Effect of conceptual transformation on electrochemistry performance of high-performing high school learners in South Africa

Kwaku Darko Amponsah[1], Millicent Narh-Kert[2], Phyllis Bernice Kwarteng Donkor[2], Priscilla Commey-Mintah[2]

Abstract

In the Ximhungwe circuit of the Bohlabela district in the South African province of Mpumalanga, learners studying physical sciences participated in wider research to establish the influence of a constructivist approach to learning on learners' understanding of electrochemistry principles. The study examined how learners in high achieving schools (HAS) responded to the conceptual change teaching strategy (CCTS), also known as collaboration on their understanding of electrochemistry principles. The investigation implemented a non-equivalent pre-test and post-test control group quasi-experimental research design. The sociocultural theory, commonly referred to as Vygotsky's theory of social constructivism, served as the foundation for the study's theoretical framework. Using a table of random numbers, a sample of 51 physical sciences students in the 12th grade from two top-performing public schools in the circuit was chosen at random to take part in the study. Both a pre- and post-test were provided to the learners: the ECT (Electrochemistry Concept Test) and the CCEQ (Chemistry Classroom Environment Questionnaire). Students taught using the CCTS significantly outperformed students taught using the traditional teaching method (TTM) in terms of learning scientific conceptions related to electrochemistry, according to one-way between group analysis of covariance (ANCOVA) and post hoc analysis with a Bonferroni adjustment performed on ECT. A substantial correlation between performance and students' perceptions of their chemistry classroom setting was also found using Pearson Product-Moment Correlation. The study offers statistical proof of the value of social interaction and meaningful learning in raising students' grasp of electrochemistry.

Keywords Conceptual change teaching strategy; conventional teaching method; collaboration; electrochemistry; high achieving schools

Introduction

Learners experience conceptual change (CC) when they go from a false belief to a widely held belief in their studies (Nadelson, *et al.,* 2018). In addition, many professionals agree that substantial cognitive participation is necessary for encouraging conceptual change (Heddy, *et al.,* 2018). To address these, researchers have proposed so many strategies to be used in the classroom situation, such as learner centred teaching strategies. Learners instead of the educator are the focus of interest when using learner-centred teaching practices. These methods include active learning, when students collaborate in groups to address problems, offer explanations for questions, formulate new questions, and discuss, explain, debate, or conceptualise throughout class (Brent, *et al.,* 2021). Other approaches used by teachers in their classrooms include enquiry-based learning (IBL) that is a method that is

[1]Kwaku Darko Amponsah is in the Department of Teacher Education, University of Ghana, Legon, Accra, Ghana, and the Department of Science and Technology Education, University of South Africa, Pretoria, South Africa. *Email: kdamponsah@ug.edu.gh.

[2,3&4]Millicent Narh-Kert, Phyllis Bernice Kwarteng Donkor, and Priscilla Commey-Mintah are all in the Department of Teacher Education, University of Ghana, Legon, Accra, Ghana.

 DOI: https://dx.doi.org/10.4314/ajesms.v19i1.3

centred on the needs of the learners, propelled by their natural interest and inquiries (Mohammed, *et al.,* 2020; Mohammed & Amponsah, 2021a; Mohammed & Amponsah, 2021b), collaboration (Amponsah, *et al.,* 2021; Amponsah, 2020; Amponsah & Ochonogor, 2018; Amponsah, *et al.,* 2018), reciprocal teaching/learning (Gomaa, 2015), problem-based learning (PBL) (Aidoo, *et al.,* 2016), and cooperative learning (Kibirige & Lehong, 2016). So, while studying how science information is developed, it is essential to consider the social environment in which it is developed and approved (Chakravartty, 2022). Science entails the development of ideas and explanations for phenomena that have been observed, and any proposed explanation is subject to criticism (Hepburn, & Andersen, 2021). What is scientific only changes because of debates and disputes to design, technique, analysis, and results (Lamers, *et al.,* 2021). Sadly, opportunities like this are infrequently presented in science classes even though scientists have created social networks that allow their membership to check claims and challenge supporting data and hypotheses (Lamers, *et al.,* 2021). All throughout the world, science educators have similar worries.

Given the foregoing, it is now generally acknowledged that learners who express their past knowledge and explain their understanding to one another can more effectively learn science. As a result, conception changes because of this method. Hence, according to Nadelson et al., (2018), conceptual change is explored by putting a focus on the discourse exchanges and social creation of knowledge in the classroom. Additionally, scientists have created social networks that allow their membership to check claims and challenge supporting data and hypotheses (Chi, 2008; Kang, 2010). They contend that conceptual transformation is a slow and complex process, with students' deliberate learning practices serving as mediators for the incremental revision of their initial conceptual frameworks (Sinatra, *et al.,* 2015; Sinatra & Pintrich, 2003).

According to Vosniadou (2008), conceptual change necessitates meta-conceptual awareness, and students can only learn science principles and concepts if they are aware of what they already know and if their early attitudes toward science have changed. So, it's crucial to design learning settings that allow learners to realise the internal explanatory frameworks and ideas they already hold. Examining conceptual transformation that considers not just individual cognitive growth, but also social and collective elements is becoming more and more important. Naturally, socio-cognitive dialogue is important in promoting conceptual transformation and improving problem-solving abilities.

Such a change in communication can be facilitated by assigning learners a difficult problem to solve. Peer collaboration, often known as collaboration, offers students the chance to hone their developing science communication abilities. It is possible to compare this situation to the scientific world, which demands that its members convey their thoughts in well-defined manners. For example, scientists place a great priority on the requirement that claims made by its membership be supported by proof. As a result, in a collaborative group in a scientific classroom, the group works out its comprehension and establishes its guidelines or standards for conduct and ideas, or what the group believes to be acceptable (Le, et al., 2018). Students' personal conceptions are combined through their collaborative efforts, and the conversation that results may help everyone understand the concepts at hand. For group members, this gives a chance for conceptual growth and/or transformation. The conceptual comprehensions that each group member leaves the experience with may differ from the level of conceptual understanding that they had before, and this shift is at least in part a result of the interpersonal communication that occurs within the group. Hence, learning refers to the act of comprehending and adopting conceptions because it considers them to be understandable and rational, in accordance with the conceptual change theory (Posner, et al., 1982). Conceptual shift is the idea that students bring a variety of prior experiences and ideas to any new learning experience and generate explanations that make sense to them but may not be compatible with what the teacher intended or survive rigorous scientific investigation. Learners' mental conceptions about science may be immature, hasty, or even erroneous (Nadelson, et al., 2018). This means that teaching students new scientific concepts would be conceptual change education (Nadelson, et al., 2018). This would require helping learners to clear up their misconceptions, help them to transform their vague ideas into usable, integrated comprehensions, and help them to create thinking skills that they could use in a wide range of settings (Suping, 2003). According to Posner et al. (1982), a learner will only experience conceptual change if an event occurs for which his or her current grasp offers an inadequate or insufficient explanation. Differences will unavoidably arise when group members communicate their various interpretations of the issue they are facing. This inconsistency may present the type of destabilising circumstance that results in the displeasure outlined by Posner et al. (1982). After that members of the group negotiate to settle these disagreements.

One of the most challenging chemistry topics, according to a study on misunderstandings and challenges (Bojczuk, 1982), is electrochemistry. In fact, due to the large number of confusing and abstract concepts it uses, as well as the apparent lack of coherence and logic in how it is represented, one of the most difficult subspecialties in chemistry, according to a large body of literature, is electrochemistry (Schmidt et al., 2007; Amponsah, et al., 2021; Amponsah, 2020; Amponsah & Ochonogor, 2018; Amponsah, et al., 2018). Understanding electrochemistry principles requires a grasp of chemical equilibrium. Consequently, it follows that learners will have trouble comprehending chemical equilibrium principles if they have trouble with electrochemistry. A study was carried out in South Africa, is particularly noteworthy because it revealed that while many students can answer qualitative questions on electrochemistry that need a higher conceptual understanding, very few can (Amponsah & Ochonogor, 2018; Ogude & Bradley 1994). It appears that one of the factors contributing to difficulties is the traditional approach to teaching. Many of their faculty members believe that traditional teaching approaches are no longer as successful at the tertiary level, according to Hanson and Wolfskill (1998). They also think that more and more pupils are finding it challenging to use concepts to solve problems.

Theoretical Framework

Conceptual change, understood as the real knowledge that the group collectively develops and agrees upon, is the central idea of this work. Posner et al.'s (1982) conceptual change theory serves as the theoretical foundation for this investigation and provides compelling evidence that learning is a social activity and that communication aids in learning. The cognitive model of conceptual change put out by Posner et al. (1982) explains how people alter their pre-existing conceptual frameworks to make room for new knowledge. They contend that conceptual change happens because of learners intentionally rearranging their prior knowledge and beliefs to make room for new material.

Posner et al. 's model is divided into three phases:

1. Preconceptions: During this stage, students have pre-existing ideas or mental representations that direct

their analysis of a certain concept. These assumptions could be erroneous, partial, or founded on scanty information.

2. Accommodation: During this stage, students are exposed to fresh knowledge or experiences that contradict their preconceived notions. As a result, there may be a cognitive conflict or disequilibrium that motivates students to reconcile the discrepancies between their pre-existing ideas and the new facts.
3. Restructuring: During this stage, students actively rearrange their mental models to make room for the fresh data. To achieve a more precise and thorough grasp of the notion, they may need to modify or dismiss their current views or combine them with the new information.

According to Posner et al., conceptual transformation is a dynamic process that involves the interaction of learners' prior knowledge, new information, and the cognitive operations necessary for reorganising their mental models. This perspective has had a big impact on educational research and practice, especially when it comes to creating instructional methods (Amponsah & Ochonogor, 2018) and curricular plans (Okrah & Amponsah, 2020) that encourage conceptual change.

This conceptual change theory has an impact on the development of an active social participation in the classroom, much like the process workshop. The ability to restructure one's knowledge and intellectual capability is made possible by an effective learning environment that encourages learners' inventiveness, interest, and creation of high order thinking abilities. The learner actively and deliberately pursues learning as a natural occurrence on an individual basis. After being introduced to the learning experience, the student has a tendency to look for and build meaningful, reliable models of knowledge stored in both short- and long-term memory. Social constructivism is a sociological theory of knowledge that extends constructivism's overarching philosophy to social contexts, according to Vygotsky (1962, 1978). In sociology and education, social constructivism holds that knowledge and reality are socially constructed. Social constructivism holds that people actively construct their worldview through their experiences and interactions with others. Social constructivism holds that knowledge is co-constructed by people with different viewpoints and experiences. Knowledge is contextual and moulded by culture, history, and society. In education, social constructivism has promoted collaborative, inquiry-based learning environments that stress social interaction and knowledge co-construction. Since social norms and values shape individual and group identities, it has been used to evaluate and critique social institutions and power structures. Furthermore, Mercer (2002) underlines the need for science teachers to comprehend the significance of constructivism, particularly considering the debate that takes place. According to Treagust and Duit (2008), conceptual shift acknowledges the value of communication. Yet, Scott (1998) argues that for pupils to learn science concepts, teachers must talk about commonplace ideas and scientific perspectives. The socially mediated learning theory put forth by Vygotsky in 1978 supports discursive teaching.

According to Vygotsky, social circumstances help people understand and learn new things. After hearing descriptions from the outside, pupils turn these words inside, changing or transforming their prior understanding. According to Kew and Tasir (2021) and Delfino (2019), students' cognitive engagement is increased when they participate actively in social settings where they argue, discuss, or criticize one another's ideas. In a similar vein, Mcleod

(2023) asserted that learning occurs when a person interacts with a competent person. This indicates that educators can be extremely important for students' conceptual growth and meaning formation (Amponsah & Ochonogor, 2018). Students can learn topics by utilising dialogue to explore scientific ideas with their teachers. Teacher speech that is lengthy and elaborate aids students in changing their conceptual orientation. From a social constructivist perspective, classroom discourse gives students the chance to evaluate the truth of their arguments and create meaning that is more complex (Amponsah, et al., 2021). Conversation within a group creates the possibility for an idea clash. Discussion between students and between students and teachers is crucial in a science classroom. Students can learn about the scientific community's tools and culture through discussion (Amponsah, 2020). Consequently, conversation offers a setting for students to participate communally in an important learning process.

Statement of the Problem

When the National Senior Certificate (NSC) was implemented in 2009, South African high school learners have struggled with electrochemistry, which served as the study's focus (Department of Education, Mpumalanga Province, DEMP, 2015). This has been linked to conceptual challenges learners reported because of how knowledge is learned in the classroom and challenges, they encounter when attempting to solve problems. By identifying the challenges students encounter and potential solutions to overcome those challenges, researchers have made several attempts to support students' learning. Due to the abstract nature of chemistry concepts, research on chemistry education has found that pupils usually have difficulty understanding them (Amponsah & Ochonogor, 2018; Ogude & Bradley 1994). Fundamentally, in a classroom, educators talk, and learners listen; prolonged, in-depth discussion is uncommon. When educators in South African science classrooms practically fight to finish a curriculum that is overburdened, they do not permit any prolonged classroom discussion. In most rural schools, practical investigation and hands-on experiences are essentially non-existent. The same educator or many educators who are regarded as specialists in a few of the intricate physical science fields, like electrochemistry, must repeatedly teach the same material to students. Despite this, most students score poorly, making it challenging to achieve 30% or more on the NSC exams.

Hypotheses

The following two null hypotheses (Ho) were developed for the study:

i. in the high-achieving schools (HAS), there is no statistically significant difference in the mean post-test and pre-test scores between students who learned electrochemistry topics through the conceptual change teaching strategy (CCTS) and those who learned them through the traditional teaching method (TTM).

ii. high achieving physical science students' electrochemistry topic comprehension and their post-test mean scores on their perception of their chemistry classroom environment do not statistically correlate.

Methods

Because it was difficult to randomly assign students to a particular class session and because this approach was acceptable for the topic, the research used a quasi-experimental study design. Convenience sampling was implemented consequently (Creswell & Creswell, 2018). Despite the fact that the two schools were chosen at random, no student was put into a certain group at random. 51 learners from two of the best schools in the Ximhungwe circuit who were majoring in the physical sciences made up the study's sample. A table of random numbers was used to choose these two high schools at random from the top five high schools in the circuit. A baseline class of 23 learners was the comparison group and was taught according to the same curriculum using the traditional teaching approach, which is known as classroom instruction. 28 students made up the experimental class, which used the collaboration teaching method as specified in the lesson plan. The schools were also chosen based on how well they did on the NSC exams. This is done to guarantee that the study's conclusions were exclusively based on the variations in the techniques of instruction.

The experimental group (collaborative group) received teaching using a conceptual change teaching strategy in contrast to the control group, which was instructed using the traditional classroom methodology for each electrochemistry topic. Comparing their pre-intervention cognitive evaluation to their post-intervention cognitive test allowed researchers to identify changes in their level of knowledge. The diagnostic tests administered both before and after the intervention were utilized to analyse the changes in achievement.

Instrumentation

In the primary investigation, two instruments were employed to gather data, viz Chemistry Classroom Environment Questionnaire (CCEQ) and the Electrochemistry Concept Test (ECT). A portion of the ECT was created by the researchers, while other portions were modified by four seasoned physical science educators and experts after comparison with other sources of literature. On a five-point Likert-type scale, values were assigned to the 40 items on the CCEQ. Each of the five subscales or dimensions on the CCEQ included eight items. Based on the framework created by Treagust, a two-tiered, ten-question test was created for the ECT (1988). Each set of questions had two tiers, with the first tier focused on procedural knowledge and the second tier based on conceptual knowledge, with the first tier requiring the respondent to give a justification for their selection. When evaluating students' work, this sort of inquiry may be able to discern between procedural knowledge and conceptual knowledge (Treagust, 1988). In most situations, pupils only receive first-tier scores on most of the electrochemistry questions in the grade 12 National Senior Certificate (NSC) exams. The CCEQ was taken from the literature, but because this study was conducted in a rural area, only five of the seven scales were relevant.

Method of Data Collection

The control group was one of the two schools used in the research, and the experimental group (EG) was the other. The EG was taught through group activities, whilst the former was taught through the usual methods a classroom instructor is used to. The ECT and CCEQ were administered as a pre-test in the second week of August 2015, prior to the start of classes in the third week of August 2015. After treatment, during the third week of August 2015, the post-test was given. For the post-test of the ECT, an electrochemistry concept test was administered using pencil and paper. The researcher educated two physical science teachers in preparation for the investigation. According to the physical sciences course syllabus for grade 12, instructors should spend eight hours, divided into two weeks of four hours each, teaching electrochemistry. The educators spent three hours per week—or one and a half hours every class period—during the four weeks of treatment. The control group was taught by one of the educators, while the experimental group was taught by the other. In the Ximhungwe and Agincourt circuits for the academic years 2011, 2012, and 2013, respectively, the Department of Education judged that these educators, who have 10 years of teaching experience in physical sciences as the best.

The teacher for the collaborative group was taught by the researcher the strategies he needs to use to implement collaboration in the classroom. This he implemented on ten students for a class of twenty students. The other ten used the traditional method for two weeks as pilot test. This was to ensure that the process was incident free, valid, and reliable. Collaboration in the classroom was implemented as activity of the conceptual change teaching strategy in a variety of ways as it is a crucial component of learning. These are the methods used to encourage teamwork in the classroom during the pilot and research process.:

1. The facilitator offered group assignments that need students to collaborate to complete a task or address an issue. This enabled the students to communicate, assign assignments, and share ideas to accomplish a common objective.
2. The group members were urged to provide comments to their peers. They gain knowledge of effective feedback-giving and -receiving techniques as a result.
3. Collaborative conversations were introduced: The facilitator led class discussions in by inviting students to contribute their opinions. They learned from one another and strengthened their critical thinking skills as a result.
4. The facilitator assigned pair work, which called for the learners to collaborate on a project or activity. This taught the learners how to interact with one another and cooperate to finish a task.
5. The facilitator organised group brainstorming sessions to inspire students to generate innovative ideas collectively. This taught students how to work together and expand on one another's ideas.
6. The facilitator used collaborative learning exercises: These are exercises that require students to cooperate to finish a task or resolve a problem. Students gained collaborative abilities and learned efficient collaboration techniques as a result.

In doing the above, it was critical to keep in mind that collaboration in the classroom demands a defined set of rules and standards. Thus, the facilitator provided guidelines for how students should effectively collaborate, share ideas, and communicate. It helped the facilitator to foster a collaborative learning atmosphere that aids in the academic success of the learners by putting these methods into practice.

Lev Vygotsky, a Russian psychologist, coined the term "More Knowledgeable Other," or MKO. Although Vygotsky did not use the term "MKO" directly, the idea has been expanded in light of his views on social development and the importance of language and interaction in learning. The more knowledgeable other (MKO) is a learner who is more experienced or knowledgeable than the other learners in a collaborative classroom ((Wertsch, 1991; Rogoff, 1990; Tharp & Gallimore,1988; Vygotsky, 1978; Wood, Bruner, & Ross, 1976). The MKO's job is to support, direct, and give feedback to the students to facilitate their learning process. The following are some methods in which the MKO can aid learning in a group setting:

1. Model successful learning behaviour patterns: The MKO served as a good example of how to ask questions, explore ideas, and get feedback. This promoted a good learning environment and aided in the learners' development of a deeper grasp of how to approach learning tasks.
2. Feedback: The MKO provided the students comments on their work,

assisting them in identifying their strong points and places for development. Any criticism was specific and useful, and it was both constructive and favourable.

3. Provide direction: The MKO provided direction to students as they worked on assignments, assisting them in understanding the task's requirements and helping when necessary. This advice was given according to the needs of the students and in a way that promotes autonomous thought and problem-solving.
4. Encouraged learners to share their thoughts, pose questions, and build on one another's thinking by facilitating discussions with the MKO. This promoted a sense of community in the classroom and aided students in developing their communication and teamwork abilities.
5. Offer scaffolding: The MKO did this by dividing up more difficult activities into smaller, more manageable steps. This aided students in developing their subject-matter confidence and expertise as they progressively move toward more difficult tasks.

In a collaborative classroom, the MKO's overall responsibility is to promote learners' growth and development by offering advice, criticism, and encouragement. The MKO can contribute to the development of a constructive and effective learning environment that fosters the academic and personal development of the learners by collaborating with the students.

There could be a variety of roles or responsibilities available in a collaborative class that students might fill to support and improve the collaborative learning process. In view of this, the facilitator formed collaborative groups made up of four members. Each member was given a task to perform to enhance the work of the group. The facilitator oversees directing the conversation and ensuring that everyone stays on topic. They can encourage involvement from all participants and ensure that everyone gets the chance to voice their opinions. These are the four key roles adopted by the facilitator to enhance and generate learning.

1. Note-taker: This individual oversaw recording the conversation's points of discussion and summarising them. They served as a record of the group's work and guarantee that crucial ideas were not lost or forgotten.
2. The group was made to stay on schedule by having a timekeeper who would keep track of the passing minutes. They assisted in making sure that everyone had an opportunity to speak and that the conversation doesn't go on.
3. Researcher/leader: This person supervises doing the necessary investigation and information collecting on the subject under discussion. They can contribute to the group's general grasp of the subject by giving the group additional views and perspectives.
4. Presenter: This individual oversees outlining the group's thoughts and conclusions for the remainder of the class. These can aid in showcasing the group's work and give the group a chance to impart their wisdom and thoughts to others.

These roles are not all-inclusive and may change based on the nature of the partnership and the project's objectives. To decide which roles are suitable for each member of the group, communication and cooperation are essential.

Results and Discussion

To test the first null hypothesis that there is no statistically significant difference in the mean post-test and pre-test scores between high-achieving school (HAS) students taught electrochemistry topics through conceptual change teaching strategy and those taught through the traditional teaching technique, a one-way analysis of covariance test was conducted. It was possible to determine how the two different teaching methods affected the post-test HAS students' scores.

Before the ANCOVA was performed, it was assumed that all groups of the independent variable, teaching technique in HAS, had a linear relationship between the pre-test and the post-test. The mean post-test and pre-test scores of the experimental and control groups are represented in the scatterplot shown in Figure 1.

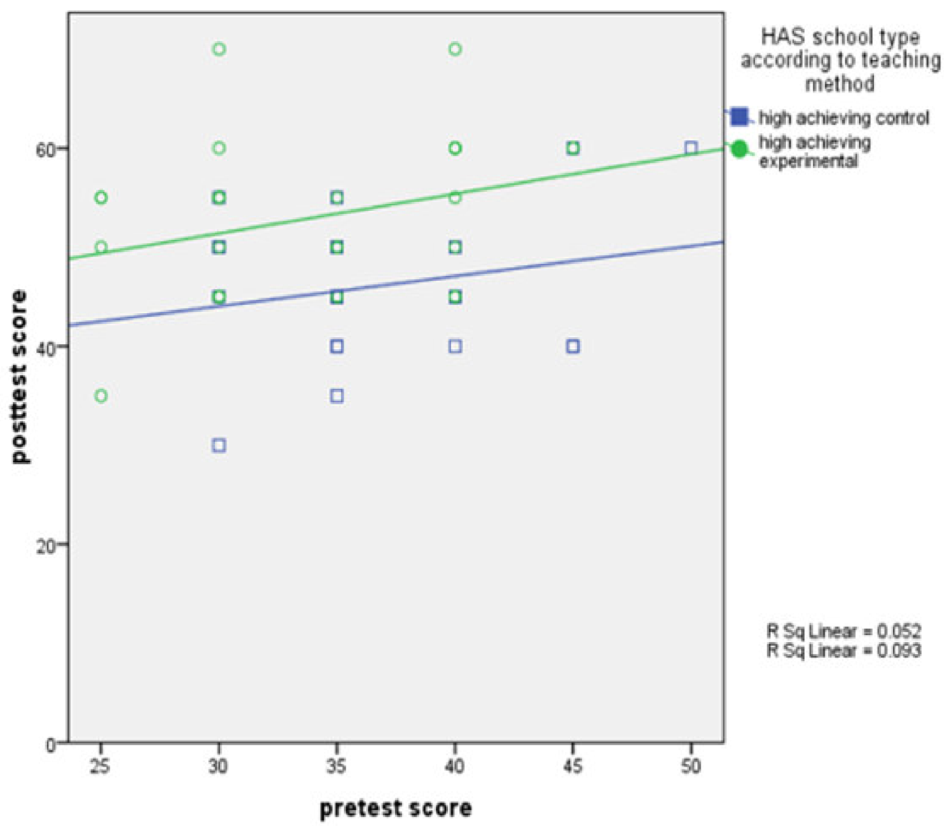

Figure 1 Post-test results plotted versus pre-test results by teaching style for HAS

The pre-test and post-test scores for each type of HAS intervention show a linear relationship, which can be seen visually by examining the scatterplot in Figure 1. Also, it was anticipated that the HAS teaching technique and the pre-test wouldn't interact. This was quantitatively assessed by determining the statistical significance of the teaching method*pre-test interaction term. A general linear model univariate analysis was carried out to achieve this. The outcome showed that the slopes of the regression were homogeneous because $F(1,47) = .066$, $p = .799$ indicated that the interaction term was not statistically significant. After running the Explore process, it was discovered that the post-test results for both the HAS control and HAS experimental groups were normally distributed, according to the results of the Shapiro-Wilk test ($p > .05$). Levene's test of homogeneity of variance revealed that there was homogeneity of variance as well ($p = .825$). This discovery is consistent with the outcomes produced by Amponsah & Ochonogor, 2018; Amponsah, et al., 2018.

Table 1 ANCOVA's Summary Report on Understanding for the HAS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Pre-test scores	219.208	1	219.208	3.903	.054	.075
Teaching method used in HAS	748.881	1	748.881	13.335	.001	.217
Total	130525.000	51				

a. R Squared = .235 (Adjusted R Squared = .203)

Table 1 displays the ANCOVA analysis's findings. Table 1 shows that the post-test scores for the HAS control and HAS experimental groups differ statistically significantly ($F(1,48) = 13.335$, $p = .001$, partial $\eta^2 = .217$. The association between the manner of instruction and students' understanding of electrochemistry principles was highly significant (Chittleborough & Treagust, 2007; Cooper, et al., 2010; Galloway & Bretz, 2014; Kibirige & Maoko, 2014; Yang & Staver, 2002).

These studies indicated that using various teaching strategies, such as visual illustrations, interactive exercises, and student-centred techniques, improved students' comprehension of electrochemistry principles. These findings collectively imply that teaching strategies can significantly influence how well students learn and comprehend electrochemistry. There were few and weakly supported research studies that revealed a negative or no correlation between the manner of education and students' grasp of electrochemistry principles. When the pre-test is considered as a covariate, instruction technique explains 21.7% of the variation of the dependent variable. The experimental HAS group had the highest post-test scores, which were statistically substantially higher than the post-test scores of the control group ($p = .001$) when post hoc analysis with a Bonferroni adjustment was carried out. In Table 2, the outcomes are displayed. This is line with some studies in literature (Amponsah & Ochonogor, 2018; Amponsah, et al., 2018).

When it came to understanding of electrochemistry concepts in the high

Table 2: Comparing HAS experimental and control groups using the pairwise method

Teaching method		Mean Difference	Std. Error	Sig.
TTM	CCTS	-7.899*	2.163	.001
CCTS	TTM	7.899*	2.163	.001

CCTS → conceptual change teaching strategy; TTM → Traditional Teaching Method achieving schools, the post-test mean scores of students taught using TTM and those taught using the CCTS differed significantly, as shown by the ANCOVA results shown in Table 1. To confirm this, the analyse and compare means approach was conducted. The post-test means and standard deviations for the experimental and control groups are shown in Table 3. The experimental group's mean ECT post-test score (53.04±7.97) was higher than the mean post-test ECT score for the control group (46.06±7.38), as shown by the results in the table. Various research has highlighted the fact that students who go through the collaborative teaching perform better than those who are taught using the traditional teaching method (Amponsah, et al., 2021; Amponsah, 2020; Lamers, et al., 2021; Kibirige, & Lehong, 2016).

Table 3: Mean and Standard deviation for HAS

Teaching Method	Mean	Standard deviation	N
TTM with HAS (Control)	46.06	7.379	23
CCCT with HAS (Experimental)	49.55	7.974	28
Total		8.883	51

CCTS → conceptual change teaching strategy; TTM → Traditional Teaching Method

The findings imply that following the intervention, the students who had been taught using CCTS had a greater comprehension of electrochemistry principles. The experimental group outperformed the control group generally, but there were a few items where they performed worse than the control group despite having a higher overall mean score.

Ho2: high achieving physical sciences students' post-test mean scores on how they felt about the chemistry classroom atmosphere and how well they understood electrochemistry principles did not show any statistically significant correlation. Table 4 displays the findings of the analysis.

Product-Moment Pearson with regard to learners' opinions of their chemistry classroom environment, correlation was employed to examine correlation between CCEQ and ECT post-test mean scores. According to the findings, there is a substantial correlation between student evaluations of their chemistry classroom environment and achievement ($p < 0.05$). This implies that improving student achievement on the ECT is correlated with improving student impressions of their chemistry classroom. There have been several studies on the beneficial connection between students' academic success and their learning environment (Ruzek, et al., 2016; Wang & Eccles, 2013). It is important to note that there have also been studies that have identified a negative association between student achievement and the classroom environment (Hanushek, et al., 2004; Konstantopoulos, & Chung, 2011), even though a substantial body of data suggests a good relationship between the two. It's important to note, nevertheless, that the preponderance of data points to a favourable correlation between the learning environment in the classroom and learner performance. While many research points to a connection between a supportive classroom atmosphere and student progress, several studies

Table 4 Correlation between CCEQ and ECT Scores of HAS Students

Variable	N	Correlation Coefficient	p-values
CCEQ	90	0.4	0.0001
ECT	90		

CCEQ → Chemistry Classroom Environment Questionnaire
ECT → Electrochemistry Concept Test

have found no conclusive evidence of this association (Anastasiou & Kauffman, 2013; Reyes, et al., 2012; Kim, 2015). These studies, including those that found no conclusive link between these variables, give several angles, and approaches for examining the connection between the learning environment and student accomplishment. It's important to note, nevertheless, that most data points to a favourable correlation between the learning environment in the classroom and student performance.

Conclusion

Compared to the traditional style of instruction, the constructivist approach of instruction adopted in this study led to a higher degree of knowledge of electrochemistry topics. Gain scores in the experimental group outperformed those in the control group by a large margin. The outcomes of the ANCOVA analysis highlight the variations in ECT performance between the experimental and control groups. In contrast to the control group, which provided answers that were less thorough and lacked some essential elements of scientific explanations, students in the experimental class gave better organized and precise answers to the fill-in questions, demonstrating that they had a higher level of scientific comprehension. As a result, this study has shown that teaching strategies that include collaboration and conceptual change in texts improve students' understanding of electrochemistry topics and of Chemistry in general. As a result, there must be certain elements of teamwork that contributed to these variations in these groups' performance. The findings of this study provide some empirical support for the hypothesis that regular classroom instruction has given students the support they need to produce thorough, factual explanations of chemical phenomena, but they also show that many students experienced conceptual difficulties in this learning area. About a difficult area of chemistry, this needs to be addressed in the process of teaching and learning in the classroom. The results also imply that the lecture, talk, chalk, or telling teaching methods that characterize the normal classroom are ineffective for enhancing students' conceptual knowledge. The conceptual knowledge that students in the experimental group had at the end of the session can therefore be compared to that of students in the control group in order to determine the effectiveness of the collaboration. The findings also showed that, in favour of the experimental group, there was a positive significant link between achievement and the classroom environment, which included student cohesion, teacher support, student involvement, student cooperation without competitiveness, and equity. This shows that students perform better on the ECT if their perception of their chemistry class is higher. In conclusion, some components of the partnership along with texts that address conceptual transformation may have accomplished specific teaching and learning goals.

Recommendations

In South African classrooms, the suggested teaching method from this study has a bright future as a tool to improve students' conceptual understanding of electrochemistry concepts for higher accomplishment, claims the paper. Thus, it is proposed that the chemistry teacher try to identify key ideas in the chemistry curriculum and acquire the necessary knowledge and applicability of relevant teaching approaches, such as collaboration on a global scale. As a result, the teacher will become even more effective and efficient.

Acknowledgment

The Institute of Science and Technology Education (ISTE), College of Graduate Studies, University of South Africa, and grant number 00108/54003/74241/00000 from UNISA STUDENT FUNDING made it possible to complete the work detailed here and to prepare this publication.

References

Aidoo, B., Boateng, S. K., Kissi, P. S., Ofori, I. (2016). Effect of problem-based learning on students' achievement in chemistry. Journal of Education and Practice, 7(33), 103-108.

Amponsah, K. D., Boateng, F. K., & Mohammed, S. M. (2021). Pre-service science teachers' conceptual understandings of electrochemistry at the University of Ghana. African Journal of Chemical Education (AJCE) 11(2), 129-147.

Amponsah, K. D. (2020). South African twelfth grade students' conceptions regarding electrochemistry. Journal of Education and Learning (EduLearn), 14(3), 363-369.

Amponsah, K. D., Kotoka, J. K., Beccles, C., & Dlamini, S. N. (2018). Effectiveness of Collaboration on Low and High Achieving School Students' Comprehension of Electrochemistry in South Africa. European Journal of STEM Education, 3(2), 1-15. https://doi.org/10.20897/ejsteme/2685

Amponsah, K. D. & Ochonogor, C. E. (2018). Facilitating Conceptual Change in Students' Comprehension of Electrochemistry Concepts through Collaborative Teaching Strategy. American Journal of Educational Research, 6(6): 596-601. doi: 10.12691/education-6-6-3.

Brent, R., Prince, M. J., & Felder, R. M., (2021). Promoting and Managing Student-Student Interactions in Online STEM Classes: Approaches and Recommendations. International Journal of Engineering Education, 37(3), 797-813.

Chakravartty, A. (2022) Scientific Knowledge vs. knowledge of science. Sci & Educ. https://doi.org/10.1007/s11191-022-00376-6

Chi, M. T. H. (2008). Three types of conceptual change: belief revision, mental model transformation, and categorical shift. In S. Vosniadou (Ed.), Handbook of research on conceptual change (pp. 61-82). Hillsdale, NJ: Erlbaum.

Chittleborough, G., & Treagust, D. F. (2007). The role of submicroscopic and symbolic representations in chemical explanations. International Journal of Science Education, 29(11), 1353-1374.

Cooper, M. M., Grove, N. P., Underwood, S. M., & Klymkowsky, M. W. (2010). Lost in abstraction: Pitfalls of learning and teaching chemistry. International Journal of Science Education, 32(8), 1061-1083.

Delfino, A. P. (2019). Student Engagement and Academic Performance of Students of Partido State University. Asian Journal of University Education, 15, 42-55. https://files.eric.ed.gov/fulltext/EJ1222588.pdf

DEMP (2015). Feedback on the 2014 NSC examination and resource material in physical sciences. Mpumalanga Province: Mpumalanga Department of Education.

Duit, R., and Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. International Journal of Science Education, 25(6), 671-688.

Galloway, K. R., & Bretz, S. L. (2014). Investigating the relationship between general chemistry students' understanding of structure–property relationships and student-centred instruction. Journal of Chemical Education, 91(5), 676-683.

Gomaa, O. M. K. (2015). The effect of reciprocal teaching intervention strategy on reading comprehension skills of 5th grade elementary school students with reading disabilities. International Journal of Psycho-Educational Sciences, 4(2), 39-45.

Hanushek, E. A., Kain, J. F., & Rivkin, S. G. (2004). Why public schools lose teachers? Journal of Human Resources, 39(2), 326-354.

Heddy, B. C., Taasoobshirazi, G., Chancey, J. B., & Danielson, R. W. (2018). Developing and validating a conceptual change cognitive engagement instrument. Front. Educ. 3, 43. doi: 10.3389/feduc.2018.00043

Hepburn, B. & Andersen, H. (2021). "Scientific Method", The Stanford Encyclopedia of Philosophy (Summer 2021 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/sum2021/entries/scientific-method/>.

Kang, H., Scharmann, L. C., Kang, S., & Noh, T. (2010). Cognitive conflict and situational interest as factors influencing conceptual change. International Journal of Environmental & Science Education, 5(4), 383-405.

Kew, S. N. & Tasir, Z. (2021). Analysing students' cognitive engagement in e-learning discussion forums through content analysis. Knowledge Management & E-Learning, 13(1), 38-57. https://files.eric.ed.gov/fulltext/EJ1294748.pdf

Kibirige, I. & Maoko N. (2014). Getting it from the horse's mouth: a case of dialogic teaching in high school. Journal of Educational Studies, 13(2) 193-215.

Kibirige, I. & Lehong, M. J. (2016). The effect of cooperative learning on grade 12 learners' performance in projectile motions, South Africa. Eurasia Journal of Mathematics, Science & Technology Education, 12(9), 2543-2556. doi: 10.12973/eurasia.2016.1250a

Konstantopoulos, S., & Chung, V. (2011). Teacher effects on minority and disadvantaged students' achievement in elementary schools. Elementary School Journal, 112(3), 471-490.

Lamers, W. S., Boyack, K., Larivière, V., Sugimoto, C. R., van Eck, N. J., Waltman, L., Murray D. (2021). Investigating disagreement in the scientific literature. Elife. 2021 Dec 24;10:e72737. doi: 10.7554/eLife.72737. PMID: 34951588; PMCID: PMC8709576.

Le, H., Janssen, J., & Wubbels, T. (2018). Collaborative learning practices: teacher and student perceived obstacles to effective student collaboration. Cambridge Journal of Education, 48(1), 103-122, DOI: 10.1080/0305764X.2016.1259389

Mcleod, S. (2023). Vygotsky's zone of proximal development and scaffolding. https://simplypsychology.org/Zone-of-Proximal-Development.html

Mercer, N. (2002). Words and minds: how we use language to think together. Routledge.

Mohammed, S. M., Amponsah, K. D., Ampadu, E., & Kumassah, E. K. (2020). Extent of implementation of inquiry-based science teaching and learning in Ghanaian junior high schools. EURASIA Journal of Mathematics, Science and Technology

Education, 16(12), 1-15. Available: https://doi.org/10.29333/ejmste/9373

Mohammed, S. M. & Amponsah, K. D. (2021a). Junior high school teachers' attitudes toward inquiry-based science teaching: enabling or disabling dispositions? Journal of Education and Training Studies, 9(7), 41-54.

Mohammed, S. M., Amponsah, K. D. (2021b). Teachers' and educational administrators' conceptions of inquiry: do they promote or constrain inquiry-based science teaching in junior high schools? Journal of Curriculum and Teaching 10(3), 58-71Niaz, M. (2002). Facilitating conceptual change in students' understanding of electrochemistry. International Journal of Science Education, 24(4), 425,439.

Nadelson, L. S., Heddy, B. C., Jones, S., Taasoobshirazi, G. & Johnson, M. (2018). Conceptual Change in Science Teaching and Learning: Introducing the Dynamic Model of Conceptual Change. International Journal of Educational Psychology, 7(2), 151-195. doi:10.17583/ijep.2018.3349

Ogude, A. N., and Bradley, J. D. (1994). Ionic conduction and electrical neutrality in operating electrochemical cells. Journal of Chemical Education, 71, 29-34.

Okrah, A. K. & Amponsah, K. D. (2020). Science related senior high school curriculum in Ghana and its relevance to the world of work. Social Science learning Education Journal 5(5), 142-156.

Posner, G. J., Strike, K. A., Hewson, P. W., and Gertzog, W. A. (1982). Accommodation of a scientific conception: toward a theory of conceptual change. Science Education, 66(2), 211-227.

Rogoff, B. (1990). Apprenticeship in thinking: cognitive development in social context. Oxford University Press.

Ruzek, E. A., Hafen, C. A., Allen, J. P., Gregory, A., Mikami, A. Y., & Pianta, R. C. (2016). How teacher emotional support motivates students: The mediating roles of perceived peer relatedness, autonomy support, and competence. Learning and Instruction, 42, 95- 103.

Scott, P. (1998). Teacher talk and meaning making in science classrooms: A Vygotskian analysis and review. Studies in Science Education, 32(1), 45–80. doi:10.1080/03057269808560127

Sinatra, G. M. & Pintrich, P. R. (Eds.). (2003). Intentional conceptual change. Lawrence Erlbaum Associates.

Sinatra, G. M. (2005). The "warming trend" in conceptual change research: the legacy of Paul R. Pintrich. Educ. Psychol. 40, 107–115.doi: 10.1207/s15326985ep4002_5

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. Educ. Psychol. 50, 1–13.doi: 10.1080/00461520.2014.1002924

Suping, S. M. (2003). Conceptual change among students in science. Web document, retrieved 20th September, 2015 from www.eric.ed.gov on.

Tharp, R. G., & Gallimore, R. (1988). Rousing minds to life: Teaching, learning, and schooling in social context. Cambridge University Press.

Treagust, D. F., and Duit, R. (2008). Conceptual change: A discussion of theoretical, methodological and practical challenges for science education. Cultural Studies of Science Education, 3(2), 297-328.

Vosniadou, S. (2008). International handbook of research on conceptual change. Routledge.

Vygotsky, L. (1962). Thought and language. MIT Press.

Vygotsky, L. S. (1978). Mind and society: The development of higher mental processes. Harvard University Press.

Wang, M. T., & Eccles, J. S. (2013). School context, achievement motivation, and academic engagement: a longitudinal study of school engagement using a multidimensional perspective. Learning and Instruction, 28, 12-23.

Wertsch, J. V. (1991). Voices of the mind: a sociocultural approach to mediated action. Cambridge, MA: Harvard University Press.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. Journal of Child Psychology and Psychiatry, 17(2), 89-100.

Yang, X., & Staver, J. R. (2002). The association between the method of instruction and students' understanding of electrochemistry principles. Journal of Chemical Education, 79(6), 752-756.