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GENDER DIFFERENCES IN CONSTRUCTIVIST APPROACH TO HIGH SCHOOL LEARNERS' 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 study reports on research findings on the effect of collaboration combined with text manipulation on male and female learners' comprehension of electrochemistry concepts in the Ximhungwe circuit of the Bohlabela district in the Mpumalanga province of South Africa. 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. This theory strongly proves that learning is a social process and communication facilitates learning. An intact sample of 47 12th grade physical sciences learners from two public schools in the circuit participated in the study. One of the schools was a high achieving school (HAS) and the other a low achieving school (LAS) as was classified by the Department of Education. Learners were given electrochemistry concept test (ECT) and Chemistry Classroom Environment Questionnaire (CCEQ) as pretest and post-test. After the treatment using a self-designed conceptual change teaching strategy of collaboration combined with conceptual change texts, ANCOVA conducted on posttest scores of the learners showed that there was no significant mean difference between male and female learners in their comprehension of electrochemistry concepts. Similarly, there was no significant interaction effect between gender and treatment. However, Pearson Product-Moment Correlation revealed that there was positive relationship between achievement and learners' perception of their chemistry classroom environment. It was concluded that collaboration combined with text manipulation was equally effective for both males and females.

Key words: Collaboration, conceptual change texts, electrochemistry, gender, social constructivism

INTRODUCTION

Researches for the past three decades on gender and achievement have revealed mixed results regarding gender differences in science achievement. Whereas some argue that there are instances where females perform equally well as their male counterparts others found that there are differences in achievement between males and females from lower grades through high school to college, especially when measured by standardised tests (Ingels and Dalton, 2008). Halpern, (2012) has indicated that much research has focused on gender differences in various areas of intellectual achievement. Else-Quest, Hyde and Linn, (2010) and Penner, (2003) reported that gender differences in mathematics and science achievement were typically in favour of males but it is insignificant, however, Hyde, Lindberg, Linn, Ellis and Williams (2008) and Lindberg et al. (2010), suggest that the gap is closing up and even disappearing in these fields. Some researchers have argued that these findings have essentially become part of the stereotypical view of men and women (Lindberg et al., 2010; Nosek et al., 2009). In contrast, achievement test results over the years have continuously shown an ever increasing gap in the performances of boys and girls in chemistry at senior secondary school level (Onekutu, 2002). Gafoor and Shilnar (2014) found that nearly 15 per cent variation in performance in organic chemistry was accountable to test format which was in favour of the girls when multiple choice items were used. Similarly, a research conducted by Voyer, and Voyer (2014) showed that gender differences in school achievement favoured females in all fields of study. These variable research findings indicate that research in this area is still inconclusive. Accordingly, Dhindsa and Emran, (2011) contend that extant constructivist approaches that influence classroom

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

environment help cognitive development in both male and female learners, which consequently reduces gender differences in their academic achievement in all areas including science subjects.

Theoretical Framework

The underlying concept of this study is conceptual change interpreted as what actual knowledge a group collectively produces and agrees upon as a final take. The conceptual change theory proposed by Posner et al. (1982) strongly indicates that learning is a social process based on social constructivism in which learner dialogue supersedes teacher`s talks in the classroom thereby facilitating learning. This conceptual change theory influenced the emergence of an active social interaction in the classroom like collaboration. Cognitive level and knowledge restructuring of individual is facilitated by an appropriate instructional setting that enhances learners' curiosity, creativity and development of higher–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 the short- and long-term memories once exposed to the learning process. Scott, Asoko and Leach, (2007) opined that conceptual change is examined by emphasizing the social construction of knowledge and discursive interactions in the classroom. Current research on intentional conceptual change points to the need for designing learning environments that encourage learners to employ goal-directed, reflective strategies, explanatory frameworks and to develop meta-conceptual awareness (Lederman, Lederman and Antink, 2013). Understandably, socio-cognitive discourse plays a key role in facilitating conceptual change as well as enhancing problem solving skills (Chan, Lam and Leung, 2012; Heng, Surif and Seng, 2014).

From a Vygotskian social-constructivism perspective, a major role of schooling is to create social contexts for learning such that individuals master the use of cultural tools (Smagorinsky and O'Donnell-Allen, 2000). Vygotsky's theories stress the fundamental role of social interaction in the development of cognition (Vygotsky, 1978; Wertsch, 1985). Collaboration, an aspect of social constructivism, can be described as interactions in which participants mutually discover solutions and create knowledge together (Kittleson and Southerland, 2004). Collaborative learning experiences, then, provide a social context within which learners can jointly build understanding. When collaborating, learners work together to solve a given problem. According to Galloway (2001) two of the main principles of Vygotsky's work linked to collaboration are the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD). The MKO refers to someone who has a better understanding or a higher ability level than the learner, with respect to a particular task, process, or concept. the MKO and the ZPD form the basis of the scaffolding component of the cognitive apprenticeship model of instruction. Vygotsky (1978) defines the ZPD as the distance between the "actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). Vygotsky believed that when a student is at the ZPD for a particular task, providing the appropriate assistance (scaffolding) will give the student enough of a "boost" to achieve the task.

Gee (2005) describes the ability to combine language with behaviours to enact a socially recognizable identity as a discourse. Gee indicates that science discourse is a specialized way of talking and acting that reflects the values and identities associated with members of the social group known as scientists. This would imply, then, that replicating features of the activities of the scientific community in the classroom provides learners the opportunity to take part in and practice science discourse. A collaborative group confronted with a challenging problem is reflective of a scientific community working together to find possible solution to a given problem. Members of the scientific community establish the norms and expectations for their group. For example, scientists place a heavy emphasis on the importance of evidence in backing their claims. Thus, members' individual concepts are pooled and the discourse that ensues may lead to a consensus concept representing potential conceptual change and the co-construction of science knowledge. Learners presented with the opportunity to engage in problem-solving collaboration group are in other words exposed to a situation similar to the scientific community.

Much remains to be understood about the nature of the interaction between members of a collaborative group (Kittleson and Southerland, 2004). Describing and examining learner discourse generated during the normal course of classwork can uncover the goals, agenda, and premises that influence what conceptual understanding is shaped by the group and the way this understanding develops (Kittleson and Southerland, 2004). Since discourse is language in use, examination of discourse includes what happens before, during, and after a discourse event. It reveals shift in reasoning within the group as well as the strategies used and social procedures enacted while developing the group constructs. Describing and examining the discourse will reveal the socially constructed nature of science knowledge (that is, how members organize, retrieve, present, and manipulate their conceptual understandings). This type of research can help make sense of the interaction patterns within a group by describing the ways of thinking, action, and interaction common to the group. It is these patterns that constrain and shape the meaning members will construct as a group (Gee, 2005).

Statement of the Problem

Research has shown that South Africa has shortages in scarce skill areas like science and technology in spite of the various interventions the government has continuously put in place. This is evidenced by the poor performance of learners in science and mathematics at the high school level. The problem that formed the focus of this study is that high school learners in South Africa have been performing poorly in chemistry topics including electrochemistry since 2009 (Department of Education Mpumalanga Province (DEMP) 2015). This has been attributed to conceptual difficulties experienced by learners 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 learners often have difficulty in understanding chemistry concepts due to their abstract nature and many attempts have been made by researchers to assist learners' learning by identifying misconceptions, the difficulties experienced by learners and possible solutions to overcome such problems (Sanger and Greenbowe, 1997a and 1997b; Niaz, 2002; Niaz and Chacon, 2003; O'grady-Morris, 2008; Ozkaya et al., 2006). As a result, the Department has put various programmes such as winter schools, spring schools and camps in place to help improve learners' performance, yet majority of learners continue to perform poorly in the National Senior Certificate (NSC) examinations. Essentially, teachers talk and learners listen, and it was against this background that this study was undertaken.

Purpose of the Study

Based on the problems highlighted above, the study designed a conceptual change teaching strategy, specifically collaboration combined with conceptual change texts to enhance learners' comprehension of electrochemistry. It was also to investigate the changes in science conceptual comprehension between males and females when they have the opportunity to collaborate, define, discuss and determine possible solutions to extended science problems assigned by the classroom teacher.

Hypotheses

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

1. Ho_1: there is no significant difference between posttest and pretest mean scores of male and female learners with respect to their comprehension of electrochemistry.
2. Ho_2: there is no significant interaction effect between gender and conceptual change teaching strategy with respect to learners' comprehension of electrochemistry concepts.
3. Ho_3: there is no significant relationship between males and females in perception of their chemistry classroom environment and their achievement in electrochemistry concepts.

Significance

First this study will illuminate the sources of learners' misconception, miscomprehension and difficulties in electrochemistry. It will promote comprehensive discourse in the problem areas among male and female learners in order to generate positive cognitive conflicts that will enhance conceptual comprehension. This study will also provide useful information as to the processes that learners go through in solving a particular problem through collaboration.

Scope and delimitation of the Study

This study confined itself to the Ximhungwe circuit because it is one of the low-performing circuits in the Bohlabela district in the Mpumalanga province. The study covered grade 12 physical sciences learners because the researchers observed that they have had some three years physical sciences education in the high school. So, they should have had some experience needed to respond to the statements in the questionnaire and also answer the ECT questions effectively.

METHODS

The study is a descriptive study and utilized a pretest and posttest non-equivalent control group quasi-experimental research design. According to Gliner, Morgan and Leech (2011), a quasi-experimental design is appropriate for a study such as this because it was not possible to randomly assign individual learners to particular classes or groups. In other words, in the research schools, learners were not randomly assigned as individuals to experimental groups and control groups. Therefore, all learners within any particular classroom were randomly assigned as an intact group to serve as an experimental group (EG) or control group (CG). A four-week special teaching programme using conceptual change teaching strategy of collaboration combined with conceptual change texts for the two participating schools was carried out on the topic of electrochemistry with one chemistry teacher purposefully trained for this study. The changes in achievement males and females were determined using the pre-intervention and post-intervention diagnostic tests.

Sample and Sampling Technique

The sample consisted of grade 12 physical sciences learners in their intact classes in two high schools, one high achieving school (HAS) and the other, low achieving school (LAS) in the Ximhungwe circuit. These two schools were randomly selected from 10 high schools, using the table of random numbers. In addition, the schools were categorized as HAS or LAS by the department of education in the Mpumalanga province (DEMP, 2015). The sample consisted of 47 grade 12 physical sciences learners. There were 28 grade 12 physical science learners from HAS and 19 from LAS. The 47 intact class learners was made up of 28 females (17 are from HAS and 11 are from LAS) and 19 males (11 are from HAS and 8 are from LAS).

Instrumentation

Two instruments were used to collect data in this study. The instruments are Electrochemistry Concept Test (ECT) and Chemistry Classroom Environment Questionnaire (CCEQ). The researchers developed the ECT by consulting the various literatures, textbooks and previous examination papers. They were then validated by some experienced physical sciences teachers and supervisors. The ECT showed a reliability value of .79 as determined using Kuder-Richardson formula 20 and the CCEQ had a reliability ratio of .82 with the Crombach`s alpha calculation. The CCEQ was adapted from literature with modifications to be applicable to this study, which took place in a rural setting.

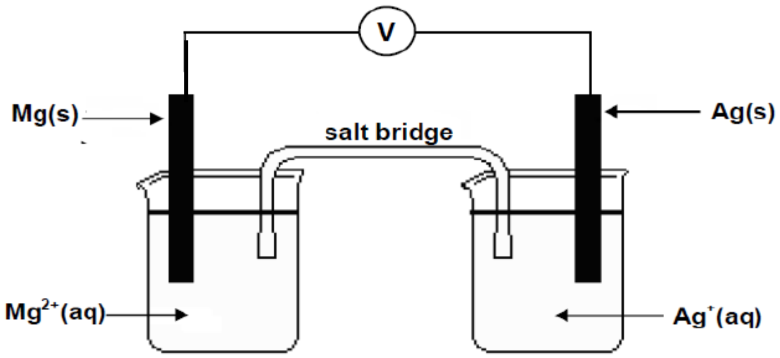
Method of Data Collection

A conceptual change teaching strategy (collaboration combined with conceptual change texts) was used to collect data. These texts were developed by the researchers to support the collaboration. 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. These conceptual change texts are proven for their effectiveness (Ozkan and Sezgin Selcuk, 2013) and complimented collaboration to enhance learner participation and comprehension and to reduce discursive teaching and interaction among group members. 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 two teachers used in this study 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 two questions.



Numerical Response

1-1. Identify the anode and cathode, and explain how they were identified.
1-2. Explain the concept of the charges on the anode and cathode.
1-3. Discuss the movement of electrons and ions through the cell. In your discussion, name the direction in which the electrons and ions move.

Figure 1. First part of the text

During the implementation stage, the teacher allowed group members to discuss the issues raised thoroughly to enable students grasp the problem situation better. The second part features common misconceptions and answers that are scientifically wrong.

. The most frequent answer about this is "The identity of the anode and cathode depends on the physical placement of the half-cells" misconception. What about you? What do you think? Now, read the next text very carefully.
. The most frequent answer about this is "The anode is negatively charged and because of this it attracts cations. The cathode is positively charged and because of that it attracts anions" misconception. What about you? What do you think? Now, read the next text very carefully.
. The most frequent answer about this is "Electrons enter the electrolyte at the cathode, move through the electrolyte, and emerge at the anode" 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, Posner et al.'s intelligibility and plausibility principle are taken into consideration. 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

Electrodes are electrical conductors that are placed in an electrolyte to provide a surface for oxidation or reduction half-reactions. The nature of the electrodes and the electrolyte determine the oxidation and reduction reactions which occur. Inert electrodes, such as graphite and platinum, are made from substances which conduct electricity and are not chemically altered in cell reactions. The labelling of the electrodes as anode or cathode depends on the site of the oxidation and reduction half-reaction and not their positions in the half-cells. The electrodes at which oxidation occurs is called the anode while the electrode at which reduction occurs is called the cathode. The anode is labelled (-) because oxidation takes place there to produce electrons while the cathode is labelled (+) because electrons from the external circuit enter the electrolyte here.

If the anode is oxidised, electrons move directly from the anode to the cathode through the external circuit and positive ions are released into solution around the anode as it dissolves. At the cathode the substances being reduced accept electrons from the external circuit. If the anode does not react, electrons are transferred directly from the oxidised substance onto the anode and then through the external circuit to the cathode. At the cathode the substance being reduced accept electrons. An electrolyte conducts electricity within a cell by the movement of dissolved positively and negatively charged ions. The movement of ions completes the circuit and maintains electrical neutrality. Anions move through the electrolyte to the anode and cations move to the cathode. A salt bridge contains ions in solution and provides a continuous path for the movement of ions between separate half-cells.

Figure 3. Third part of the text

In the fourth part, when students perceive the difference between misconceptions and scientific explanations, they are asked to express their own opinions. The aim in this part is to measure how much awareness has been created among students and see if they still have misconceptions.

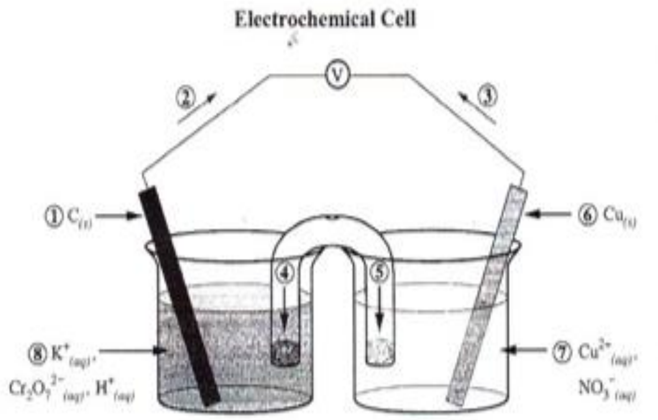
Did you change your mind after reading the text? If you did, please express your views once again by considering the text, and give an example.

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.



Identify the anode and cathode in the electrochemical cell above and explain your choice

How is electrical neutrality ensured?

Figure 5. Fifth part of the text

Two physical sciences teachers were trained by the researchers and used in the study. At the commencement of the study a pretest was administered on chemistry classroom environment questionnaire (CCEQ) and electrochemistry concept test (ECT) to all the grade 12 learners in the two schools, who agreed to participate in the research. The teaching was for 3 hours a week and was taught for the four weeks of treatment after normal school hours. At the end of the treatment, a posttest on the same instruments was conducted. ECT and CCEQ were administered as pretest in the third week of July 2015 before the instruction begun in the fourth week of July 2015. Posttest was administered after the treatment, precisely in the fourth week of August 2015. The ECT involved pencil and paper test.

Data Analysis

Hypotheses one and two were analysed using analysis of covariance (ANCOVA). Hypothesis three was analyzed using Pearson Product-Moment Correlation to check the relationship between CCEQ and ECT posttest mean scores.

RESULTS and FINDINGS

Electrochemistry Concept Test Results

Ho_1: there is no significant mean difference between posttest and pretest mean scores of male and female learners with respect to their comprehension of electrochemistry. The results are presented in Table 1.

Table 1: ANCOVA Summary on Comprehension based on Gender

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1019.049[a]	4	254.762	4.242	.006	.288
Intercept	2419.899	1	2419.899	40.293	.000	.490
pre	171.476	1	171.476	2.855	.098	.064
Gender	16.280	1	16.280	.271	.605	.006
Gender*Pre	.496	1	.496	.008	.928	.000
Error	2522.441	42	60.058			
Total	119050.000	47				
Corrected Total	3541.489	46				

a. R Squared = .288 (Adjusted R Squared = .220)

The Analysis of covariance results above shows that there was no significant mean difference between male and female learners in terms of comprehension of electrochemistry concepts ($F(1,42) = .271$, $p = .605$, partial $\eta^2 = .006$). The strength of the relationship between gender difference and comprehension of electrochemistry concepts was very weak. Gender difference accounted for only 0.6% of the variance of the dependent variable with the pretest scores as covariates. Analysis from descriptive statistics indicated that the posttest ECT mean score of (48.68 ± 8.64) for males was not statistically significantly different from posttest ECT mean score (50.18 ± 8.97) for the females. Similarly, an analysis of the result indicated that there was homogeneity of variances, as assessed by Levene's test of homogeneity of variance (p = .799). This suggests that the variance within each of the groups is equal. Post hoc analysis performed with a Bonferroni adjustment as shown in Table 2, indicated that there was no statistically significant difference between males and females on the posttest scores ($p = .264$), indicating that they all benefited equally from the intervention.

Table 2: Pairwise comparison between Males and Females

Teaching method		Mean Difference	Std Error	Sig.
Male	Female	-1.976	1.757	.264
Female	Male	1.976	1.757	.264

Ho_2: there is no significant interaction effect between gender and research experimental teaching method with respect to learners' comprehension of electrochemistry concepts. This was statistically tested by determining whether there is a statistically significant interaction term, gender *pretest. In order to do this, a general linear model univariate analysis was conducted. The results revealed that there was no significant interaction effect between gender and treatment (see Table 1) on learners' comprehension of electrochemistry concepts, $F(1,42) = .008$, $p = .928$. In other words, there was homogeneity of regression slopes as the interaction term was not statistically significant.

It was assumed that the pretest is linearly related to the posttest, for all groups of the independent variable, gender. A scatterplot of posttest against pretest grouped on gender was plotted as shown in Figure 1.

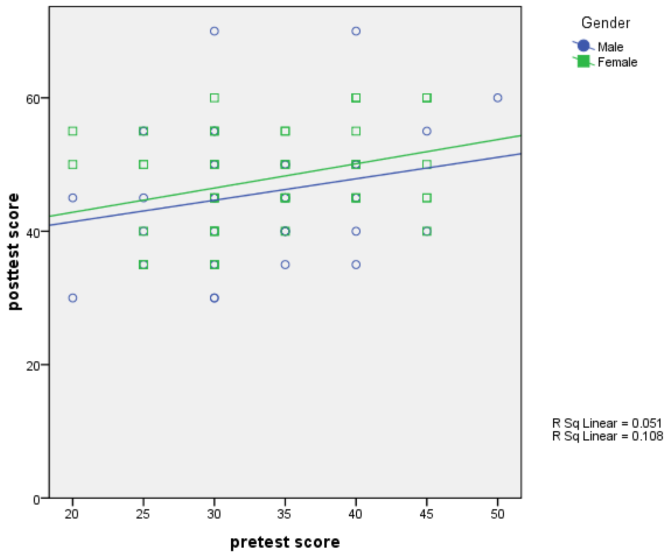


Figure 1: Scatterplot of posttest against pretest grouped on gender

Figure 1 shows that there is a linear relationship between pretest and posttest scores for each intervention type for gender, as assessed by visual inspection of the scatterplot. Similarly, an assessment by Levene's test of homogeneity of variance (p = .799) showed that there was homogeneity of variances.

Ho_3: there is no significant relationship between males and females on their perception of their chemistry classroom environment and their achievement in electrochemistry concepts. The results of the analysis are presented in Table 3.

Table 3: Correlation between CCEQ and ECT Scores of Gender

Variable	N	Correlation Coefficient	p-values
CCEQ	47	0.256	0.04
ECT	47		

Pearson Product-Moment Correlation was used to check correlation between CCEQ and ECT posttest mean scores for males and females. The results revealed that there was relationship between achievement and learners' perception of their chemistry classroom environment ($p < 0.05$). This therefore means that, as learners' perception of their chemistry classroom increases, it results in an increase in their performance on the ECT equally. This suggests that collaboration combined with text manipulation generated a positive classroom environment that resulted in improved performance for both males and females.

CONCLUSION

In conclusion, collaboration combined with text manipulations was equally effective for both males and females. In other words, males and females benefited equally when this self-designed teaching strategy was used. Hence, the designed teaching strategy has a promising potential to be used as a tool in the South African physical sciences classrooms in order to improve learners' conceptual comprehension in electrochemistry concepts in particular and chemistry in general. It was also found out in this study that there were no interaction effect between treatment teaching method and gender, indicating that the teaching strategy equally improves gender achievement. Finally, collaboration combined with text manipulation generated a positive classroom environment that resulted in improved performance for both males and females. This article contributes to the area of research on gender differences as it proves that collaboration combined with conceptual change texts as a conceptual change teaching strategy is equally effective for both males and females with a consequent improvement in achievement. However, more research is still required to determine factors related to gender differences in school science achievement, if any, as well as their possible causes. The findings of the study were limited to grade 12 physical sciences learners as well as variables investigated. Also, only rural high schools were used in the study and it is possible that the findings could have been different if urban high schools were used. Thus future researchers should make efforts to extend the study's scope to urban high schools and possibly increase the number of participating learners.

RECOMMENDATIONS and IMPLICATIONS

It is recommended to conduct a study with larger sample size ($n>47$) because research has shown that with larger sample size, statistical power will increase to get better statistical results (Ellis, 2010). Research on development of teacher training programmes about preparing and implementing collaboration combined with conceptual change texts (CCTs) in classrooms and effectiveness of this programme can be conducted. Although there was no interaction between the method and gender in this study, it is suggested that in further studies possible interaction of treatment and gender could be investigated. More research is needed to conclude that this method is equally effective for both males and females.

Implications: One of the strategies that teachers could use to eliminate misconceptions is collaboration and conceptual change texts based on conceptual change model of Posner et al. (1982). Several studies mentioned in this article have shown that constructivism minimises or eradicates gender differences in Science achievement (Balci, 2006; Dhindsa and Emran, 2011; Loofa, 2001; Önder, 2006) and help learners' gain proper comprehension of scientific concepts. This implies that both males and females could benefit equally from collaboration combined with CCTs. Teachers should design their lessons in such a way as to make learners have high and positive perceptions of their chemistry classroom environment to improve performance. The teacher must create a conducive environment during the instruction and must also provide equal chance of involvement for each learner during the instruction.

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