
The Eurasia Proceedings of Educational & Social Sciences (EPESS), 2016

Volume 4, Pages 220-231

ICEMST 2016: International Conference on Education in Mathematics, Science & Technology

IMPACT OF A CONSTRUCTIVIST APPROACH TO LEARNING ON HIGH ACHIEVING STUDENTS' COMPREHENSION OF ELECTROCHEMISTRY CONCEPTS

Kwaku Darko AMPONSAH

Institute for Science and Technology Education (ISTE), University of South Africa

Chukunoye Enunuwe OCHONOGOR

Institute for Science and Technology Education (ISTE), University of South Africa

ABSTRACT: This paper is part of a larger study to investigate 'The impact of a constructivist approach to learning on physical sciences students' comprehension of electrochemistry concepts' in the Ximhungwe circuit of the Bohlabela district in the Mpumalanga province of South Africa. The study explored the impact of using a constructivist type of teaching intervention – collaboration combined with conceptual change texts, otherwise called conceptual change teaching strategy (CCTS) on students in high achieving schools (HAS) in their comprehension of electrochemistry concepts. The study utilized non-equivalent pretest and posttest control group quasi-experimental research design. The theoretical framework for this study was based on Vygotsky's social constructivism theory, which he defines as a sociological theory of knowledge that applies the general philosophy of constructivism into social settings. A sample of 51 12th grade physical sciences students from two high achieving public schools in the circuit was randomly selected using a table of random numbers to participate in the study. Students were given electrochemistry concept test (ECT) Chemistry Classroom Environment Questionnaire (CCEQ) as pretest and posttest. One-way between group analysis of covariance (ANCOVA) and post hoc analysis with a Bonferroni adjustment conducted on ECT showed that students taught with the CCTS had significantly better acquisition of scientific conceptions related to electrochemistry than students taught with the traditional teaching method (TTM). Pearson Product-Moment Correlation also revealed that there was significant relationship between achievement and students' perception of their chemistry classroom environment. The study provides statistical evidence on the importance of meaningful learning combined with social process to improve students' understanding of electrochemistry.

Key words: Collaboration, electrochemistry, high achieving schools, social constructivism, traditional teaching method

INTRODUCTION

When considering the construction of science knowledge it is important to consider the social context within which that knowledge is constructed and accepted (Kittleson & Southerland, 2004). Science involves construction of theories and explanations for observed events, and all proposed explanations are open to challenges. What comes to be acceptable as science evolves only after conflicts and challenges to design, methodologies, analyses, and conclusions have occurred. Scientific communities have established social mechanisms for validating claims and providing opportunities for its members to question evidence and explanations; unfortunately, opportunities like these rarely occur in science classrooms (Vellom, Anderson & Palinscar, 1993). This is a common concern shared by science educators all over the world.

In view of the above, it is now widely accepted that science learning can be facilitated when students articulate their prior ideas and explain their comprehension to each other. This approach consequently brings about change in conception. Accordingly, Scott, Asoko and Leach, (2007) opined that conceptual change is examined by emphasizing the social construction of knowledge and discursive interactions in the classroom. Furthermore, researchers of late question conceptual change as a sudden change or replacement of misconceptions with scientific ones through externally-driven conceptual conflict (Chan, Burtis & Bereiter, 1997). According to them,

- This is an Open Access article distributed under the terms of the Creative Commons Attribution-Noncommercial 4.0 Unported License, permitting all non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

- Selection and peer-review under responsibility of the Organizing Committee of the conference

*Corresponding author: Kwaku Darko AMPONSAH-icemstoffice@gmail.com

conceptual change involves a gradual and complex process – the gradual revision of students’ initial conceptual structures being mediated by students’ intentional learning strategies (Sinatra & Pintrich, 2003).

Current research on intentional conceptual change emphasizes the role of students’ metacognitive strategies, epistemic beliefs and agency in knowledge restructuring (Sinatra & Pintrich, 2003). It also points to the need to designing learning environments that encourage students to employ goal-directed, reflective strategies and to develop meta-conceptual awareness. Researchers have argued that conceptual change involves not only changes in concepts; there needs to be changes in students’ epistemic cognition and views about the nature of science (Duit & Treagust, 2003). Cognitive research has shown that students’ epistemic beliefs can constrain or facilitate their thinking, reasoning, and science learning. For example, Stathopoulou & Vosniadou (2007) examined the relationship between chemistry-related epistemic beliefs and chemistry conceptual comprehension among 10th grade students; Conley, Pintrich, Vekiri and Harrison (2004) also attempted to investigate the changes in 5th grade students’ epistemic beliefs in science, and findings indicated that students became more sophisticated in their beliefs about source and certainty of knowledge.

Vosniadou (2008) noted that conceptual change involves meta-conceptual awareness where students will be able to learn science concepts and principles only if they are aware of their prior comprehension and the shift of their initial views toward scientific explanations. Therefore, it is necessary to design learning environments that enable students to become aware of their existing internal explanatory frameworks and beliefs. Increasingly the emphasis is to examine conceptual change that includes not only individual cognitive development but also social and collective aspects. Understandably, socio-cognitive discourse plays a key role in facilitating conceptual change as well as enhancing problem solving skills.

Having students work together to solve a challenging problem can facilitate such a communication shift. Peer collaboration, otherwise called collaboration provides students with opportunities to practice their emerging science communication skills. This is a situation that is reflective of the scientific community, which requires its members to communicate their ideas in much defined ways. For instance, scientists place a great emphasis on the importance of evidence in backing up claims made by its members. So, a collaborative group in a science classroom negotiates its conceptual comprehensions and establishes its cultural norms—that is, what the group considers valid science knowledge (Kelly & Green, 1998).

Through their collaboration efforts, students’ individual concepts are pooled and the discourse that ensues may lead to a mutual comprehension of the concepts involved. This represents an opportunity for conceptual development and/or change for group members. The conceptual comprehensions each member of the group takes away from the experience is potentially different from the comprehension level the member entered the experience with, and this change is at least partly due to the social interaction that occurs within the group. Thus conceptual change theory describes learning as coming to comprehend and accept ideas because they are seen as intelligible and rational (Posner, Strike, Hewson & Gertzog, 1982). Conceptual change refers to the idea that students come to any new learning experience with a host of prior experiences and beliefs for which they have constructed explanations that work for them, but may or may not be congruent with what the teacher intended and may not stand up to rigorous scientific analysis. The conceptual constructs students hold or develop in the classroom may be naïve, premature, or actually incorrect in relation to accepted science (Duit, 2003). This implies that teaching for conceptual change would mean engaging students in developing new comprehensions of science phenomena (Dykstra, 2005). This would involve helping students to correct their misconceptions; facilitate the reorganization of their naïve concepts into useable, integrated comprehensions; and develop intellectual tools useful to them in a variety of contexts (Suping, 2003). Science education, as part of the cultural institution of school, is charged with transmission of the scientific knowledge created by scientists and deemed important by society and is therefore the agent for conceptual change (Kelly & Green, 1998). Also, conceptual change can be thought of as a “journey toward literacy within a domain” (Alexander, 1998, p. 56) and a collaborative group is a potent source for generating this change. Posner et al (1982), contend that conceptual change will only occur if a learner encounters an event for which his or her existing comprehension provides an unsatisfactory or incomplete explanation. As members of a collaborating group express their differing renditions of the problem they are confronting, discrepancies will inevitably result. This discrepancy may provide the kind of disequilibrating event that provokes the dissatisfaction described by Posner et al (1982). What follows among the group members is a negotiation of these discrepancies.

The importance of the role played by existing concepts, including erroneous concepts, has been identified in constructivist and generative learning theories (Osborne and Wittrock 1983, Wittrock 1974). Of further importance is the recognition of social influences on the construction of students’ understanding of science that have been thoughtfully explicated by Solomon (1987). Many studies of students’ understandings of science are based on constructivist learning theories and the notion that existing concepts influence learning outcomes because learners link new information with prior knowledge. Novak (2002) stated that group learning facilitates meaningful learning and new knowledge construction. This study used the collaboration approach, a type of

group learning that is expected to facilitate and encourage meaningful learning. Collaboration approach is a student-centered method of teaching. It allows students to work independently in performing the activities, then working in small groups to discuss answers to questions, exercises and problems. Group outputs are reported in class by followed deliberation of correct answers to questions, exercises and problems. The teacher is a facilitator to ensure that students stay on task. If meaningful learning will be achieved, then correct knowledge structuring will be enhanced; as a result, misconceptions will be minimised if not entirely eliminated.

The study of misconceptions and difficulties in chemistry (Bojczuk, 1982) ranked electrochemistry as one of the most difficult topics in chemistry. In fact, numerous literature have widely reported electrochemistry as being one of the most difficult topics in chemistry because it contains many ambiguous and abstract terms and has an apparent lack of consistency and logic in its representation (Sanger & Greenbowe, 1997a & 1997b; Ozmen, 2004; Ozkaya et al., 2006; Schmidt et al., 2007).

Chemical equilibrium is a prerequisite knowledge in understanding concepts in electrochemistry. Naturally if students find electrochemistry difficult, then it is imperative that students also experience difficulty in understanding concepts in chemical equilibrium. Several studies have reported misconceptions about electrochemistry (Garnett & Treagust, 1992a, 1992b; Ogude & Bradley, 1994; Sanger & Greenbowe, 1997a, 1997b). Of particular note is a research study conducted in South Africa by Ogude and Bradley (1994) which indicated that many students can solve quantitative electrochemical problems in examinations, few are able to answer qualitative questions requiring a deeper conceptual knowledge of electrochemistry. Traditional method of instruction appears to be one of the causes that foster difficulty. Hanson and Wolfskill (1998) relate that many of their faculty perceive that traditional teaching methods have become less effective at the tertiary level. They also believe that more and more students have difficulty in applying concepts when solving problems.

Theoretical Framework

The underlying concept of this study is conceptual change interpreted as what actual knowledge the group collectively produces and agrees upon. The theoretical frame work of this study is rooted in Posner et al's Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change. The conceptual change theory of Posner et al (1982), strongly proves that learning is a social process and communication facilitates learning. This conceptual change theory influenced the emergence of an active social interaction in the classroom like the process workshop. Cognitive level and knowledge restructuring of individual is facilitated by an appropriate instructional setting enhancing learners' curiosity, creativity and development of high-order thinking skills that are characteristics of a meaningful learning. Learning is a natural process pursued personally by the learner in an active meaningful way. The learner tends to seek and create meaningful, coherent representations of knowledge stored in his/her short- and long-term memory, once exposed to the learning process.

Vygotsky (1962, 1978) defined social constructivism as a sociological theory of knowledge that applies the general philosophy of constructivism into social settings. He indicated that social constructivism has three components: (a) knowledge and knowing originate in social interaction; (b) learning proceeds from the interpsychological plane (between individuals) to the intrapsychological (within an individual) plane with the assistance of knowledgeable members of the culture; and (c) language mediates experience, transforming mental processes. Additionally, Mercer (2002) emphasizes that science teachers should understand the importance of constructivism especially in terms of the discourse that happens. Treagust and Duit (2008) maintain that conceptual change recognizes the importance of dialogue. However, Scott (1998) has posited that teachers' talk focused on everyday concepts and scientific perspectives is critical to helping students learn science concepts. Discursive teaching is supported by Vygotsky's (1978) view of socially mediated learning.

Vygotsky has indicated that social contexts facilitate meaning and learning. When students first hear outward descriptions, they then turn these words inward, thus leading to modifications or transformations of their knowledge base. Guthrie and Wigfield (2000) indicated that cognitive engagement is enhanced when students are actively involved in social spaces where they discuss, debate, or critique each other's idea. Similarly, Wells (2000) has stated that an individual learns by interacting with a competent person. This means that lecturing can play a critical role in students' meaning making and conceptual development (Scott, 1998). A teacher's encouragement for exploration of scientific ideas through discourse can help students understand concepts. Extended and elaborate teacher discourse helps students to shift their conceptual understanding. From a social-constructivist position, classroom discourse provides opportunities for students to test the validity of their ideas and develop meaning of higher complexity (Aufschnaiter & Aufschnaiter, 2007). Discourse within a group provides potential for a clash of ideas. Student-to-student and student-to-teacher discourse is important in a science classroom. Discourse provides students with the tools and culture of the scientific community (Vosniadou, 2008). Thus, discourse provides a platform for students to be socially engaged in a meaningful learning process.

Statement of the Problem

The problem that formed the focus of this study is that high school students in South Africa have been performing poorly in electrochemistry since 2009, when the National Senior Certificate (NSC) was introduced (Department of Education Mpumalanga Province (DEMP), 2015). This has been attributed to conceptual difficulties experienced by students as a result of the way knowledge is acquired in the classroom as well as problem solving difficulties they experience. Research in chemistry education has shown that students often have difficulty in understanding chemistry concepts due to their abstract nature and many attempts have been made by researchers to assist students' learning by identifying the difficulties experienced by students and possible solutions to overcome such problems (Sanger & Greenbowe, 1997a and 1997b; Niaz, 2002; Ozmen, 2004; Ozkaya et al., 2006). Essentially, teachers talk and students listen, and lengthy, on-subject discourse in classrooms is a rare event. This appears to be the norm in the South African science classroom since teachers have to virtually struggle to complete overloaded curriculum and therefore do not tolerate any lengthy classroom discourse. Practical investigation with hands-on experiences is virtually nonexistent in most rural schools. Students have to be taught the same topic over and over again with the same teacher or different teachers who are presumed to be experts in some of the challenging areas in the physical sciences and electrochemistry is no exception. In spite of this, majority of the learners perform poorly to the extent that it becomes so difficult to get 30% and above in the NSC examinations.

Purpose of the Study

Based on the problems highlighted, the study designed a conceptual change teaching strategy, specifically collaboration combined with conceptual change texts to enhance students' comprehension of electrochemistry. It was also to investigate the changes in science conceptual comprehension that takes place when students have the opportunity to collaborate on solutions to extended science problems assigned by the classroom teacher. The study focused on the outcome of students' discourse during collaboration because it is the way students make their conceptual comprehension apparent, and it is the primary tool the students use to negotiate their conceptual comprehensions when faced with other students' potentially different comprehensions. This study analyzed the collaborative discourse as a teaching strategy in order to understand the group process and its effects on conceptual comprehension and thereby possibly enhance students' comprehension and improve performance by using both experimental and control groups.

Hypotheses

Two null hypotheses (Ho) were formulated for the study as follows: that

1. There is no significant mean difference between posttest and pretest mean scores of students taught electrochemistry concepts with conceptual change teaching strategy and students taught with traditional teaching method in the high achieving schools (HAS).
2. There is no significant relationship between high achieving physical sciences students' posttest mean scores on their perception of their chemistry classroom environment and their achievement in electrochemistry concepts.

Significance

First this study illuminated the sources of students' misconception, miscomprehension and difficulties of electrochemistry. It promoted comprehensive discourse in the problem areas among students in order to generate positive cognitive conflicts that enhanced conceptual comprehension, conceptual change, problem solving capabilities and resultant improvement of students' performance. Secondly, the study unearthed and documented practices and situations in both the control and the experimental groups, which might give some insight into the factors contributing to the low performance of students in electrochemistry. Finally, this study will have significance for future policy formulators in South Africa on the use of specific teaching strategies to enhanced students' comprehension and consequent performance in challenging high school chemistry topics such as electrochemistry.

Scope and delimitation of the Study

There are sixteen circuits in the Bohlabela district in the Mpumalanga province. However, the study confined itself to the Ximhungwe circuit because of its proximity to the researchers and the fact that it is one of the low-performing circuits. The study also restricted itself to only physical sciences students in high achieving schools because the researchers wanted to look at the effect of the chemistry classroom environment on performance. Only grade 12 students were used as respondents because they have had some three years physical sciences education and would have had some experience needed to respond to the statements in the questionnaire.

METHODS

The study utilized a quasi-experimental research design. A quasi-experimental design was appropriate for this study because it was not possible to randomly assign students to a particular class sessions, so convenience sampling technique was used (Leedy and Ormerod, 2010). Even though the two schools were randomly selected, students were not individually randomly assigned to a particular group. The sample of the study consisted of fifty one grade 12 physical sciences students in 2 high achieving schools in the Ximhungwe circuit. These two schools were randomly selected using the table of random numbers from five high achieving schools in the circuit. The experimental group consisted of 28 students and followed the designed teaching sequence called the collaboration and a baseline class of 23 students served as a comparison group and followed a similar curriculum but normal classroom teaching termed traditional teaching method. In addition the schools were selected based on their performance in the NSC examinations. This is to ensure that the findings from this study were solely based on the differences in the teaching methods used.

For each electrochemistry topic, the control group was the traditional teaching method classroom, while the experimental group was the conceptual change teaching strategy (collaborative) classroom, which involved collaboration combined with conceptual change texts. Changes in the knowledge level were determined by comparing their pre-intervention cognitive test and post-intervention cognitive test. The changes in achievement were determined using the pre-intervention and post-intervention diagnostic tests.

Instrumentation

Two instruments were used to collect data in the main study. The instruments were Electrochemistry Concept Test (ECT) and Chemistry Classroom Environment questionnaire (CCEQ). Some parts of the ECT were developed by the researchers and others adapted by comparing with various literatures and validated by three experienced physical science teachers and research supervisors. The 40 items on the CCEQ were assigned values on a five-point Likert-type scale format. The CCEQ had five sub-scales or dimensions with each subscale comprising eight items. In the ECT a two-tiered, ten-question test was constructed based on the format developed by Treagust (1988). The first tier of each pair of questions was based on procedural knowledge and the second tier was based on conceptual knowledge, with the respondent choosing a reason for his/her choice in the first tier. This type of questioning has the potential to distinguish between procedural knowledge and conceptual knowledge when examining student's work (Treagust, 1988). Most electrochemistry questions in the grade 12 National Senior Certificate (NSC) examinations have sub-questions in this format and in most cases students score the first tier but not the second. The CCEQ was adopted from literature, but only five of the seven scales were applicable to this study, which took place in a rural setting.

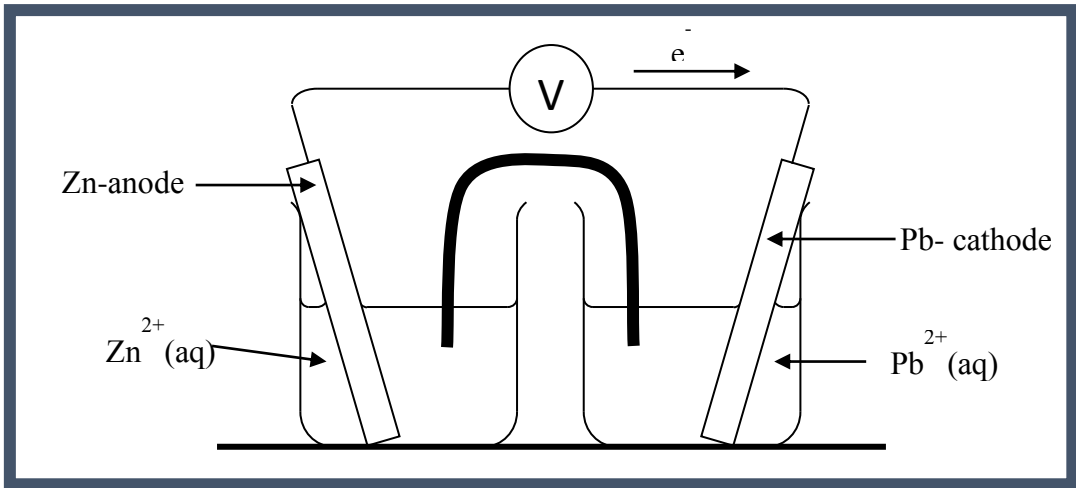
Method of Data Collection

Of the two schools selected for the research, one school represented the control group and the other school represented the experimental group. The latter was taught using collaboration combined with CCTs, and the former with the traditional method that the classroom teacher is familiar with. The ECT and CCEQ were administered as pretest in the fourth week of July 2015, before instruction began in the fifth week of July 2015. The posttest was administered after treatment, precisely in the fourth week of August 2015. The ECT involved a pencil and paper test on electrochemistry concepts for the post-test. Two physical sciences teachers were trained by the researcher for the study. According to the syllabus for grade 12 physical sciences, teachers should use 8 hours to teach electrochemistry in two weeks, four hours per week and one hour per class period. Instead, the teachers used three hours per week, one and half hours per class period for the four weeks of treatment. The experimental group was taught by one of the teachers and the control group by the other teacher. These teachers have been teaching physical sciences for 7 years and were the best teachers in physical sciences for 2011, 2012 and 2013 academic years in the Ximhungwe circuit and Agincourt circuit respectively as judged by the Department of Education.

The texts were developed by the researchers to support the collaborative group. Three texts on galvanic, electrode potential and electrolytic cells were produced for the study. The conceptual change texts were developed according to the Conceptual Change Approach introduced by Posner et al. (1982) that is based on the conditions of dissatisfaction, intelligibility, plausibility and fruitfulness. The following is a sample of the texts. The conceptual change texts used in this study are proven for their effectiveness (Ozkan and Sezgin Selcuk, 2013) and complimented collaboration to enhance learner participation and comprehension. The conceptual change texts designed is made up of five parts and has been planned in accordance with the conditions of dissatisfaction, intelligibility, plausibility and fruitfulness in the conceptual change approach developed by (Posner et al, 1982). It was recommended that students be given the five parts separately to prevent them from reading the answers in the next part and change their answers accordingly.

The teacher in the collaboration class started the teaching-learning process by handing out worksheets to each group member that include the first step of the conceptual change texts. The students were told to follow the instructions carefully. Since the purpose of this exercise is to diagnose and overcome the misconceptions the students have, and especially to see the effect of the group process on learner achievement, the teacher directed the students to study in groups of five within a specified time frame and provide their answers as requested. After distributing the texts, the teacher asked each group to select a volunteer to read the text to the hearing of all their group members. Each group member was allowed sometime to independently solve the problem. After this, the students discussed the subject matter with their group members, giving them the opportunity to correct their friends' mistakes if any are made and come up with a pooled answer. Throughout this period, the teacher was a facilitator or guide. The teacher did not correct students' mistakes directly, but encouraged them to discover the reasons for their mistakes by offering clues (Vygotsky, 1978). The first part of the texts aimed to identify any possible misconceptions students may have and to create an inconsistency that is, dissatisfaction. This allows a teacher to understand how a student's comprehension is influenced within the group.

Use the following information to answer the next three questions.



Numerical Response
Describe the direction of the electric current.
Why is there a need for standard half-cell?
1-3. How is the cell potential obtained? Calculate it.

Figure 1. First part of the text

During the implementation, a discussion environment is created in the classroom within each group to enable students grasp the problem better. The second part features common misconceptions and answers that are scientifically wrong.

1. The most frequent answer about this is "Conventional current is the flow of positive charges" misconception. What about you? What do you think? Now, read the next text very carefully.
2. The most frequent answer about this is "The designation of the E° for the H_2 (1M/ H^+) standard half-cell is based on the chemistry of H^+ and H_2 " misconception. What about you? What do you think? Now, read the next text very carefully.
3. The most frequent answer about this is "cell potentials are derived by adding individual reduction potentials" misconception. What about you? What do you think? Now, read the next text very carefully.

Figure 2. Second part of the text

After the students have given the problem a second thought, the scientific conceptions concerning the subject are explained. That explanation must be very clear and intelligible. In this section, arrangement should be made as taking into consideration Posner et al.'s intelligibility and plausibility principle. The students are allowed to discuss the subject matter with their group members as they compare their previous answers with the explanation provided by the conceptual change texts. Supporting collaboration with conceptual change texts gives direction to group members and reduces boredom and monotony and improves learner comprehension and achievement.

Let's see if your answer is correct

In a voltaic cell:

- There is a spontaneous chemical reaction which converts stored chemical energy into electrical energy. The oxidation-reduction reaction which takes place is controlled and the oxidation and reduction half-reactions usually occur in separate compartments called half-cells. A cell potential is spontaneously produced and an electric current results, where electrons move from the anode to the cathode through the external circuit. The relative tendencies of the reactants to be oxidized or reduced determine the resulting oxidation-reduction reaction. The cell potential generated depends on the nature of half-cell reactions. The cell potential generated indicates the capacity of the cell to do electrical work. The cell potential of the cell is measured in volts.

Half cells:

- Half cells are compartments in which separate oxidation and reduction half-reactions occur. Consist of an electrode immersed in an electrolyte. They are linked by a salt bridge which allows the transfer of ions in the internal circuit. Cations from the salt bridge move into the electrolyte in the cathodic compartment to replace cations from the electrolyte that were reduced at the cathode whereas anions from the salt bridge move into the electrolyte in the anodic compartment to neutralize the cations produced as a result of the oxidation that occurred in the anode. Half-cells enable the transfer of electrons from one reactant to another to take place through an external circuit or metallic conductor which links the electrodes.

Reduction potential, standard reduction potentials and standard reduction potential tables:

- Reduction potential indicates the relative tendency of substances to be reduced and on reduction potential table, are listed by half-reaction equations in order of decreasing tendency to be reduced (decreasing strength as oxidizing agent) or increasing tendency to be oxidized (increasing strength as reducing agent). Standard reduction potentials are determined in relation to the $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$ half-cell reaction which is assigned an arbitrary E° value of 0V . Substances more readily reduced than hydrogen ions are listed above hydrogen and have positive E° values while those which are more difficult to reduce are listed below and have negative E° values (Refer to Table 4A). Standard reduction potentials assume conditions of 1.0 mol/L or 1.0 mol/dm^3 concentration, 101.3 kPa pressure and usually 25°C temperature. Standard reduction potential can be read as standard oxidation potentials if the sign of the E° is changed and the equation is read in the reverse direction (from right to left). Standard reduction potential tables list oxidizing agents (oxidants, oxidizers or oxidisers) in decreasing strength from the top to the bottom on the left side of the table and reducing agents (reductants or reducers) in decreasing strength from the bottom to the top of the right side of the table (refer to 4A). Standard reduction potential tables can be used to predict whether or not oxidation-reduction reactions are likely to occur, either in a cell or by the direct mixing of reagents. Standard reduction potential tables can be used to predict the oxidation and reduction half-reactions that may occur at the anode and cathode, and the equation for the half-reaction can be combined to determine the net cell reaction and equation. The half reaction with the highest reduction potential value will be the reduction half reaction. For example, For the half reaction pairs, $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$; $\text{Pb}^{2+} + 2\text{e}^- \rightarrow \text{Pb}$, state:

i Which metals will be used as anode and cathode?

ii Name suitable electrolytes for each half cell as well as the salt bridge.

iii Give the cell notation.

iv Calculate the cell potential.

Solution

i Anode: Mg Cathode: Pb

ii Electrolyte in beakers - any soluble metal salt solution. (Just make sure that no precipitation reaction will occur because of exchange in metal ions. Chlorides or sulphates will precipitate with lead; nitrates are safe to use because all nitrates are soluble. Salt bridge - NaNO_3).

iii $\text{Mg}(\text{s}) \text{ I } \text{Mg}^{2+}(\text{aq}) \text{ II } \text{Pb}^{2+}(\text{aq}) \text{ I } \text{Pb}(\text{s})$

iv $E_{\text{cell}} = E_{\text{o cathode}} - E_{\text{o anode}}$
 $= E_{\text{o(Pb)}} - E_{\text{o(Mg)}}$
 $= -0,13 - (-2,36)$
 $= 2,23\text{ V}$

Standard reduction potential tables can be used to predict the site of the anode and cathode in an electrochemical cell. Standard reduction potential tables can be used to predict the cell potential of a voltaic cell. (Predictions should be interpreted with caution since they provide no information about the rate of the reaction, the concentration of the reaction species or another factor which affect reduction potentials). The strongest oxidizing agent (has the greatest tendency to be reduced) i.e. it undergoes reduction easily, which means it is the weakest reducing agent and has the least tendency to be oxidized. It has the highest reduction potential or the least oxidation potential. The strongest reducing agent (has the greatest tendency to be oxidised) i.e. it undergoes oxidation easily, which means it is the weakest oxidising agent and has the least tendency to be reduced. It has the least reduction potential or the highest oxidation potential.

Figure 3. Third part of the text

In the fourth part, when students perceive the difference between misconceptions and scientifically true explanations, they are asked to express their own opinions. The aim in this part is to measure how much awareness has been raised among students and see if they still have some question marks in their minds or not.

Did you change your mind after reading the text? If you did, please express your views once again by considering the text, and give an example.

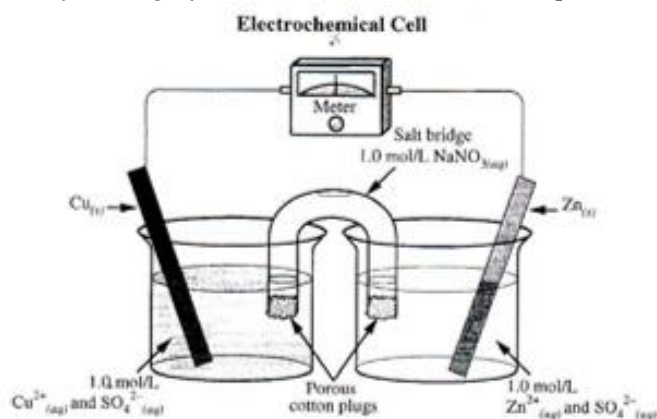
Figure 4. Forth part of the text

In the last part, the purpose is to understand whether or not the students have grasped the text well. In this section, Posner et al's fruitfulness principles is applied to a new problem situation to see if learners can transfer knowledge acquired to a new problems situation.

Now, let's answer the following questions:

Use the following information to answer the next two questions.

Use the following information to answer the next two questions.



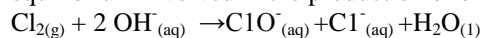
Numerical Response

4-1. A student attempted to replicate a traditional Daniell cell by setting the electrochemical cell shown above. Under standard conditions, the electrical potential of the cell should be -/+ _____ V. (Record your **three-digit answer** in the numerical-response section on the answer sheet.)

4-2. In the electrochemical cell above, electrons move through the electrolyte because they are attracted to the positive ions in the solution electrolyte in one direction and protons move through the electrolyte in the opposite direction wire from the electrode with the lower reduction potential to the electrode with the higher reduction potential wire from the electrode with the higher concentration of electrons to the electrode with the low concentration of electrons

Use the following information to answer the next two question.

Common household bleach is an aqueous solution that contains approximately 5% sodium hypochlorite. The equilibrium involved in the production of bleach from chlorine can be represented by the reaction equation:



In the production of bleach, write down the oxidation and reduction half-reactions.

Write the overall cell reaction.

Figure 5. Fifth part of the text

RESULTS and FINDINGS

Ho1: there is no significant mean difference between posttest and pretest mean scores of students taught electrochemistry concepts with conceptual change teaching strategy and students taught with traditional teaching method in the high achieving schools (HAS). A one-way analysis of covariance was conducted to determine the effect of the two different teaching methods on posttest scores for HAS. Before the ANCOVA was ran, it was assumed that the pretest is linearly related to the posttest, for all groups of the independent variable, teaching method in HAS. A scatterplot of posttest against pretest groups on teaching method is plotted as shown in Figure 1.

Figure 1: Scatterplot of posttest against pretest grouped on teaching method for HAS

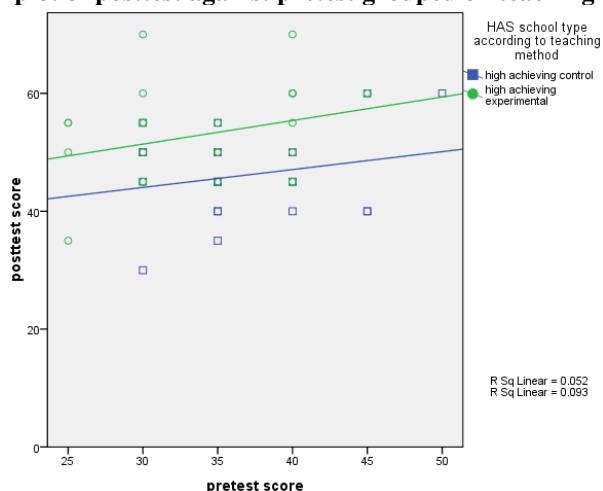


Figure 1 clearly shows that there is a linear relationship between pretest and posttest scores for each intervention type for HAS, as is confirmed by a visual inspection of the scatterplot. It was also assumed that there is no interaction between the pretest and the teaching method for HAS. This was statistically tested by determining whether there is a statistically significant interaction term, teaching method*pre-test. In order to do this, a general linear model univariate analysis was conducted. The result indicated that there was homogeneity of regression slopes as the interaction term was not statistically significant, $F(1,47) = .066, p = .799$. When the Explore procedure was ran, it emerged that posttest scores were normally distributed for both HAS control ($p=.342$) and HAS experimental ($p=.094$), as assessed by Shapiro-Wilk's test ($p > .05$). Similarly, there was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p = .825$). ANCOVA was ran for only HAS. The results of ANCOVA analysis are presented in Table 1. From Table 1, it is observed that there is a statistically significant difference in posttest scores between HAS control and HAS experimental, $F(1,48) = 13.335, p = .001$, partial $\eta^2 = .217$. The strength of the relationship between instruction method and comprehension of electrochemistry concepts was strong. Instruction method accounted for 21.7% of the variance of the dependent variable when the pretest is controlled as a covariate.

Table 1: ANCOVA Summary on Comprehension for HAS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	828.928a	2	414.464	7.380	.002	.235
Intercept	1767.350	1	1767.350	31.471	.000	.396
pre	219.208	1	219.208	3.903	.054	.075
SchtypteachHAS	748.881	1	748.881	13.335	.001	.217
Error	2695.582	48	56.158			
Total	130525.000	51				
Corrected Total	3524.510	50				

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

When post hoc analysis was performed with a Bonferroni adjustment, the experimental group for HAS had the highest posttest scores, which were statistically significantly higher than the posttest scores of the control group ($p = .001$). The results are presented in Table 2.

Table 2: Pairwise comparison between HAS experimental and control groups

Teaching method		Mean Difference	Std Error	Sig.
HAS Control	HAS Experimental	-7.899*	2.163	.001
HAS Experimental	HAS Control	7.899*	2.163	.001

The ANCOVA results presented in Table 1 showed that there was a significant difference between the posttest mean scores of students taught with the traditional teaching method and those taught with the conceptual change teaching strategy with respect to comprehension of electrochemistry concepts in the High Achieving Schools. To confirm this, analyse and compare means procedure was run. Table 3 presents the posttest means and standard deviations of the control and experimental groups. The results from the table indicate that mean posttest ECT score (53.04 ± 7.97) for the experimental group was higher than mean posttest ECT score (46.06 ± 7.38) for the control group.

Table 3: Mean and Standard deviation for HAS

Teaching Method	Mean	Standard deviation	N
High achieving Control	46.06	7.379	23
High achieving Experimental	53.04	7.974	28
Total	46.83	8.883	51

The results suggest that the students taught with CCTS had a better understanding and hence higher comprehension level of electrochemistry concepts after the intervention. Even though the experimental group had a higher overall mean score than the control group, there were some items for which the experimental group scores decreased compared to the control group.

Ho2: there is no significant relationship between high achieving physical sciences students' posttest mean scores on their perception of their chemistry classroom environment and their achievement in electrochemistry concepts. The results of the analysis are presented in Table 4.

Table 4: Correlation between CCEQ and ECT Scores of EG Students

Variable	N	Correlation Coefficient	p-values
CCEQ	51	0.217	0.02
ECT	51		

Pearson Product-Moment Correlation was used to check correlation between CCEQ and ECT posttest mean scores with respect to students' perceptions of their chemistry classroom environment. The results revealed that there was a significant relationship between achievement and students' perceptions of their chemistry classroom environment ($p < 0.05$). This suggests that as students' perceptions of their chemistry classroom increase, it results in an increase in their performance on the ECT.

CONCLUSION

The Constructivist approach to instruction used in this study caused an improved level of understanding of electrochemistry concepts compared to traditional method of instruction. Gain scores of experimental group were significantly higher than those of control group. The results of the ANCOVA analysis show the differences between the experimental and control groups' performance on ECT. The students in the experimental class provided better structured and more precise answers in the fill-in questions, showing that they had higher level of scientific comprehension and were more confident in writing their responses than the control group, whose answers were shorter and lacked some key features of the scientific explanations. Consequently, this study has provided evidence that Collaboration combined with conceptual change text teaching strategy enhances students' level of comprehension of electrochemistry concepts in particular and Chemistry in general.

Thus, there must be some aspects of the collaboration combined with conceptual change texts that contributed to these differences in the achievement of these groups. The findings in this study have provided some empirical evidence that many students developed conceptual difficulties in this learning area and the results do not support any assumption that normal classroom teaching has provided essential support for students to generate detailed, factual explanations about the chemical phenomena. This calls for concern and needs to be tackled in the classroom teaching and learning regarding a specific, difficult area in chemistry. Also, the findings suggest that the typical classroom teaching and learning strategy characterized by lecture or talk and chalk or telling method of teaching is incongruous for improving students' conceptual understanding. Drawing from this, the effectiveness of the collaboration combined with conceptual change texts can be determined according to whether or not students in the experimental group had developed a better conceptual understanding after teaching in comparison to the controlled group.

The results also indicated that there was a positively significant correlation between achievement and classroom environment (encompassing students' cohesiveness, teacher's support, student involvement, students' cooperation without competition and equity) in favour of the experimental group. This suggests that the higher the students' perception level of their chemistry classroom, the higher is their achievement on the ECT. In conclusion, some aspects of the collaboration combined with conceptual change texts may have achieved some particular teaching and learning aims.

RECOMMENDATIONS

The designed teaching strategy of this study has a promising potential to be used as a tool in the South African classroom in order to improve students' conceptual understanding of electrochemistry concepts for higher achievement as is shown in the report. It is therefore recommended that the Chemistry teacher should endeavour to determine necessary concepts in the chemistry syllabus and acquire the appropriate knowledge and

applicability of relevant instructional strategies such as collaboration combined with conceptual change text for improved achievement of students. This will further increase the efficiency and effectiveness of the teacher.

ACKNOWLEDGEMENT

The work described herein and the preparation of this article were made possible by 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.

REFERENCES

- Alexander, P. A. (1998). Positioning conceptual change within a model of domain literacy. In B. Guzzetti & c. Hynd (Eds.), *Perspectives on conceptual change* (pp.55-76). Mahwah, N.J.: Lawrence Erlbaum Associates.
- Bojczuk (1982). Electrochemistry Misconception. *School Science Review*. 64, 545-551.
- Chan, C., Burtis, J., & Bereiter, C. (1997). Knowledge building as a mediator of conflict in conceptual change. *Cognition and Instruction*, 15, 1-40.
- Conley, A.M., Pintrich, P.R., Vekiri, I. & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary Educational Psychology*, 29, 186-204.
- DEMP (2015). *Feedback on the 2012 NSC examination and resource material in physical sciences*. Mpumalanga Province: Mpumalanga Department of Education.
- Duit, R. (2003). Conceptual change: a powerful framework for improving science teaching and learning. *International Journal of Science Education*, 25(6), 671- 688.
- Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, 25(6), 671-688.
- Dykstra, D. I. J. (2005). Against realist instruction: Superficial success masking catastrophic failure and an alternative. *Constructivist Foundations*, 1(1), 49-60.
- Garnett, P. J. & Treagust, D. F. (1992a). Conceptual difficulties experienced by senior high school students of electrochemistry: electrochemical (galvanic) and electrolytic cells. *Journal of Research in Science Teaching*, 29, 1079-99.
- Hanson et al. (1998). Improving Teaching and Learning Process in General Chemistry. *Journal of Chemical Education*. 75(2), 143-147.
- Kelly, G., & Green, J. (1998). The social nature of knowing: Toward a sociocultural perspective on conceptual change and knowledge construction. In B. Guzzetti & C. Hynd (Eds.), *Perspectives on conceptual change: Multiple ways to understand knowing and learning in a complex world*. (pp. 145-182). Mahwah, N.J.: Lawrence Erlbaum.
- Kittleson, J. M., & Southerland, S. (2004). The role of discourse in group knowledge construction: A case study of engineering students. *Journal of Research in Science Teaching*, 41(3), 267-293.
- Leedy, P. D., Ormrod, J. E. (2010). *Practical research planning and design* (9th ed.). Boston: Pearson Education Inc.
- Niaz, M. (2002). Facilitating conceptual change in students' understanding of electrochemistry. *International Journal of Science Education*, 24(4), 425,439.
- Novak (2002). Meaningful Learning. *Science Education*. 548-571.
- Ogude, A. N. & Bradley, J. D. (1994). Ionic conduction and electrical neutrality in operating electrochemical cells. *Journal of Chemical Education*. 71, 29-34.
- Osborne, R., & Wittrock, M.C. (1983). Learning science: A generative process. *Science Education*, 67, 489-508.
- Özmen, H. (2004). Some students' misconceptions in chemistry: A literature review of chemical bonding. *Journal of Science Education and Technology*, 13(2), 147-159.
- Özkaya, A. R. (2002). Conceptual difficulties experienced by prospective teachers in electrochemistry: Half-cell potential, cell potential, and chemical and electrochemical equilibrium in galvanic cells. *Journal of Chemical Education*, 79(6), 735-738.
- Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66(2), 211-227.
- Sanger, M. J., & Greenbowe, T. J. (1997a). Common student misconceptions in electrochemistry: Galvanic, electrolytic, and concentration cells. *Journal of Research in Science Teaching*, 34(3), 377 - 398.
- Sanger, M. J., and Greenbowe, T. J. (1997b). Students' misconceptions in electrochemistry: Current flow in electrolyte solutions and the salt bridge. *Journal of Chemical Education*, 74(7), 819-823.
- Schmidt, H-J., Marohn, A., & Harrison, A. G. (2007). Factors that prevent learning in electrochemistry. *Journal of Research in Science Teaching*, 44(2), 258-283.
- Scott, P., Asoko, H. & Leach, J. (2007). Student conceptions and conceptual learning in science. In S.K. Abell and N.G. Lederman (Eds.). *Handbook of research on science education*. (pp. 31-56). Mahwah, N.J.: Lawrence Erlbaum Associates.

- Sinatra, G.M. & Pintrich, P.R. (Eds.). (2003). *Intentional Conceptual Change*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Solomon, J. (1987). Social influences on the construction of pupils' understanding of science. *Studies in Science Education*, 14, 63-82.
- Stathopoulou, C. & Vosniadou, S. (2007). Exploring the relationship between chemistry-related epistemological beliefs and chemistry comprehension. *Contemporary Educational Psychology*, 32, 255-281.
- Suping, S. M. (2003). Conceptual change among students in science. Retrieved January 18, 2005, from www.eric.ed.gov
- Treagust D.F., (1988), Development and use of diagnostic tests to evaluate students' misconceptions in science, *International Journal of Science Education*, 10, 159-169.
- Treagust, D., & Duit, R. (2008). Conceptual change: A discussion of theoretical, methodological and practical challenges for science education. *Cultural Studies of Science Education*, 3, 297-328.
- Vellom, R. P., Anderson, C. W., & Palinscar, A. (1993). *Scientific reasoning in school contexts*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Atlanta, Georgia.
- Vosniadou, S. (Ed.). (1994). Capturing and Modeling the Process of Conceptual Change. In S. Vosniadou (Guest Editor), Special Issue on Conceptual Change, *Learning and Instruction*, 4, 45-69.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Wandersee, J., Mintzes, J., & Novak, J. (1994). Research on alternative conceptions in science. In D. Gabel (Ed.), *Handbook of research on science teaching and learning*. (pp. 177-210). New York: MacMillan.
- Wittrock, M.C. (1974). Learning as a generative process. *Educational Psychology*, 11, 86-95.