STUDENTS' AND TEACHERS' ALTERNATIVE CONCEPTIONS ABOUT ELECTROCHEMISTRY

Sipho Nhlanhla Dlamini[1] & CE Ochonogor[2]
University Of South Africa[1] & Cape Peninsula University of Technology[2]
30498597@mylife.unisa.ac.za[1], Ochonogorc@cput.ac.za[2]

ABSTRACT–The aim of this research was to explore the alternative conceptions about galvanic cells by both teachers and students. The achievement of students has been low in the galvanic cells questions over the past years which is of a great concern and had not been researched on, in Mpumalanga, South Africa. The main research question was: How can teachers' and students' alternative conceptions about galvanic cell in electrochemistry be addressed to improve students' achievement? Research efforts had been on teaching strategies to address alternative conceptions about galvanic cells and no studies available to the researchers, have been reported on the latest alternative conceptions nor reported on how teachers had tried to address these alternative conceptions in recent times. Alternative conceptions about galvanic cells, teaching strategies and teaching approaches form part of the conceptual framework. Convergent mixed method with teachers' and students' questionnaires, teacher and student interview schedules as research instruments was adopted for. Atlas.ti and SPSS software were used for analysis. The results showed a relationship between teachers' and students' levels of alternative conceptions; and relationship between the level of students` alternative conceptions and their examination achievements. Qualitative results revealed that both teachers and students show alternative conceptions about galvanic cells, and were supported by the quantitative findings.
Keywords: Alternative conception; Electrochemistry; Galvanic cell.

1. INTRODUCTION

Sanger and Greenbowe (1997) studied the alternative conceptions relating to the flow of current in electrolytes and within a salt bridge and developed a table of coded alternative conceptions. Davidowitz & Potgieter (2011) and Huddle & White (2000) conducted a study of electrochemistry alternative conceptions on first-year university students in South Africa. It was discovered that first year students display alternative conceptions in electrochemistry. This could result from the lack of adequate conceptual understanding of electrochemistry concepts. Researchers like Sanger & Greenbowe, (1997) in the field of electrochemistry documented and coded quite a number of ALTERNATIVE conceptions in electrochemistry. The data from these researchers on alternative conceptions in electrochemistry were used to select some alternative conceptions about galvanic cells that were studied in this research. Alternative conceptions about galvanic cells of students and teachers were identified in the research sample. The research looked at the relationship between the level of alternative conceptions about galvanic cells of teachers and students and the level of achievement of students in the examination. This paper reveals the latest alternative conceptions shown by teachers and students about galvanic cells. Teaching strategies that practicing teachers with experience had employed in order to address alternative conceptions about galvanic cells are well discussed in the text. The paper also discusses the alternative conceptions about galvanic cells from teachers' perspectives as well as teaching strategies that teachers employ to address these alternative conceptions for the improvement of student achievement.

2. Conceptual framework

Teaching approaches like the teacher-centred approaches and student-centred approaches (Arends, 2012 and Burden and Byrd, 2013) were part of the concepts in the conceptual framework of this research. The teaching approaches are: Student-centred approach with sub- approachesas *Cooperative approach, Problem-based approach, Discussion approach, Simulations and games*, *Inquiry-based teaching approach;* while teacher-centred approach include the following sub-approaches: *Lecture approach, Direct instruction, Demonstration, Modelling approach and Socratic approach*.

The teaching strategies to address identified alternative conceptions about galvanic cells as investigated by many researchers like Huddle and White (2000) on model to teach electrochemistry; Avargil, Bruce, Amar and Bruce (2015) on three-phase learning cycle known as CORE (Chemical Observations, Representations, Experimentation); Karamustafaoğlu and Mamlok-Naaman (2015) on Predict-Observe-

Explain (POE) strategy; Lee and Osman (2012) on interactive multimedia module with pedagogical agent (IMMPA) named 'EC Lab' to assist in students' understanding of electrochemistry also formed part of the conceptual framework of this research. Nine alternative conceptions about galvanic cells as documented by Sanger & Greenbowe, (1997) and others were also chosen as part of this research's conceptual framework. The teaching approaches and teaching strategies were used as reference posts to study teachers' and students' alternative conceptions about galvanic cells in this research.

3. Objectives of the study

The main objective of the study was to explore the approaches and strategies that teachers employ to address alternative conceptions about galvanic cells in order to improve students' achievement. This was to: 1. to identify students' alternative conceptions about galvanic cells in electrochemistry; 2 to identify teachers' alternative conceptions about galvanic cells in electrochemistry; 3. to compare the levels of alternative conceptions of students and teachers about galvanic cells in electrochemistry. Furthermore, it was to: 4. compare the students' level of alternative conceptions about galvanic cells with the students' level of achievement in the examinations; and 5. to assess how teachers address alternative conceptions about galvanic cells known to them in order to improve students' level of achievement in the examination.

4. Research questions and hypotheses

The main research question posed in this paper was: How can teachers' and students' alternative conceptions about galvanic cells in electrochemistry be addressed to improve students' achievement? The research sub-questions were: 1. What are the students' alternative conceptions about galvanic cells in electrochemistry? 2. What are the teachers' alternative conceptions about galvanic cells in electrochemistry? 3. What is the relationship between teachers' and students' level of alternative conceptions about galvanic cells in electrochemistry? 4. What is the relationship between students' level of alternative conceptions about galvanic cells and their examination achievements in galvanic cells? 5. How do teachers address alternative conceptions about galvanic cells that are known to them in electrochemistry? The following two null hypotheses were stated and tested in this study: H_{01}: There is no statistically significant relationship between teachers' and students' level of alternative conceptions about galvanic cells. H_{02}: There is no statistically significant relationship between the level of students` alternative conceptions about galvanic cells and their examination achievements.

5. Methodology

5.1. Population, sample and sampling technique

The Physical Science teachers and students of the one hundred and one Mathematics, Science and Technology (MST) Academy schools in the whole Mpumalanga province constituted the population of this study. The sampling technique was stratified sampling. Five strata were taken from Nkomazi municipality as the circuits that make up the municipality. Five MST Academy schools were sampled from the five strata with one school from each circuit. The sampling technique was a convenience sampling within one municipality since not all the MST academy school spread all over the province were well represented.

The study was carried out on a sample of five schools. 160 out of 171 questionnaires were received back from the students and all the six questionnaires were received back from the teachers who participated in the study. Since the context of the study was mathematics, Science and Technology Academic schools, all participants were drawn from Ehlanzeni district of Mpumalanga Province. Furthermore, 208 trial examination scripts of students from the five schools were used to generate marks obtained by students in the galvanic cell question.

5.2. Research design

This study adopted a pragmatic approach paradigm employing a mixed-method design which uses both qualitative and quantitative research data in a research (Creswell, 2015; Leedy and Ormrod, 2016). The epistemology in pragmatism considers a phenomenon to be observable and that subjective meanings provide acceptable knowledge according to a research question; while ontology in pragmatism is of external and of multiple realities. (Creswell, 2014, Mertens, 2014 and Wahyuni, 2012). Teachers and students provided their own meanings around alternative conceptions about galvanic cells in their own respective school realities. Convergent (mixed method) design was used to collect both quantitative and qualitative data at the same time with respect to the same general research problem (Leedy & Ormrod, 2016). The data generated from both qualitative and quantitative questionnaires were used for both identification of alternative conceptions about galvanic cells for the purpose of triangulation of data and results. The quantitative data was use to find out if there was any relationship between students' and teachers' level of alternative conceptions as well as if there is any relationship between levels of students' alternative conceptions about galvanic cells and their level of achievement in the examination. The qualitative data were further used to find out teaching approaches and strategies teachers use in their classes to address alternative conceptions about galvanic cells. These two sets of data were analyzed to answer the research sub-questions of the research.

5.3. Data collection instruments

5.3.1. Questionnaires and interview schedules

Questionnaires and interview schedules were the two instruments used to collect data for this study. Teachers' and students' questionnaires were used to collect data for quantitative data to triangulate the qualitative data. The Likert scale statements in the teachers' and students' questionnaires were the same. Reliability test was performed on the quantitative instruments for internal reliability using the Cronbach Alpha and was found to be 0.7. This value indicated a strong reliability value for the instruments. Responses to teachers' interview schedule and students' interview schedules were also used to answer the research sub-questions and for triangulation of quantitative data. The interview schedules were checked by the physical science provincial coordinator, natural science provincial coordinator and a grade 12 physical science teacher with a master's degree in curriculum studies. Data generated from teachers' interview schedule and students' interview schedule were the only basis to answer research sub-question 5 raised in this research.

5.4. Data Analysis

Identification and confirmation of alternative conceptions about galvanic cells using the Likert scale which had 1. Strongly Agree, 2. Disagree, 3. Not sure 4. Disagree and 5. Strongly agree, was carried out. Strongly agree and agree were considered as agree and disagree and strongly disagree as disagree in the process of analysis. All the disagree and strongly disagree responses were considered to have alternative conceptions about galvanic cells. Not sure responses were taken as lack of knowledge about the galvanic cell concepts. The data from teachers' and students' questionnaires were analyzed using the Pearson's correlation statistic with SPSS version 21 to test the two null hypotheses of the study. Null hypothesis 1: There is no statistically significant relationship between teachers' and students' level of alternative conceptions about galvanic cells. The result showed that all the p-values were $0.000 < 0.05$ which led to the rejection of the first hypothesis. In other words, there is statistically significant relationship between teachers' and students' level of alternative conceptions about galvanic cells. Null hypothesis 2: There is no statistically significant relationship between the level of students` alternative conceptions about galvanic cells and their examination achievements. The analysis also showed p= 0,000 less p value of 0.05. This proved that there is a statistically significant relationship between the level of students` alternative conceptions about galvanic cells and their examination achievements.

The teachers' and students' interview schedules were analyzed with the Atlas.ti software. Qualitative results revealed that both teachers and students show alternative conceptions about galvanic cells, and these were supported by the quantitative findings. Some teaching strategies and approaches to address alternative conceptions about galvanic cells were found with the qualitative instruments to be used by teachers to address alternative conceptions about galvanic cells in their classes.

5.5. Findings

5.5.1. Quantitative findings

5.5.1.1. Teachers' and students' alternative conceptions about galvanic cells

Common alternative conceptions about galvanic cells were found to exist among students and teachers which are priori coded as E1-E10. The codes in brackets are the international codes used in this report. The following alternative conceptions were found in the study to be in agreement with those listed by Sanger & Greenbowe, (1997) and others. They were triangulated between teachers' and students' quantitative data: E1: Standard reduction potentials list metals by decreasing reactivity (8b), E3: In an ordered table of reduction potentials, the species with the most positive E° value is the anode (8a), E5: Electrons move in a solution by one ion being attracted to another (10b), E7: The anode is positively charged because it has lost electrons; the cathode is negatively charged because it has gained electrons, E8: Electrons enter the solution from the cathode, travel through the solutions and the salt bridge and then emerge at the anode to complete the circuit, E9: Electrons move through a solution by being attracted to the ions at the cathode and are carried by those ions to the anode (2i), and a new finding , E10: Ions from the one half-cell and the other half-cell move through the salt bridge to maintain electrical neutrality.

5.5.1.2. The relationship between teachers and students 'alternative conceptions about galvanic cells

The 1^{st} null hypothesis was rejected since the p-value were $0.000 < 0.05$, hence a conclusion was made that there exists a statistically significant relationship between teachers' and students' level of alternative conceptions about galvanic cells.

5.5.1.3. The relationship between the level of students' alternative conceptions and students' examination achievement about galvanic cells

The 2^{nd} null hypothesis was also rejected since p= 0,000 was less than required p value of 0.05, hence a conclusion was made that there is a statistically significant relationship between the level of students' alternative conceptions about galvanic cells and the examination achievement of students.

5.5.2. Qualitative findings

5.5.2.1. Teachers' and students' alternative conceptions about galvanic cells

The qualitative findings also showed that teachers and students had the following alternative conceptions about galvanic cells as Sanger & Greenbowe, (1997) documented: E1: Standard reduction potentials list metals by decreasing reactivity (8b), E5: Electrons move in a solution by one ion being attracted to another (10b), E7: The anode is positively charged because it has lost electrons; the cathode is negatively charged because it has gained electrons (11b), E8: Electrons enter the solution from the cathode, travel through the solutions and the salt bridge and then emerge at the anode to complete the circuit (10a) and the new one E10: Ions from the one half-cell move to the other half-cell through the salt bridge to maintain electrical neutrality.

The following were revealed by teachers as alternative conceptions about galvanic cells according to their perspective which stand as new findings of this study. These were inductively coded as ACs: AC

Anode and cathode are similar, AC2: Gaseous electrode and solid electrode are the same concept, AC3: Any gaseous electrode is hydrogen electrode, AC4: Cell notation and cell reaction are synonymous, AC7: Ions move through the salt-bridge, AC 10: EMF is independent of concentration, which are not found in Sanger & Greenbowe, (1997) list of alternative conceptions in electrochemistry. E10 as a new finding surfaced again as an alternative conception that teachers perceived as an alternative conception about galvanic cells.

5.5.2.2. Teachers' teaching approaches and teaching strategies

Teachers were asked to share how they address the above alternative conceptions of students that are known to them as listed in the above paragraph. The findings were categorized into teaching approaches and strategies employed by teachers to address alternative conceptions as per conceptual framework of this research. The Table 1 below summarizes the prevalent teaching approaches and strategies used by teachers to address alternative conceptions about galvanic cells:

TEACHING APPROACH		TEACHING STRATEGY	
Student-centred	Teacher-centred	Student-centred	Teacher-centred
Group work	Direct instruction	Experiment	Prompt
Discussion	Demonstration		

Table 1: Teaching approaches and strategies

The following were found to be prevalent among the teachers on triangulation of the both teachers' and students' qualitative data: 1. teaching approaches: Group work and discussion which are student-centred approaches; direct instruction and demonstration which are teacher-centred approaches. 2. Teaching strategies: Experiment is student-centred teaching strategy while prompt is a teacher-centred strategy. Prompt is some kind of teacher-centred strategy that teachers use to assist students to remember the learned content in galvanic cells. Direct instruction, discussion and demonstration (Arends, 2012; and Burden and Byrd, 2013) are well documented in science education books. The teaching strategies and approaches to address alternative conceptions about galvanic cells were investigated through the qualitative data.

6. Conclusion

The quantitative data were triangulated with the qualitative data as well as teachers' data was also confirmed with students' data. The following alternative conceptions about galvanic cells were found in the qualitative and quantitative data sets of both teachers and students: E1: Standard reduction potentials list metals by decreasing reactivity (8b), E3: In an ordered table of reduction potentials, the species with the most positive E° value is the anode, E5: Electrons move in a solution by one ion being attracted to another (10b), E7: The anode is positively charged because it has lost electrons; the cathode is negatively charged because it has gained electrons (11b), E8: Electrons enter the solution from the cathode, travel through the solutions and the salt bridge and then emerge at the anode to complete the circuit (10a), E9: Electrons move through a solution by being attracted to the ions at the cathode and are carried by those ions to the anode(2i), and the new finding E10: Ions from the one half-cell and the other half-cell move through the salt bridge to maintain electrical neutrality. The 1st null hypothesis was rejected since all p-values were $0.000 < 0.05$ hence a conclusion was made that there is a statistically significant relationship between teachers' and students' level of alternative conceptions about galvanic cells. It can then be concluded that teachers unconsciously hand down their alternative conceptions about

galvanic cell to their students. The 2nd null hypothesis was also rejected since p= 0,000 was less than required p value of 0.05 hence a conclusion was made that there is a statistically significant relationship between the level of students' alternative conceptions about galvanic cells and the level of examination achievement of students. These relationships led to a conclusion that the alternative conceptions of students about galvanic cells infiltrate through to reflect in the level of achievement of students in the examinations. Hence the achievement of students in the examination is affected by their alternative conceptions. This infiltration is independent of the attempts teachers employ to address alternative conceptions about galvanic cells.

Data on teaching approaches and strategies were confirmed within the qualitative data of teachers and students. The following teaching approaches and strategies were discovered to be used by teachers to address alternative conceptions about galvanic cells. It is of notable interest that one teaching strategy from the range of teaching strategies listed in literature appears in the above table and that is experiment (Karamustafaoğlu, & Mamlok-Naaman, 2015). Experiment appears to be the only student-centred strategy used by teachers to address alternative conceptions about galvanic cells. The experiment was not even used the way Karamustafaoğlu, & Mamlok-Naaman, (2015) suggested in the predict-observe-explain strategy where prediction is part not only observe and explain. Teachers used experiment for demonstration purposes and also for group work and that is where discussion features as well. Teaching of the students in the sampled schools seemed to follow a kind of teaching model that used teaching approaches and teaching strategies that are mainly teacher centred. It would then be logical to consider teachers' tendency to use mainly teacher-centred approaches and strategies. Below is a proposed model of this research towards addressing the alternative conceptions about galvanic cells after having analyzed how teachers addressed alternative conceptions.

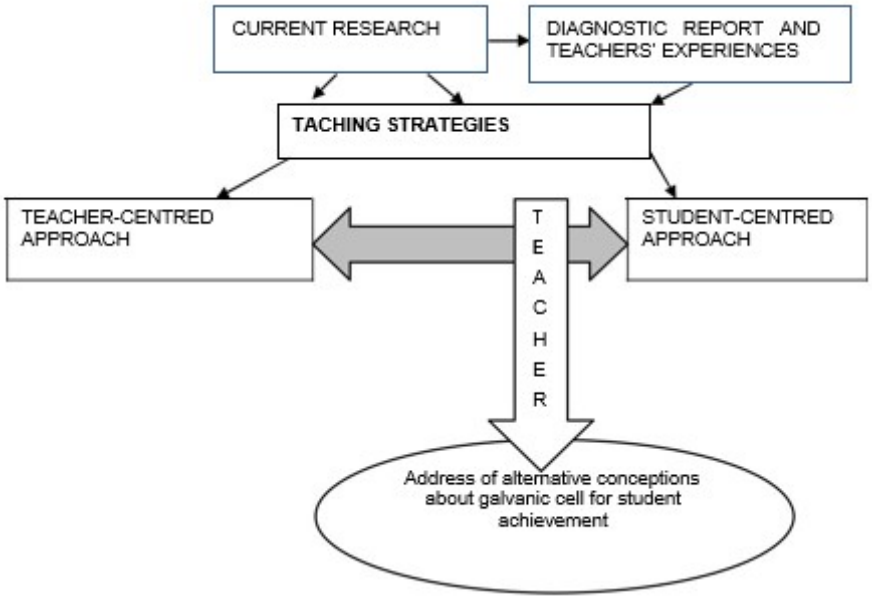

Figure 1: Teacher-student continuum model: A proposed model to address alternative conceptions about galvanic cells

The model presented above suggest that teacher need to lean more towards student-centred teaching strategies in an attempt to address alternative conceptions about galvanic cells for student achievement. It combines both teacher-centred and student-centred approaches to address alternative conceptions. The above proposed model attempted to accommodate the merits of teacher-centred strategies with student-centred strategies in teaching as a measure of its strength.

This research concluded on the main questions that states: How can teachers' and students' alternative conceptions about galvanic cell in electrochemistry be addressed to improve students' achievement? Teaching strategies to address alternative conceptions need not only come from the diagnostic report

and teachers' teaching experiences but also from research literature since there are a variety of teaching strategies that are student-centred that addresses alternative conceptions about galvanic cells.

Alternative conceptions about galvanic cells might be transferred from teachers to students during teaching, which in turn eventually reflects in the achievement of students in the examination. The proposed model above can then be of assistance to combine teaching strategies that are teacher-centred and student-centred in order to address alternative conceptions about galvanic cells, but the teaching need to be inclined towards student-centred teaching strategies. Students` alternative conceptions about galvanic cells can then be avoided to improve the achievement of students in the examination.

REFERENCES

Arends, R.I. (2012). Learning to teach. (9th ed.). Singapore: McGraw-Hill International edition

Burden, P.R. and Byrd (2013). Methods for Effective Teaching: Meeting the Needs of All Students (6th ed.).United States of America: Pearson Education

Avargil, S., Bruce, M. R., Amar, F. G., & Bruce, A. E. (2015). Students' Understanding of Analogy after a CORE (Chemical Observations, Representations, Experimentation) Learning Cycle, General Chemistry Experiment. *Journal of Chemical Education, 92(10), 1626-1638*.

Davidowitz, B., & Potgieter, M. (2011). Preparedness for tertiary chemistry: Multiple applications of the chemistry competence test for diagnostic and prediction purposes. *Chemistry Education Research and Practice, (12), 193–204.*

Department of Basic Education. (2014). Report on the 2014 National Senior Certificate examination: National Diagnostic Report on Student Performance.

Huddle, P.A. & White, M.D. 2000, "Using a teaching model to correct known alternative conceptions in electrochemistry", *Journal of chemical education, vol. 77, no. 1, pp. 104-110*.

Karamustafaoğlu, S., & Mamlok-Naaman, R. (2015). Electrochemistry Concepts using the Predict-Observe-Explain Strategy. *Eurasia Journal of Mathematics, Science & Technology Education, 11(5), 923-936.*

Karslı, F., & Ayas, A. (2011). Developing a laboratory activity on electrochemical cell by using 5e learning model for teaching and improving Science process skills. *Proceedings of 3rd Cyprus International Conference on Educational Research. North Cyprus, Lefkosa*.

Lee, T. T., & Osman, K. (2012). Interactive multimedia module in the learning of electrochemistry: Effects on students' understanding and motivation. *Procedia-Social and Behavioral Sciences, 46, 1323-1327.*

Leedy, P.D., & Ormrod, E.O. (2010). Practical research: Planning and design. (9th ed.). New Jersey: Pearson Education.

Sanger, M. J. and Greenbowe, T. J. (1997), Common student alternative conceptions in electrochemistry: Galvanic, electrolytic, and concentration cells*. J. Res. Sci. Teach., 34: 377–398*.

Mertens, D. M. (2014). Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods. Sage publications.

Talib, O., Matthews, R. & Secombe, M. (2005). Computer-Animated Instruction and Students' Conceptual Change in Electrochemistry: Preliminary Qualitative Analysis. *International Education Journal, 5(5), 29-42.*

Wahyuni, D. (2012). The research design maze: Understanding paradigms, cases, methods and methodologies.