American Journal of Educational Research, 2018, Vol. 6, No. 6, 596-601
Available online at http://pubs.sciepub.com/education/6/6/3

DOI:10.12691/education-6-6-3

Facilitating Conceptual Change in Students' Comprehension of Electrochemistry Concepts through Collaborative Teaching Strategy

Kwaku Darko Amponsah[1,*], Chukunoye Enunuwe Ochonogor[2]

[1]Department of Science, OLA College of Education, Cape Coast, Ghana
[2]Department of SP & FET, Faculty of Education, Cape Peninsula University of Technology, Cape Town, South Africa
*Corresponding author: kwadaramp@gmail.com

Abstract This paper reports on a study to determine the effectiveness of collaborative teaching on physical sciences students' comprehension of electrochemistry in the Ximhungwe circuit of the Bohlabela district in the Mpumalanga province of South Africa. The design of the teaching strategy draws upon theoretical insights into perspectives of social constructivism and empirical studies to improve upon the teaching of the main topic, specifically galvanic cells, electrolytic cells and electrode potentials. In addition, the effect of collaboration as a teaching strategy on students' perception of their chemistry classroom environment was also investigated. A sample of 90 grade 12 physical sciences students from four intact public schools was conveniently selected to participate in the study. Students were given electrochemistry concept test (ECT) as well as chemistry classroom environment questionnaire (CCEQ) as pre-test and post-test. One-way analysis of covariance (ANCOVA) conducted showed that students taught using collaboration had significantly better acquisition of scientific conceptions related to electrochemistry than students taught using lecture method. Pearson Product-Moment Correlation also revealed that there was a significant positive relationship between achievement and students' perception of their chemistry classroom environment. However, ANCOVA and ANOVA results indicated that there was no significant contribution of students' perception of their chemistry classroom environment to their comprehension of electrochemistry concepts. This study provides statistical evidence on the importance of meaningful learning combined with social process to improve students' understanding of electrochemistry.

Keywords: *collaboration, electrochemistry, electrolytic cells, galvanic cells, social constructivism*

Cite This Article: Kwaku Darko Amponsah, and Chukunoye Enunuwe Ochonogor, "Facilitating Conceptual Change in Students' Comprehension of Electrochemistry Concepts through Collaborative Teaching Strategy." *American Journal of Educational Research*, vol. 6, no. 6 (2018): 596-601. doi: 10.12691/education-6-6-3.

1. Introduction

Several studies have reported misconceptions about electrochemistry and indicated that electrochemistry is 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 [1-5]. These studies indicate that most of the students lack conceptual knowledge because assessments in electrochemistry are mainly on algorithmic problems and as such students do not focus on concepts in electrochemistry. Reference [6] claimed that if teachers believe in the importance of teaching concepts in electrochemistry, they teach and assess concepts, so that conceptual knowledge of the students will also improve.

A number of studies proposed strategies to facilitate conceptual change in students' understanding of electrochemistry [7,8,9]. Reference [9] found that many South African students can solve quantitative electrochemical problems in examinations; few are able to answer qualitative questions requiring a deeper conceptual knowledge of electrochemistry. Lecture method of instruction appears to be one of the causes that foster difficulty. Similarly, Reference [10] conducted a research in two underperformed South African high schools using active learning model and a special form of cooperative learning strategy nick-named "goat and sheep method" with extra activities including animation to teach the experimental class. It was found out that upward of 87% of learners in the intervention class showed remarkably improved pass rate in quantity and quality in the post-test. He concluded that topics taught using this method became more learner-friendly to the learners/students while the educator also achieves higher confidence and proficiency in dealing with the subject with little efforts.

Some of the researchers also report that their techniques sometimes fail to completely overcome students' alternative conceptions on the various topics in science in general and electrochemistry in particular [1]. Accordingly, [4] indicated that using just one teaching method to accomplish conceptual change may in fact result in some disadvantages. According to them, it is generally not possible to find a course book or curriculum document that incorporates conceptual change text for all topics of study at school. In any case students soon become bored with continued reading of conceptual change texts or using only one method as it becomes too monotonous [11]. It is against this backdrop that this study used the collaboration approach (a type of group learning that is expected to facilitate and encourage meaningful learning) combined with conceptual change texts to facilitate students understanding of electrochemistry. Reference [12] stated that group learning facilitates meaningful learning and new knowledge construction. Thus, if meaningful learning is to be achieved, then correct knowledge structuring could be enhanced; thereby eliminating misconceptions in order to enhance students' achievement in electrochemistry.

2. Theoretical Framework

Conceptual change theory describes learning as a situation of comprehending and accepting ideas because they are seen as intelligible and rational [13]. Conceptual change refers to the idea that students acquire as new learning experience with a host of prior experiences and beliefs for which they have constructed explanations that work for them. The conceptual constructs shown or developed by students in the classroom may be naïve, premature, or actually incorrect in relation to accepted science [14]. This implies that teaching for conceptual change would mean engaging students in developing new comprehension of science phenomena [15]. This involves helping students to correct their miscomprehensions, facilitate the reorganization of their naïve concepts into useable, integrated comprehensions and develop intellectual tools useful to them in a variety of contexts [16]. 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. Discrepancies inevitably results as members of a collaborating group express their differing renditions of the problem they are confronted with. This discrepancy may provide the kind of dis-equilibrating event that provokes the dissatisfaction described by [13]. What follows among the group members is a negotiation of these discrepancies. In fact, many studies have shown the importance of students` joint discourse has on achievement [17]. The conceptual change theory of [13] strongly prove 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 their short- and long-term memory, once exposed to the learning process. Reference [18,19] 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 inter-psychological plane (between individuals) to the intra-psychological (within an individual) plane with the assistance of knowledgeable members of the culture; and (c) language mediates experience, transforming mental processes. Additionally, [20] emphasized that science teachers should understand the importance of constructivism especially in terms of the discourse that happens. In tandem with the perspective of Vygotskian model of social constructivism, schooling is responsible for the creation of a social context of learning insofar as the individuals turn out to be immensely proficient with the deployment of the cultural tools [21]. Thus, the idea of collaboration can be understood as the interactions that take place whereby the participants in a symbiotic manner tend to discover the pertinent solutions as well as generate knowledge in association with each other [21]. Furthermore, the idea of collaboration involves learning experiences, which facilitate a social context in association with which the learners understand one another by jointly working together. In the course of the process of collaboration, the students jointly operate together in order to solve a problem. Accordingly, [19] and [22] have indicated that the role of social interaction in the development.

3. Statement of the Problem

Pre-tertiary education in South Africa is bedeviled with many challenges especially in mathematics and science, which have been labeled as scarce skills subjects. As a result, the South African government, over the years have been recruiting expatriate teachers to help learners to improve their achievement in these subjects. Even though the expatriate teachers continue to support the students, their effort is still not enough to cause a quantum leap in student achievement. Thus, the centre of interest of this study is that high school students in South Africa have been performing poorly in physical sciences in general and in topics in electrochemistry in particular, since 2009, when the National Senior Certificate (NSC) examination was introduced [23]. It has become a common observation that the goal of promoting scientific literacy, with its component standards and strategies designed to promote student communication, is not being met in most science classrooms today. Instead, communication in science classrooms is in the form of teacher-talk with reproductive comprehension by the students [24]. According to them, teachers talk and students listen, and lengthy, on-subject discourse in classrooms seldom occur. 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 countenance any lengthy classroom discourse. Most rural schools do not have science laboratories let alone science equipment and chemicals. Practical investigation with hands on experiences is virtually nonexistent. 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. To supplement these efforts, the Department of Education of Mpumalanga Province (DEMP) is continuously putting in place programmes to facilitate and improve student performance in the NSC examinations. Examples of such programmes organized by the Department of Basic Education (DBE) to improve performance of grade 12 students in particular in physical sciences include Winter schools, Spring schools, as well as special weekend camps where expert teachers are brought together to teach students. Despite all these efforts, majority of grade 12 students still perform poorly, especially in the Bohlabela district of the Mpumalanga Province in the final NSC examinations. Results in physical sciences, paper 2 (chemistry) and electrochemistry continue to decline since 2010 [23] except in 2012. It is against this backdrop that this study was carried out to to determine the effectiveness of collaborative teaching strategy on physical sciences students' comprehension of electrochemistry in the Ximhungwe circuit of the Bohlabela district in the Mpumalanga province of South Africa.

4. Purpose of the Study

Based on the problems highlighted, the study designed a conceptual change teaching strategy (CCTS), specifically collaborative learning to enhance students' comprehension of electrochemistry. It was also to investigate the conceptual changes in science conceptual comprehension that take 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. It is the primary tool that the students use to negotiate their conceptual comprehensions when faced with other students having different comprehensions about the same task. This study analyzed the collaborative discourse with CCTs as a teaching strategy in order to understand the group dynamics and their effects on conceptual comprehension. It was all aimed at possibly enhancing students' comprehension and improving their performance in Physical Science.

5. Null Hypotheses

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

1. Ho_1: there is no statistically significant mean difference in post-test mean scores between students taught electrochemistry concepts with conceptual change teaching strategy and those taught with lecture teaching method.
2. Ho_2: there is no statistically significant difference in post-test mean scores of students` perception of chemistry classroom environment between students taught electrochemistry concepts with lecture method and those taught with conceptual change teaching strategy.
3. Ho_3: there is no statistically significant relationship between physical sciences students' post-test mean scores on their perception of their chemistry classroom environment and their achievement in electrochemistry concepts.

6. Methodology

6.1. Research Design

The study was based on a quasi-experimental non-equivalent pre-test-post-test group control research design. A quasi-experimental design was appropriate for this study because it was not possible to randomly assign students to a particular class section, so convenience sampling was used [25]. Students were not randomly assigned as individuals to experimental groups and control groups in the study. Therefore, the researcher used quasi experimental research design where all students within any particular classroom were assigned as an intact group to serve as an experimental group (EG) or control group (CG).

Four pre-established or intact groups (classes) were used in this study. ECT was administered as pre-test for 60 minutes whereas CCEQ was administered for 20 minutes in the week before the treatment instruction began. The same pretest and the post-test instruments, CCEQ and ECT were administered to both control and experimental groups. The Post-test was administered after the treatment. According to the pace setter for grade 12 physical sciences, teachers should use 8 hours to teach electrochemistry in two weeks, four hours per week, one hour per class period. But for the purposes of this research each school had one and half hours per class period as a result of the activities the students were involved in. Instructions were held after normal school hours as prescribed by the Mpumalanga Department of Education Research unit.

Of the four schools selected for the research, two schools represented the control group and the other 2 schools represented the experimental group. Both groups were taught by two teachers. Each teacher taught one experimental group and one control group. The treatment took four weeks. Each group had two Chemistry periods of three hours duration each per week. The main materials in this study were conceptual change texts (CCTs), prepared by the researchers based on students' misconceptions in electrochemistry retrieved from literature. The other materials were formula sheet and electrode potential tables relevant to the study of electrochemistry. The materials were checked by two experienced chemistry teachers and a chief marker of chemistry (physical sciences paper 2). Furthermore, the researchers also checked the instrument for validation. For the control group no materials were prepared for them because the teacher was expected to have the materials that he previously used for his students but should be similar to that of the experimental group in terms of scope and questions assigned after teaching.

To use this template, you will need to (1) apply the embedded styles to each paragraph-level item in your manuscript or (2) use the specifications shown in Table 1 to format your manuscript, with this template as a visual guide. Information about paper submission is available from the Journal website.

7. Results and Findings

The researchers undertook a one-way analysis of covariance to find out whether the two teaching methods used in the study have effect on the performance of learners. The instruction method, either conceptual change teaching strategy (CCTS) or traditional teaching method (TTM) was the independent variable. The dependent variable was the students' comprehension of electrochemistry concepts (post-test scores), and the covariate was students' pre-test scores. The interaction term was not included in the ANCOVA output as the presumption of homogeneity of regression slopes has already been validated. The hypotheses were analysed as follows:

Ho_1: there is no statistically significant mean difference in post-test mean scores between students taught electrochemistry concepts with conceptual change teaching strategy and those taught with traditional teaching method.

The results of ANCOVA analysis are presented below in Table 1.

Table 1. ANCOVA Summary on Comprehension for CG and EG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2335.609	2	1167.805	21.677	.000	.333
Intercept	2166.197	1	2166.197	40.210	.000	.316
Pre-test	1477.261	1	1477.261	27.422	.000	.240
Teaching method	1523.193	1	1523.193	28.274	.000	.245
Error	4686.891	87	53.872			
Total	204425.000	90				
Corrected Total	7022.500	89				

a. R Squared = .333 (Adjusted R Squared = .317).

After adjustment for pre-test scores, there was a statistically significant difference in post-test scores between the interventions, P (1.87) = 28.274, $p < .0005$, partial $\eta^2 = .245$. From Table 1 the relationship between instruction method and comprehension of electrochemistry concepts was found to be positive. Instruction method accounted for 24.5% of the variance of the dependent variable when the pre-test is controlled as a covariate. Table 2 shows that when post hoc analysis was performed with a Bonferroni adjustment, the experimental group had the highest post-test scores, which was statistically significantly higher than the post-test scores of the control group ($p < .0005$).

Table 2. Pairwise comparison between experimental and control groups

Teaching method		Mean Difference	Std Error	Sig.
Control	Experimental	-8.592	1.616	.0005
Experimental	Control	8.592	1.616	.0005

The ANCOVA results presented in the previous section showed that there was a significant difference between the post-test 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. Table 3 presents the post-test means and standard deviations of the control and experimental groups.

Table 3. Mean and Standard deviation for CG and EG

Teaching Method	Mean	Standard deviation	N
Control	43.60	7.426	43
Experimental	49.79	9.146	47
Total	46.83	8.883	90

The results from Table 3 indicate a post-test ECT mean score of 49.79 for the experimental group as higher than a post-test ECT mean score of 43.60 for the control group. This suggests that the experimental group benefitted tremendously from the CCTS compared with the control group, who had to go through the traditional teaching method (TTM).

Ho_2: there is no statistically significant difference in post-test mean scores of students` perception of chemistry classroom environment between students taught electrochemistry concepts with lecture method and those taught with conceptual change teaching strategy.

The results are presented in Tables 4 and 5 showing the means, standard deviation; and one-way MANOVA report.

Table 4. Mean (M) and Standard Deviation (SD) Responses for EG and CG on Chemistry Classroom Environment (CCE) Sub-scales

CCE Sub-Scale	Variability			
	Experimental		Control	
	Mean	SD	Mean	SD
Student Cohesiveness [SC]	3.78	0.57	4.32	0.41
Teacher Support [TS]	3.49	0.94	4.40	0.71
Involvement [IV]	3.47	0.70	4.06	0.58
Cooperation [CO]	3.63	0.68	4.35	0.97
Equity [EQ]	3.79	0.88	4.28	0.66
Total	3.63	0.75	4.28	0.67

N=43 Control; N=47 Experimental.

The results in Table 4 showed that students taught with the conceptual change teaching strategy had a higher perception of their chemistry classroom environment than those taught by the traditional teaching method.

For further analysis, one-way MANOVA was used to determine if there were statistically significant differences between the two groups of students in terms of their perceptions of their chemistry classroom environments. The MANOVA test presented in Table 5 showed that the

Wilks' lambda (λ) value of 0.66 was statistically significant, $F(5, 85) = 10.42$; $p < .05$; partial eta squared = .345.

Table 5. One-way MANOVA on CCE scales and type of school

Effect	Value	F	Hypothesis (df)	Error (df)	p-values
Variability	0.66	10.42	5.00	85.00	0.0005

Significant p<.05.

This suggests that the population mean scores on the five sub-scales of chemistry classroom environment are not the same for the EG and CG and hence the hypothesis was therefore rejected. This means that there is a statistically significant difference between the perceptions of physical sciences students in the experimental and control groups across the five sub-scales of their chemistry classroom environment. As a follow-up test to the MANOVA, a one-way ANOVA with teaching method as the independent variable was conducted for each of the five sub-scales of the chemistry classroom environment as shown in Table 6.

As shown in Table 6, all sub-scales of the chemistry classroom environment were statistically significant using a Bonferroni adjusted alpha level of 0.05. The partial eta squared values recorded for the five sub-scales indicate that all five sub-scales account for the variances in physical sciences students' perceptions of their chemistry classroom environment in CG and EG. However, it is the ANOVA which has shown where the significant differences in the post-test means exist in the sub-scales.

Table 6. Results of ANOVA as a follow up to the one–way MANOVA on the five sub-scales of chemistry classroom environment

CCE Sub-Scales	df	Mean Squared	F	p-values	Partial Eta Squared
Student Cohesiveness	1	488.6	30.5	0.0005*	0.228
Teacher support	1	1391.1	30.5	0.0005*	0.229
Involvement	1	578.3	21.8	0.0005*	0.175
Cooperation	1	866.3	19.8	0.0005*	0.161
Equity	1	413.9	10.5	0.002*	0.093

*Bonferroni Adjusted significant at P<.05.

Ho_3: there is no statistically significant relationship between physical sciences students' post-test 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 7.

Table 7. Correlation between CCEQ and ECT Scores of EG Students

Variable	N	Correlation Coefficient	p-values
CCEQ	90	0.556	0.04
ECT	90		

Pearson Product-Moment Correlation was used to check correlation between CCEQ and ECT post-test mean scores. The results revealed that there was a statistically significant strong and high relationship between achievement and students` perceptions of their chemistry classroom environment (p < 0.05). As shown in Tsble 6 the higher the students' perceptions of their chemistry classroom, the higher was the performance of students on the ECT.

8. Conclusion

Conceptual change teaching strategy provided better understanding of electrochemistry concepts for experimental group as compared with the control group. There was a statistically significant difference in the post-test mean scores between experimental groups. Post-test mean scores for experimental group as well as their corresponding mean gain scores were higher than those of the control group. There results of the study showed the need of the using collaboration combined with conceptual change texts which contributed to making differences in the achievements of experimental group.

The findings of this study have provided some empirical evidence that many students do have conceptual difficulties in electrochemistry learning area. Yet, the results do not support any assumption that usual classroom teaching of simple lecture method has provided needed support for students to generate detailed, factual explanations about the chemical phenomena. 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 has been determined to a great extent with students in the experimental group having acquired higher level of conceptual understanding in comparison to the controlled group of the study.

9. Recommendations

The designed teaching strategy of this study has the 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 and Physical Science teachers should endeavour to determine necessary concepts in the chemistry syllabus and apply relevant instructional strategies such as collaboration combined with conceptual change text for improved achievement of students. This approach will further improve the efficiency and effectiveness of the teachers.

10. Limitations

The most crucial limitation of the research was the sampling technique, as intact groups were employed in the present research; thus, it was likely to have limited generalizability. A research that uses random sampling and a big sample size would provide more precise inferences and offer superior generalizability. The sample could also symbolise a bigger population.

11. Implication

The outcomes in the present research recommend these implications for chemistry teaching in secondary schools:

- Teachers need to know the variation between learning by heart and purposeful learning and must plan their teaching to encourage purposeful learning.
- Students come to the class with their prior concepts about chemistry topics. It is imperative therefore for teachers to identify students' preconceived ideas before any topic is started. Recognising Alternative conceptions could direct the instructor to eradicate Alternative conceptions.

Acknowledgements

The University of South Africa is hereby acknowledged for granting the primary researcher a bursary and ethical clearance that enabled this work to be carried out. The Mpumalanga Department of Education is also acknowledged for granting the researcher permission to conduct the study in the Province.

References

[1] Ahmad, N. J & Che Lah, Y. (2012). Improving Students' Conceptual Understanding of a Specific Content Learning: A Designed Teaching Sequence. http://files.eric.ed.gov/fulltext/ Retrieved on 16 March, 2015.

[2] Al-Balushi, S. M, Ambusaidi1, A. K, Al-Shuaili, A. H. & Taylor, N (2012). Omani twelfth grade students' most common misconceptions in chemistry. Science Education International, 23(3), 221-240.

[3] Karsli, F. Ayas, A. (2013). Is it Possible to Eliminate Alternative Conceptions and to improve Scientific Process Skills with Different Conceptual Change Methods? 'An Example of Electrochemical Cells. Journal of Computer and Educational Research, 1(1), 1-26.

[4] Karslı, F. & Çalık, M. (2012). Can Freshman Science Student Teachers' Alternative Conceptions of 'Electrochemical Cells' Be Fully Diminished? Asian Journal of Chemistry, 23, 12, 485-491.

[5] Özkaya, A., Üce, M., and Şahin, M. (2003). Prospective teachers' conceptual understanding of electrochemistry: Electrochemical and electrolytic cells. University Chemical Education, 7(1), 1-12.

[6] Sanger, M. J. & Greenbowe, T. J. (2000). Addressing student misconceptions concerning electron flow in aqueous solutions with instruction including computer animations and conceptual change strategies. International Journal of Science Education, 22(5), 521-537.

[7] Niaz, M. (2002). Facilitating conceptual change in students' understanding of electrochemistry. International Journal of Science Education, 24(4), 425,439.

[8] Yang, E., Andre, T. & Greenbowe, T. J. (2003). Spatial ability and the impact of visualization/animation on learning electrochemistry. International Journal of Science Education, 25(3), 329-349.

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

[10] Ochonogor, C. E. (2011). Beyond the Usual Approach of Chemistry Teaching in High Schools. US-China Education Review B, 5, 643-653.

[11] Orgill, M. & Bodner, G. (2004). What Research Tells Us About Using Analogies to Teach Chemistry. Chemistry Education Research and Practice in Europe, 5(1), 15-32.

[12] Novak (2002). Meaningful Learning. Science Education. 548-571.

[13] 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.

[14] Duit, R. (2003). Conceptual change: a powerful framework for improving science teaching and learning. International Journal of Science Education, 25(6), 671-688.

[15] Dykstra, D. I. J. (2005). Against realist instruction: Superficial success masking catastrophic failure and an alternative. Constructivist Foundations, 1(1), 49-60.

[16] Suping, S. M. (2003). Conceptual change among students in science. Retrieved from www.eric.ed.gov Retrieved on 24 February, 2016.

[17] 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.

[18] Vygotsky, L. (1962). Thought and language, Cambridge, MA: MIT Press.

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

[20] Mercer, N. (2002). Words and minds: How we use language to think together. London: Routledge.

[21] Smagorinsky, P., and O'Donnell-Allen, C. (2000). Idiocultural diversity in small groups: The role of the relational framework in collaborative learning. In P. Smagorinsky and C. D. Lee (Eds.), Vygotskian perspectives on literacy research: Constructing meaning through collaborative inquiry (pp. 165-190). Cambridge: Cambridge University Press.

[22] Wertsch, J. V. (1991). Voices of the mind: A sociocultural approach to mediated action. Cambridge: Harvard University Press.

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

[24] Driver, R., Newton, P. & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. Science Education, 84, 287-312.

[25] Gliner, J. A., Morgan, G. A. & Leech, N. L. (2011). Research Methods in Applied Settings: An Integrated Approach to Design and Analysis (2nd Ed.). New York: Taylor and Francis Group. Pp. 59-60.