So the TPS way of learning really helped students learn and then understand things on their own.

These results show that students have a time understanding electrochemistry and just using technology and working together is not enough to fix all the wrong ideas they have. Sometimes students keep thinking things because these ideas are connected to what they experienced before and what seems to make sense to them. The Vygotsky's Social Constructivist Theory and the Zone of Proximal Development or ZPD are important here because they help the teacher researcher understand how students learn and what they need to get the concepts.

For this reason the redesign process in cycle two became really important. After looking at the results of the learning process and tests of cycle one, the teacher researcher made some changes. The teacher researcher added texts to help with conceptual change, arranged students in better groups, made animations videos simpler, asked students' questions to think about and gave more help. These changes helped students understand better. The average score on the test after cycle two was 16.25, which was much higher than 13.38 after cycle one. The second cycle post-test test showed that the improvement was significant with a difference of 2.875 and a very low p-value of less, than 0.001. Also more students, 60.31% showed they really understood the material and also at the time the number of students who did not understand or had wrong ideas dropped to just 6.87%.

These findings show that students changed their way of thinking when they were directly faced with contradictions between what they believed and what science says is true. The conceptual change texts caused students to think about their beliefs and compare them to facts. This made students question what they thought; they knew and try to understand things in a better way. Students did not just listen to the teacher, they looked at their beliefs and compared them to scientific evidence and they talked about the differences with their friends. As a result, students' got an understanding of electrochemistry that is more accurate and in line with science. This result supports the idea that people can only change their misconceptions when they start to doubt what they think they know and consider possibilities. The fact that conceptual change texts worked well in this study shows how important it is to deal with misconceptions.

Design-Based Research is important because it is a process that keeps going forth. It is not like studies that just look at scores before and after a test (McKenney & Reeves, 2021). This study kept making changes to what it was doing based on what was happening in the classroom. The changes from the first to the second cycle show that making changes over and over again is a good way to do educational research. The first round was like a test to see what problems the students were having and what the teachers were struggling with. This information was used to make changes to what was being done. These changes made a difference in the second cycle. So this study shows that if you want to make education better you have to keep looking at what are working and what is not and make changes based on what the students need and what is really happening in the classroom. Design-Based Research is about making things better by trying and trying again. The Design-Based Research process is very helpful in education because it allows for improvement (Juuti, 2006).

5.3 Discussion of the findings with respect to the research questions

The first research question tried to find out how much technology-based teaching helps students understand electrochemistry better. The results showed that students understood electrochemistry better after using technology-based Team-Pair-Solo teaching. Students' average score went up from 7.93 before the test to 13.38 after the test. Also the number of students who really understood the subject increased from 13.13% to 41.56%. This improvement happened because technology-based teaching used animations, simulations, educational videos and visual demonstrations.

These tools helped students see processes that are hard to see. Electrochemistry involves things, like ion migration and electron transfer that are hard to visualize with traditional teaching methods. Technology-based teaching helped students connect the picture, the tiny details and the symbols used in electrochemistry as proposed by Johnstone's Triangle. Students could understand electrochemistry better with the help of technology-based teaching and electrochemistry concepts. The technology-based instruction was helpful for students to learn electrochemistry. This study is consistent in that what Lin and Wu said in 2021 is true. They said that when students learn in environments that use technology they understand chemistry ideas better Lin & Wu (2021). This is similar to what Enchalew et. al found in 2025. They found that when students use labs they understand electrochemistry ideas better. When students learn with technology they are not just sitting there listening. They are actually doing something to learn. They are looking at pictures and videos that help them understand. This means they are making their knowledge instead of just being told things (Enchalew et. al, 2025).

The second research question looked at how Team-Pair-Solo cooperative learning helps students get more engaged and motivated. The results showed that students got more engaged as the intervention went on. When they worked in teams students shared ideas talked about ways to explain things and helped each other solve problems. This probably helped students figure out where they were going wrong and understand the concepts better. When they worked in pairs students got an understanding of things by talking to each other. Finally when they worked alone students could show that they really understood the concepts.

The questionnaire results showed that students were more engaged at the second cycle than at the first cycle. Students also said in focus groups that they liked learning by talking to each other and appreciated being able to share their ideas with friends. These results make sense according to social constructivist theory, which says that people learn by talking to each other and working together to understand things. The results also support what Johnson and Johnson said about social interdependence theory, which is that when people work together and are responsible for themselves they learn more. Team-Pair-Solo cooperative learning is a way to make this happen because students work together in teams then in pairs and finally on their own. This way of learning helps students' engage with Team-Pair-Solo learning and really understands the concepts, through Team-Pair-Solo cooperative learning (Johnson & Johnson, 2009).

Moreover, the findings are further supported by Karaçöp (2016), who reported that cooperative learning significantly improved students' understanding of electrochemical concepts. Likewise, Ifeoma & Drummond (2025) found that cooperative learning promotes engagement, participation, and critical thinking in chemistry classrooms. Supporting this study, Ogunleye (2011)found that students taught using the Team–Pair–Solo (TPS) cooperative learning strategy achieved significantly higher scores than those taught using the conventional teaching method. The TPS group obtained an adjusted mean score of 9.23, whereas the conventional group obtained 7.59. The difference was statistically significant $t(1,168) = 16.45$, $p<0.05$). This result suggests that TPS is more effective than traditional teacher-centered instruction for improving students' understanding of Chemistry concepts. The improvement occurred because students first worked in teams, then in pairs, and finally individually. This gradual scaffolding process allowed learners to receive support from peers before solving problems independently. Through discussion, collaboration, and shared problem-solving, students developed deeper conceptual understanding and improved practical skills.

However, Ogunleye (2011) study contradict with the current study in that the current study found that students have positive attitude towards electrochemistry. Although students in the TPS group showed a slightly higher attitude score (36.13) than those in the conventional group (34.39) in the study of Ogunleye (2011), the difference was not statistically significant ($t(1,168)=1.42$, $p>0.05$). This means that while TPS improved academic achievement, it did not produce a strong enough overall change in students' attitudes toward chemistry. One possible reason is that attitude is often influenced by many factors such as previous learning experiences, teacher behavior, classroom environment, and students' personal interests. However the current study found students have positive attitude towards electrochemistry course as they were engaged in the cycles. Overall, the Team–Pair–Solo strategy was particularly effective because it gradually reduced support, allowing students to move from collaborative learning toward independent understanding. This progression closely aligns with Vygotsky's Zone of Proximal Development.

The third research question looked at how using technology and Team-Pair-Solo method could help students understand electrochemistry better by reducing misconception. The teacher researcher found out that after teacher researcher tried this method again the students had a better understanding of the subject. Some students thought that electrons were the reason things could conduct electricity but they learned that it is not that simple. They found out that there are kinds of conductivity like metallic and electrolytic conductivity. They also learned about oxidation and reduction. They were not confused about it anymore.

The teacher researcher made some changes in the class and that is why the students did so much better. After looking at how the students did the time the teacher researcher added some new things to the class. These things included texts that helped the students understand the concepts better, simpler videos and better ways of grouping the students. The teacher researcher also asked the students questions that made them think and understand.

All of these changes really helped the students. The average score on the test after the second cycle was increased to 16.25, which is a lot higher than the average score of 13.38, after the first cycle. More students had an understanding of electrochemistry with 60.31% of them getting it right. The number of students who did not understand it at all went down to just 6.87%. These results are what we expected based on what other people have found out about how people learn concepts. Electrochemistry and the Team-Pair-Solo method really work well together to help students learn. According to Dorsah & Yaayin (2019), conceptual change strategies help students replace scientifically inaccurate beliefs with scientifically accepted explanations. Likewise, Sukarmin et al (2020) emphasized the importance of confronting misconceptions directly through guided conceptual change activities.

The effectiveness of conceptual change texts in the present study suggests that misconceptions are not easily removed through explanation alone. Students need opportunities to compare their prior beliefs with scientific explanations and actively reconstruct their understanding while discussing in group and reflecting it alone.

5.4 Conclusion

Based on the findings of this study, several important conclusions can be drawn regarding the teaching and learning of electrochemistry within a design-based research (DBR) framework. Overall, the study demonstrates that students' learning difficulties in electrochemistry are not simply a matter of lack of effort or exposure, but are deeply rooted in prior misconceptions and the abstract nature of the subject matter. However, these challenges can be effectively addressed through carefully designed instructional interventions that integrate technology, cooperative learning, and conceptual change strategies.

First, the study established that students initially held significant misconceptions and conceptual difficulties in core electrochemistry topics such as conductivity, oxidation–reduction reactions, and galvanic cells. These misconceptions were persistent and often influenced by everyday experiences and incomplete prior knowledge. Many students were unable to correctly explain electron transfer processes or differentiate between anode and cathode functions in electrochemical cells. This confirms that electrochemistry remains one of the most conceptually challenging areas in chemistry education, particularly when taught using traditional lecture-based approaches that do not sufficiently support visualization or conceptual restructuring.

Second, the findings revealed that technology-mediated instruction played a crucial role in improving students' conceptual understanding. The use of digital simulations, animations, and interactive visualizations enabled students to observe microscopic electrochemical processes that are otherwise invisible in real-life classroom settings. By bridging the gap between the macroscopic and submicroscopic levels of chemical phenomena, technology helped learners construct more accurate mental models of electrochemical reactions. This indicates that when abstract chemistry concepts are supported with appropriate technological tools, students are better able to connect theoretical knowledge with observable phenomena, thereby reducing misunderstanding and enhancing comprehension.

Third, the implementation of the Team–Pair–Solo cooperative learning strategy significantly contributed to students' engagement, participation, confidence, and motivation. In the initial "team" phase, students benefited from collaborative discussion and shared reasoning, which allowed them to confront and correct misconceptions through peer interaction. In the "pair" phase, learners were able to refine their understanding in a more focused and supportive setting. Finally, the “solo” phase provided opportunities for individual accountability and independent thinking. This gradual transition from group support to individual performance helped students build both social and cognitive skills, ultimately strengthening their conceptual understanding of electrochemistry.

Fourth, the integration of technology-mediated instruction with the Team–Pair–Solo cooperative learning strategy produced a more significant improvement in conceptual understanding than either approach alone. The combined intervention not only enhanced comprehension but also effectively reduced persistent misconceptions. Technology provided the necessary cognitive scaffolding through visualization and simulation, while cooperative learning ensured active engagement and meaning-making through discussion and reflection. This synergy suggests that meaningful learning in abstract scientific domains is most effective when multiple instructional approaches are strategically combined rather than implemented in isolation.

Fifth, the iterative redesign process within the DBR approach played a critical role in improving instructional effectiveness. Adjustments such as the development of conceptual change texts, improved grouping arrangements, structured reflective activities, and enhanced visual representations were essential in refining the learning environment. These modifications allowed the intervention to become more responsive to students’ needs across different phases of implementation. In particular, conceptual change texts helped confront students’ prior misconceptions directly, while reflective activities encouraged learners to evaluate and reconstruct their understanding. The continuous refinement of the instructional design highlights the importance of adaptability and responsiveness in improving teaching practices.

Sixth, the study confirms that Design-based research is an effective methodology for investigating complex educational problems and developing practical solutions in authentic classroom settings. DBR enabled systematic identification of instructional challenges, guided the design and implementation of interventions, and supported iterative refinement based on real-time feedback and observed learning outcomes. Unlike traditional experimental approaches, DBR provided flexibility to improve the instructional model throughout the study, ensuring that the final outcomes were both theoretically grounded and practically relevant. This methodological approach therefore proves valuable for addressing persistent learning difficulties in science education, particularly in topics requiring conceptual change.

Finally, the findings of this study suggest that the combined use of technology integration, cooperative learning strategies, and conceptual change-based instruction constitutes a powerful and effective instructional model for teaching abstract chemistry concepts such as electrochemistry. This integrated model supports multiple dimensions of learning, including visualization of abstract processes, social interaction and knowledge construction, and the restructuring of prior misconceptions. As a result, it not only improves academic achievement but also enhances students' motivation, confidence, and engagement in learning chemistry.

In conclusion, this study provides strong evidence that meaningful improvement in students' understanding of electrochemistry can be achieved through thoughtfully designed, multi-component instructional approaches grounded in educational theory and refined through iterative classroom practice. The success of the intervention underscores the importance of moving beyond traditional teaching methods toward more interactive, technology-supported, and learner-centered approaches that actively engage students in constructing scientific knowledge.

5.5 Recommendations

Based on the findings and conclusions of the study, several recommendations are proposed to improve the teaching and learning of electrochemistry. Chemistry teachers are encouraged to integrate animations, simulations, videos, and other visual representations into electrochemistry instruction in order to reduce the level of abstraction and enhance students' conceptual understanding. In addition, teachers should adopt the Team–Pair–Solo cooperative learning strategy to promote peer interaction, active participation, and independent learning, thereby strengthening both collaborative and individual understanding of scientific concepts.

It is also important for teachers to identify students' misconceptions prior to instruction and address them through the use of conceptual change texts, guided discussions, and other targeted instructional approaches that actively challenge and reconstruct incorrect prior knowledge. Furthermore, teachers should make deliberate efforts to connect electrochemistry concepts to real-life applications such as batteries, mobile phones, electric vehicles, and various industrial processes, so that students can recognize the relevance and practical importance of what they learn.

At the school level, administrators are recommended to provide adequate technological resources, including projectors, computers, and reliable internet access, to support effective technology-mediated instruction in science classrooms.

5.6 Future direction for researchers

Future studies should investigate the effectiveness of the Team–Pair–Solo learning strategy in other chemistry topics such as chemical bonding, chemical equilibrium, and organic chemistry in order to determine its broader applicability across different content areas. Researchers are also encouraged to conduct similar Design-Based Research studies in different educational contexts to validate and refine the design principles developed in this study, ensuring that the findings are transferable.

In addition, future research may compare the Team–Pair–Solo strategy with other cooperative learning approaches to determine their relative effectiveness in improving students' conceptual understanding and engagement in chemistry learning. Furthermore, further studies should examine the long-term retention effects of technology-mediated Team–Pair–Solo instruction to assess whether the observed improvements in conceptual understanding are sustained over time and how they influence students' continued learning in chemistry.

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APPENDICES

APPENDIX A: Classroom Observation Checklist

- This observation checklist is grounded based on the basic theories that are aligned with the researcher's study area. The indicators' of this observation checklist are grounded on constructivism learning theory, conceptual change theory, co-operative learning theory (Johnson & Johnson, 2009), engagement theory (Fredricks et al., 2004) and technology integration (Koehler, 2006).

General Information

Purpose: Observation of teachers' classroom instruction.	Date:
Observer: The researcher.	Subject/ Topic:
Observed Teacher Name: Gash Tesfaye	Grade: 10th E
School: Fitawirari Habtemariam Secondary and Preparatory.	Duration: 40 Minutes.

No	Indicators	Yes	Partly	No	Remark
1	Teacher clearly states lesson objectives at the beginning of the lesson.				
2	Lesson content aligns with stated objectives.				
3	Teacher activates students' prior knowledge before introducing new content.				
4	Teacher explains concepts clearly and accurately.				
5	Teacher uses examples relevant to students' context.				
6	Teacher checks for understanding throughout the lesson.				
7	Teacher asks higher-order thinking questions (why/how questions).				
8	Teacher provides opportunities for students to explain ideas in their own words.				
9	Teacher encourages student participation from different learners.				
10	Teacher creates a supportive and respectful classroom environment.				
11	Students actively participate during the lesson.				

APPENDIX B: Observation Checklist during the Implementation of the Intervention

No	Pupils' observed behaviors' by the teacher researcher	1	2	3	4
1	Students' participate actively during team discussions.				
2	Students' remain on-task despite large class size.				
3	Students' follow teacher instructions during team–pair–solo stages.				
4	Students' take important notes from the board and from the word of the teacher.				
5	Students' pay attention during video or projector-based activities.				
6	Students' explain electrochemistry (E.g., Electrical Conductivity) concepts using basic scientific terms such as electron sea model, ions, electrons etc.				
7	Students' ask or respond to questions during discussions.				
8	Students' attempt problem-solving during pair or solo activities in the questions of metallic conductivity and electrolytic conductivity.				
9	Students' apply prior knowledge from chemistry lessons.				
10	Students' show interest (E.g., intrinsic motivation) in electrochemistry lessons during learning through technology mediated instruction like videos.				
11	Students' show confidence when sharing answers.				
12	Students' remain motivated during challenging activities that require integrating macroscopic lesson with the microscopic explanation (E.g., Why Solid NaCl compound does not conduct electricity while the aqueous salt solution does).				
13	Students' show positive reactions toward cooperative learning strategy a team-pair-solo method of instruction.				
14	Students' cooperate effectively in diverse-ability groups (high achiever, medium achiever and low achiever students').				
15	Students' support or scaffold peers who do not understand the concepts well (Such as elaborating how a substance is producing electricity using solid metals but not plastics/woods.)				

APPENDIX C: A pre assessment tests for grade 10 students' learn at Fitawirari Habtemariam Secondary and Preparatory School, Bahir Dar, Ethiopia.

Test Description

This pre-test contains three items; these are: - true/false item, multiple choice item and an extended essay items. The items are prepared in a **multitier fashion** which is best for understanding your conceptual knowledge about an electrochemistry course or subject. Students', you are politely told to response your answers' by explaining the reason why you said that for the true/false multitier item questions and for the extended essay part. While working the multiple choice multitier test, you have to choose your correct alphabet from the alternatives A, B, C and D in front of the provided space. The content of the test includes about Oxidation-Reduction reactions (Redox reactions), Metallic Conductivity, Electrolytic Conductivity, and Electrochemical cells which has two types; a Galvanic (Voltaic) cell and Electrolytic cell. Above all, it is about an Electrochemistry. Dear Students', as much as possible you have to be reasonable for your responses conceptually.

Name________________________________ Grade _______ Sex_______ Age ______

Instruction I:- After reading the statements given below carefully, write True if the statement is correct and False if it is incorrect by giving a precise reasons for each responses on the provided space.

1. **If a Zinc metal is inserted in to a solution of Copper (II) Sulphate, there will not be any transfer of electrons. T/F________ Because___________________________________**
   ____
   ____.
2. **In oxidation- reduction reactions (Redox- reaction), If a metal loses an electron, the electrons will be gained by another metallic element in the solution. T/F________ Because____**
   ____.
3. **Given: Cu(s) + AgSO4 (aq) → CuSO4 (aq) + Ag(s); in the following redox reaction, Copper is reduced and Silver is oxidized. T/F_________ Because___________________**
   ____
   ____________________________________.
4. **Reducing agent is a substance that itself is reduced by increasing the oxidation number of the other substance. T/F_________ Because _________________________________**
   ____
   _____________________________________.
5. **Metallic elements such as Silver (Ag), Copper (Cu), and Aluminum (Al) are good conductors of electricity. T/F__________ Because______________________________**
   ____
   ____.

Instruction II: - Read the following multiple choice questions attentively and choose the best answer from the given alternatives A, B, C and D and also choose the reason in the consecutive question for your response. Moreover you have to choose how much you are confident for your multitier answers.

________6. **Based on the following redox reaction, Zn(s) + CuSO4 (aq) →ZnSO4 (aq) + Cu(s), Copper (Cu) is**

A. Oxidized
B. Reduced
C. Not Known

---------- 6.1 Because the oxidation number of Copper (Cu) is………..

A. **Increased from 0 to 2.**
B. **Increased from 0 to 4.**
C. **Decreased from 2 to 0.**
D. **Decreased from 4 to 0.**

________ 6.2 I am sure for the A. 1st only B. 2nd Only C. Both 1st& 2nd D. Neither

________ 7.What result will be expected when metallic elements have <u>a positive ion in a sea of mobile electrons</u>?

A. **They will be non- conductor of electricity**
B. **They will undergo a non – metallic bond formation**
C. **They will conduct electricity**
D. **They will have low freezing point**

---------- 7.1 this is because metals have

A. **Because electrons are tightly held by metal ions and cannot move freely**
B. **Because positive metal ions move freely through the structure carrying charge**
C. **Because delocalized electrons are free to move throughout the metallic lattice and carry charge**
D. **Because metals contain neutral atoms that convert into ions during conduction**

________ 7.2 I am sure for the A. 1st only B. 2nd Only C. Both 1st&2nd D. Neither

________8. Based on the following redox reaction, $Zn(s) + CuSO4\ (aq) \rightarrow ZnSO4\ (aq) + Cu(s)$, the cathode reaction is ________.

A. **$Zn2+(aq) \rightarrow Zn + 2e$** C. **$Cu(s) \rightarrow Cu2+(aq) + 2e$**
B. **$Zn(s) \rightarrow Zn2+(aq) + 2e$** D. **$Cu2+(aq) + 2e \rightarrow Cu(s)$**

----------- 8.1 **Because cathode reactions are the one that-----**

A. **Shows an increase in oxidation number**
B. **Shows a decrease in oxidation number**
C. **Contains a substance that is oxidized**
D. **Contains a substance that is a reducing agent**

_______ 8.2 **I am sure for the A. 1st only B. 2nd Only C. Both 1st& 2nd D. Neither**

<u>Instruction III</u>: - Read the following questions thoroughly and give clear and precise answers in the blank space provided.

13. What will you do if the battery of your phone is minimum and getting shutdown? What can you say about the process happen inside your phone after you take your measurement?

____
____
____.

14. A driver drives an electric car in the town. At one day, the car suddenly stopped while it was on the way to home and the driver tried to move the car using the accelerator. But the car could not move and go forward. What is the reason behind this and what measurements can the driver take to move the car?

____
____.

APPENDIX D: A Second cycle Post Test for grade 10 Students' learn at Fitawirari Habtemariam Secondary and Preparatory School, Bahir Dar, Ethiopia

Name______________________________ Grade _______ Sex_______ Age ______ Date________________

Instruction I:- After reading the statements given below carefully, write True if the statement is correct and False if it is incorrect by giving a precise reasons for each responses on the provided space.

1. **Metallic elements such as Silver (Ag), Copper (Cu), and Aluminum (Al) are poor conductors of electricity. T/F________ Because____.**
2. **When iron (Fe) is placed in a solution of copper (II) sulfate ($CuSO_4$), electrons are transferred between substances. T/F_________ Because____.**
3. **Reducing agent is a substance that itself is reduced by increasing the oxidation number of the other substance. T/F_________ Because____.**
4. **In redox reactions, electrons are always shared between substances, not transferred.**
   T/F________ Because____.
5. **All homogenous solutions can conduct electricity. T/F_______ Because ____.**

Instruction II: - Read the following multiple choices questions attentively and choose the best answer from the given alternatives A, B, C and D and also choose the reason in the consecutive question for your response with your confidence level.

6. **Secondary cells are best described as:-**
   - **A. Only Galvanic cell**
   - **B. Only Electrolytic cell**
   - **C. Both Galvanic and Electrolytic cells**
   - **D. Neither**

6.1 Because secondary cells can convert__

- **A. Chemical energy to electrical energy spontaneously**
- **B. Chemical energy to electrical energy non- spontaneously**
- **C. Electrical energy to chemical energy spontaneously**
- **D. Electrical energy to chemical energy non- spontaneously**

6.2 I am sure the answer for ___ question. A. 1st only B. 2nd Only C. Both 1st& 2nd D. Neither

7. Why do metals conduct electricity? Due to___

- **A. High electronegativity**
- **B. Delocalized electrons**
- **C. Covalent bond they have**
- **D. Low density**

7.1 Because in metals

- **A. Electrons are fixed in position**
- **B. Positive ions move freely**
- **C. Electrons move freely in the lattice**
- **D. Atoms share electrons equally**

7.2 I am sure the answer for ___ question. A. 1st only B. 2nd Only C. Both 1st& 2nd D. Neither

8. Which one of the following solution does not conduct electricity?

- **A. Salt Solution** **C. Acids**
- **B. Sugar Solution** **D. Bases**

8.1 Because It___

- **A. Has mobile electrons** **C. Has not mobile ions**
- **B. Has delocalized electrons** **D. Has mobile ions**

8.2 I am sure the answer for ___ question. A. 1st only B. 2nd Only C. Both 1st& 2nd D. Neither

<u>Instruction III</u>: - Read the following questions thoroughly and give clear and precise answers in the blank space provided.

9. A driver drives an <u>electric car</u> in the town. At one day, the car suddenly stopped while it was on the way to home and the driver tried to move the car using the accelerator. But the car could not move and go forward. What is the reason behind this and what measurements can the driver take to move the car?____

____

____

____

____

____.

10. What is the primary thing for oxidation and reduction reaction to take place?

____

____.

APPENDIX E: Fitawirari Habtemariam Secondary and Preparatory School Lesson Plan Format

Teacher Researcher: Mulugeta G. Grade: 10^{th} E Subject: Chemistry Unit 4: Energy Changes & Electrochemistry Subtopic: 4.2 Electrochemistry Lesson: Electrical Conductivity Duration: 40 Minutes Date: 17/07/2018 E.C	Lesson Objective:- At the end of this lesson, students will able to:- ✓ Explain how metallic substances conduct electricity. ✓ Describe how electrolytic conductivity conduct electricity. ✓ Distinguish metallic conductivity with that of electrolytic. ✓ Give real life applications of metallic conductivity.

Content	Pre-requisite	Teacher Activity	Students' Activity	Methodology	Teaching Aid	Assessment
4.2.2 Electrical Condu ctivity	Ions Elements Molecule s Compou nds	<u>Introduction</u>: - Preparing students' for work. Introducing previous lesson about energy changes. Motivate students.	Take some short notes about the todays' lesson regarding electrochemistry from the black board.	This lesson uses a Co-operative learning strategy that has three stages Team- Pair- and Solo stage.	Blackboard Chalk Text Book And the main	The Assessment strategy of this lesson is included
A) Metallic Conducti Vity and	Electrons	<u>Main activity</u>: - Monitoring students while working in team, pair and solo stages. Providing technology mediated	Participate in group discussion actively. Share ideas when arranged in pair. Work attentively alone about	It uses Group Discussion	Teaching aid in this lesson is technology. It is used for Purpose of teaching videos	Under task design paper which contains activities in the Team- Pair- and

		instruction so that students can work together and inquiry it. Give guidance for students.	different metallic and electrolytic activities based on the knowledge they got from the team and pair discussion and Ask questions.			
B) Electro Lytic Conductivit y	Ions Energy change	<u>Conclusion</u>:- Briefly summarize the todays' topic using the technology as an instruction aid for video providing. Stabilize students' todays' lesson. Collecting students work. Summarizing my todays' observation checklist.	Scaffold each other while doing metallic and electrolytic conductivity questions in team and pair stage. Watch the projected videos attentively and raise conceptual questions about metallic and electrolytic conductivity. Do activities well by referring the videos projected on.	It uses Pair Discussion and Solo inquiry approach. The teacher will be Facilitator and Provide Discussion questions using videos.	About metallic and electrolytic conductivity so that students' observe it.	Solo stage.

APPENDIX F: The researcher used a lot of tasks that was aimed to be done in each stage Team-Pair-Solo both in the first and second cycle. As a sample the following team stage activity is presented.

Task Design on Metallic and Electrolytic Conductivity

(On page 178 of the text book)

Lesson Objective: - At the end of this task students will be able to: ✓ Understand the difference between metallic and electrolytic conductivity ✓ Grasp the concept of why metals conduct electricity ✓ Conceptualize how electrolytes conduct electricity

First Stage: Team Discussion Activity (15 Minutes)

Prerequisite Knowledge Questions

- From your grade 9 chemistry course, you learnt about the periodic classification of elements' on unit four. From that, can you list the elements found on 'S' and 'D' block categories. S- Block: ________, _________, __________.
  D- Block: _________, ________, __________.
- What are the general names for 'S' block elements such as group 1 and group 2 and also 'D' block elements.

Periodic Elements	also called
Group 1 Elements	
Group 2 Elements	
D Block Elements	

Now from your prerequisite knowledge which conducts electricity? Metals or Non Metals? Why?

____

____.

If so, what does Electricity mean?

____

____.

Main Activity Questions

Here students' you are politely asked to write your understanding about **metallic and electrolytic conductivity** in the tabulated form. Dear students' after watching the **video** carefully, fill the following table regarding metallic conductivity and electrolytic conductivity with your explanations in your discussion.

Given Substance	Does the substance conduct electricity? (Yes/No)	What moves? Electrons or ions.	Explain your answer?
Copper Wire			
Salt Solution			
Solid NaCl			
Sugar Solution			

<u>Real life Question</u>: - There are electric wires in your home, village, in different institutions and even on standing woods and concretes found on street roads. **Why are these electric wires made of COPPER (Cu)** but not salt solution though salt solution can conduct electricity?

APPENDIX G: Sample CCT for the second cycle

First Stage: Team Discussion Activity (15 Minutes)

Dear students' you will be grouped in to team based on your first semester chemistry course result and you will do the following team stage task. Please read the instruction and give more time on discussion before you are going to write the answers.

Instruction: - Read the following Conceptual Change Text (CCT) carefully and watch the video projected to you about metallic and electrolytic conductivity finally discuss the questions passionately.

Conceptual Change Text about Electrical Conductivity

"Many students' think that metals have low electronegativity or weak attraction as a result metals are poor conductors of electricity. Besides they believe that non- metals can conduct electricity because they have high electronegativity. However, the true understanding is not as they though and as they are thinking. Metals conduct electricity better than non-metals through their free-moving delocalized electrons.

The concept of electronegativity is related with the measure of how strongly an atom attracts electrons toward itself. This means higher electronegativity results the atom to pull the electrons towards it more strongly whereas low electronegativity results the atom not to pull towards itself more strongly. In another word, low electronegativity means the atom can loss its electrons freely.

The concept of electronegativity only matters in chemical bond not in metallic conduction or ionic flow. Therefore, it does not mean that Iodine can conduct electricity better than other metallic elements because it is the most electronegative element. It cannot conduct electricity at all because it does not want to give its electrons freely. Dear students', metallic conductivity and electrolytic conductivity depends on free charge carriers, not how strongly an atom pulls electrons towards itself."

Main Activity Questions

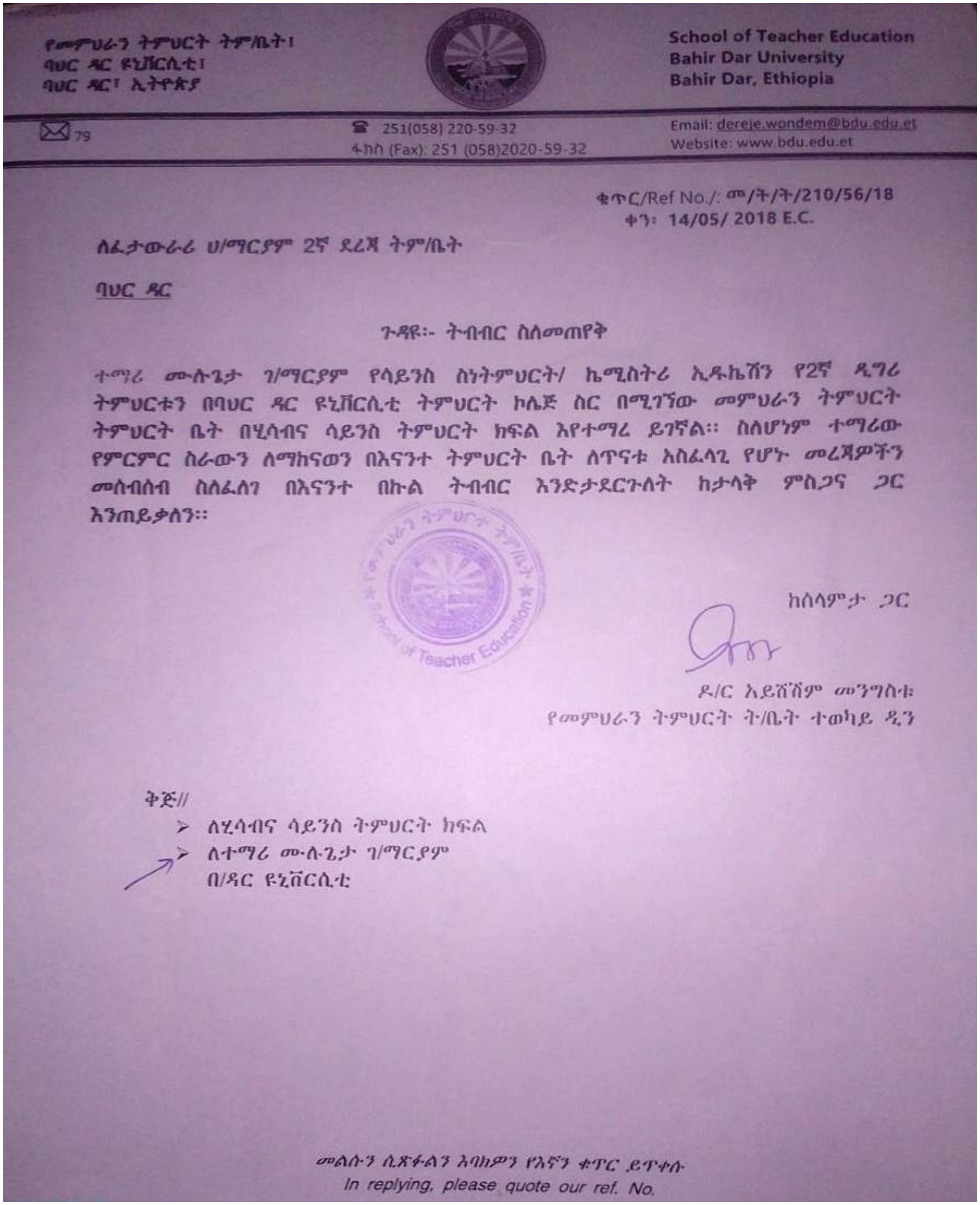
Students' please attempt the following group activity questions based on the conceptual change text you studied in team and based on the video you are watching. Do not forget to participate in the discussion actively.

1. Why electronegativity is not the evidence for the presence of metallic and electrolytic conductivity?______________________________
____
____
____
____
_________________________________.
2. Why elements that have higher electronegativity such as non- metals are generally poor conductors of electricity?
____
____
____
____
_______________________________________.
3. If you are told to connect a battery to a salt solution and to a copper metal or aluminum metal wire, what differences will occur at each stage? Can you explain it?__________________
____
____
____
_____________________________________.

APPENDIX H: Student Engagement Questionnaire

1	I actively participated in team discussions when learning oxidation–reduction reactions	1	2	3	4	5
2	I completed the pair tasks on galvanic cells as instructed by my teacher.	1	2	3	4	5
3	I stayed focused during solo activities related to conductivity.	1	2	3	4	5
4	I contributed ideas when my group discussed metallic conductivity.	1	2	3	4	5
5	I asked questions or sought clarification during TPS activities in electrochemistry lessons.	1	2	3	4	5
6	I put effort into solving electrochemistry problems during team, pair, and solo work.	1	2	3	4	5
7	Working in teams helped me understand oxidation and reduction processes more deeply.	1	2	3	4	5
8	Pair discussions helped me connect theory and practice in galvanic cells.	1	2	3	4	5
9	Solo problem-solving activities helped me think critically about Metallic and Electrolytic conductivity.	1	2	3	4	5
10	TPS activities encouraged me to explain electrochemistry concepts using my own words.	1	2	3	4	5
11	Learning metallic conductivity through TPS helped me correct my misunderstandings.	1	2	3	4	5
12	Technology-based instruction helped me understand electrochemistry concepts more clearly	1	2	3	4	5
13	I enjoyed learning oxidation–reduction reactions using the Team–Pair–Solo method.	1	2	3	4	5
14	I felt confident when solving electrochemistry tasks individually after team and pair work.	1	2	3	4	5
15	The texts made me think deeply about my understanding of electrochemistry concepts.	1	2	3	4	5
16	The conflict between my ideas and the text helped me learn better	1	2	3	4	5
17	I changed my understanding after reading the conceptual change texts.	1	2	3	4	5
18	Working in groups helped me understand the conceptual change texts better.	1	2	3	4	5
19	Individual work helped me reflect on my own understanding using CCTs	1	2	3	4	5

APPENDIX I: Consent Letter



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ቀን፡ 14/05/ 2018 E.C.

ለፈታውራሪ ሀ/ማርያም 2ኛ ደረጃ ትም/ቤት

ባህር ዳር

ጉዳዩ፡- ትብብር ስለመጠየቅ

ተማሪ ሙሉጌታ ገ/ማርያም የሳይንስ ስነትምህርት/ ኬሚስትሪ ኢዱኬሽን የ2ኛ ዲግሪ ትምህርቱን በባህር ዳር ዩኒቨርሲቲ ትምህርት ኮሌጅ ስር በሚገኘው መምህራን ትምህርት ትምህርት ቤት በሂሳብና ሳይንስ ትምህርት ክፍል እየተማረ ይገኛል፡፡ ስለሆነም ተማሪው የምርምር ስራውን ለማከናወን በእናንተ ትምህርት ቤት ለጥናቱ አስፈላጊ የሆኑ መረጃዎችን መሰብሰብ ስለፈለገ በእናንተ በኩል ትብብር እንድታደርጉለት ከታላቅ ምስጋና ጋር እንጠይቃለን፡፡

የመምህራን ትምህርት ትም/ቤት School of Teacher Education

ከሰላምታ ጋር

ዶ/ር አይሸሽም መንግስቱ
የመምህራን ትምህርት ት/ቤት ተወካይ ዲን

ቅጅ//
- ለሂሳብና ሳይንስ ትምህርት ክፍል
- ለተማሪ ሙሉጌታ ገ/ማርያም
  በ/ዳር ዩኒቨርሲቲ

መልሱን ሲጽፉልን እባክዎን የእኛን ቁጥር ይጥቀሱ
In replying, please quote our ref. No.