PRE-SERVICE SCIENCE TEACHERS'S CONCEPTUAL UNDERSTANDINGS OF ELECTROCHEMISTRY

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ABSTRACT

This research explored pre-service science educators' comprehension regarding the concepts of galvanic cells, electrode potentials, and electrolytic cells in electrochemistry. A sample of 64 first year trainee science educators selected from the Department of Teacher Education at the University of Ghana was strategically chosen to take part in this investigation in the 2018/2019 academic year. In this study, a pre-test / post-test quasi-experimental framework was adopted to determine how "conceptual change texts" (CCTs) would affect the performance of pre-service science educators in electrochemistry. A two-tier 10 multiple-choice questions (MCQs) termed "electrochemistry concept test" (ECT) was given to them. Results showed that they had difficulties interpreting electrolytic cell-related concepts and most could not differentiate electrolytic cells from galvanic cells. The achievement of learners instructed utilising the Lecture method (LM) was lower than those instructed with the CCTs when a post hoc analysis with a Bonferroni adjustment on the ECT was conducted as a follow up to the one-way between-group analysis of variance, ANCOVA. The study offers comparative data on the importance of meaningful learning for enhancing the conception of electrochemistry by learners. The findings suggest that the CCTs in the experimental group might have caused an increase in pre-service science instructors' intellectual achievement. *[African Journal of Chemical Education—AJCE 11(2), July 2021]*

INTRODUCTION

Academic success has traditionally been connected to passing cumulative assessments that are based on learning objectives. Nonetheless, [1] claim that the definition of this term is controversial because it has an "amorphous" character that varies depending on subjective viewpoints. The researcher [2] believes that psychological elements, in addition to intellectual capacity, influence academic accomplishment. Also, [2] observed that the results of participants' assertiveness, conscientiousness, and emotionality tests were found to be strongly associated to their marks, demonstrating that how learners perceive their learning experience might result in a variety of academic outcomes. It is therefore believed that academic success can be influenced by the strategy used by teachers to deliver lessons to their students.

Science seems to be a no go area for some students as they claim it is difficult to understand most of the concepts. Similarly, other sub-disciplines of science tend to scare students off. For instance, electrochemistry is classified as the subdivision of chemistry that emphasises on the use of electrical energy to trigger non-spontaneous chemical reactions and the study of electricity generation from the energy created by spontaneous chemical processes [3, 4]. Accordingly, [5] suggests that the subdivision of chemistry which explains how chemical phenomena relate to electrical processes is referred to as electrochemistry, or the branch of chemistry concerned with charge separation in liquid media such as solutions [6]. This shows that charge separation is frequently associated with charge transfer, which can occur homogeneously in solution between diverse chemical species or heterogeneously on electrode surfaces. Thus, electrochemistry is concerned with chemical processes involving the transfer of electric charge across an electrified contact between electronic and ionic conductors [7].

Most researchers have opined that electrochemistry is considered by most scholars to be among the most complex topics to study in the chemistry classroom for both learners and teachers [8-10]. Science teachers [11, 12] and students [13-17] have difficulties with the definition of electrochemistry, as it has a wide range of applications in industry and other sectors. Likewise, numerous researches have described alternative concepts of electrochemistry indicating that electrochemistry may be considered one of the most challenging, ambiguous, and laborious branches studied in the discipline of chemistry [18, 19]. Others noted it has a multitude of ambiguous and hypothetical expressions with recorded inconsistencies and contradictory explanations [20].

Besides, studies have concentrated mainly on evaluating pre-service high school and in-service chemistry teachers' conception in electrochemistry [16], and the understanding of electrochemistry among high school students [21], [8], [22, 23], in countries other than Ghana. Little consideration has been devoted to research on the comprehension of electrochemistry in the Ghanaian sense by pre-service science teachers for senior high schools. Nevertheless, these pre-service science teachers for senior high schools will be hired to teach electrochemistry within the ambit of integrated science or chemistry to students. Research [17] also suggest that the academic experience of subject-matter teachers affects their instructional methods, and ultimately the achievement of students [24, 25]. As such, it will be expedient to question issues regarding the comprehension of conceptions in electrochemistry by pre-service science teachers taking cognizance of the fact that they might carry some misconceptions into the classroom.

Statement of the Problem

Conceptual change is a shift or restructure of current information and beliefs. Learning for conceptual change is more than just memorising or picking up a new skill. It is the conceptual framework that learners utilise to solve problems, explain phenomena, and function in world [26]. Teaching for conceptual transformation involves revealing students' preconceptions about a topic or phenomenon and employing a variety of strategies to assist students in changing their conceptual framework. The role of the teacher, for instance, is changing as constructivist approaches to teaching become more prominent. Conceptual transformation is important not only in content-area instruction but also in the professional development of teachers and administrators.

Several researchers have used various teaching methods to bring about behavioural changes in learners. Some of these techniques include the learning cycle, collaboration, computer-assisted instruction, and cooperative teaching [9, 15]. Similar researches have employed a variety of texts known as "conceptual change text" to facilitate the identification and analyses of alternative concepts and to reduce students' misconceptions [27-31]. According to these researchers, conceptual change texts are recommended to bring about transformations in students' alternative conceptions with scientifically accepted ones. However, nearly all the time teachers teach learners by discoursing while disregarding the fact that learners are also capable of making a constructive contribution to the classroom discourse. It is the situation prevalent in public universities (the University of Ghana is no exception) with science lecture theatres and laboratories as there is no flexibility and time for lecturers to discourse in the classroom because the curricula have been overloaded and therefore do not have the leverage and time to have constructive discourse in class.

Considering the above, the researchers decided to use CCTs to enable the comprehension of electrochemistry concepts by pre-service science teachers, as this can lead to better training of science teachers, and improve chemistry teaching and learning in senior high schools across Ghana.

CONCEPTUAL FRAMEWORK

Conceptual Change

Conceptual change is the underlying concept of this research, defined as the strata of existential knowledge collectively generated by the requisite group and subsequently embraced by the students' undertaking such as a course of action. The term concept denotes a commonplace classification of notions, entities, individuals, or specific understandings wherein the members collectively share a plethora of tenets [32]. Accordingly, [33] thought that conceptual understanding was interpreted as knowledge of a subject that was well understood and well incorporated, with several rational associations between concrete ideas and concepts.

Given this, [34] have attempted to explain the misconceptions learners encounter in science. According to them, it can be argued that the domain of conceptual change is deeply rooted in the parameter of the conception of "alternative conceptions which then aims at developing a view of how the current conceptions of the student are enmeshed with the newer conceptions that engulf the learners in a classroom setup. As no agreement has been made on the underlying meaning of conceptual change, different researchers have defined conceptual change from their perspective. Nevertheless, conceptual adjustment is typically the mechanism by which learners modify their initial ideas to suit a normative interpretation [35].

Again, [34] proposed a conceptual change theory combining the concept of a paradigm shift [36] with the concept of accommodating new knowledge [37]. Therefore, [36] clarified that a significant transition that occurs when a novel and varied way of cogitating replaces the normal way of deliberating or performing something is referred to as a paradigm shift. In such situations, the new ideas do not fit existing understanding, and it is referred to as accommodation. Consequently, accommodation requires modifications to what is known. As a result, [34] proposed that the conceptual transition would entail four basic conditions: the student acknowledges that what they know isn't going to solve the problem (dissatisfaction); the learning material has to be meaningful for the student and the student should be able to interpret the concept to everyone else (intelligibility); the newly learned conception should be applicable in such a way as to relate to one's prior experience and solve problems (plausibility); the new idea must support the learner solve problems and open up new fields of inquiry (fruitfulness).

They were of the view that a learner in an individual manner ought to meander their way through the same process, as was envisioned in the scientific revolution. The preceding proposition suggests that it is appropriate for the student to experience a specific unexpected occurrence that cannot be explained by his or her presently operative conceptual framework. In that situation, there must be an availability of imminent understanding to the learners which will assist them with the explanation of the anomaly. Also, [34] further demonstrated the presence of four basic requirements that the learner has to go through the twin phases of accommodation or conceptual transition. The current concept, in the course of its applicability to the new experience creates certain loopholes or unclarified areas in terms of the domains of the new experience. Secondly, the new concept must be intelligible. In this situation, it is necessary to ascertain that the new concept is comprehensible, indicative of the fact that the learner should be able to discover certain rationalised arguments for the new concept. Thirdly, there has to be a plausible new alternative concept. This suggests that it needs to be ascertained that the new concept is credible or rather feasible, which is solely possible as and when the new ideologue is more logical in comparison to the previous concept, in terms of intrinsic capacity to solve the problems encountered. Lastly, it is deemed that should the new concept be successful or effective, it will have the capacity to apply those particular concepts to the other domains [34].

Purpose

In this study, CCTs were employed to compare their influence on the achievement in electrochemistry of pre-service science teachers pursuing B.Sc. science education at the University of Ghana. This was also to explore the shifts in conceptual understanding of science that arises when pre-service science teachers use CCTs on solutions to the problems of electrochemistry conceptions provided by the teacher.

RESEARCH QUESTION AND HYPOTHESES

Research question

For this investigation three research question has been formulated. The research question is:

1. What effect do conceptual change texts as a teaching technique have on the comprehension of electrochemistry concepts by pre-service science teachers?
2. What is the interaction effect between CG and EG, and the teaching method regarding pre-service science teachers' understanding of electrochemistry?
3. What is the difference between post-test mean scores of CG and EG regarding pre-service science teachers' understanding of electrochemistry?

METHODOLOGY

Research Design

The investigators in this study had to use a quasi-experimental approach, as a result of the difficulty encountered in assigning learners to a precise class partition at random [38], thereby accounting for the use of convenience sampling. For example, the investigators at the research schools did not randomly assign learners to experimental groups and baseline groups as individuals because the lecture schedule could not be changed for pre-service teachers for this investigation. Thus, students offering Biology/Chemistry and Chemistry/Biology were randomly assigned to function as an intact group such as the Experimental Group (EG) or Control Group (CG) respectively. Biology/Chemistry means Biology is the major teaching subject and Chemistry is the minor teaching subject for this category of pre-service teachers. The study employed two separate classes, consisting of first-year science students at the University of Ghana offering Biology/Chemistry and Chemistry/Biology combinations. The group taught with "conceptual change texts" was chosen as the experimental group, while the one instructed with the traditional method was the control group. By enacting a facilitator's role, the experimental group teacher employed conceptual change texts (theoretical modification texts).

Sample and Sampling Technique

Sixty-four first-year pre-service science teachers from the School of Education and Leadership, the University of Ghana formed the sample. The research (EG) and baseline (CG) groups comprised 34 and 30 students respectively. The research group was taught using the conceptual change teaching strategy called the "conceptual change text" technique whereas the baseline group followed the lecture teaching technique. Sample Distribution concerning the category of students and the age range is presented in Table 1.

Table 1: Sample Distribution across Chemistry Major/Minor and Age Range

Factors	Subscale	Freq.	Percent %
Chemistry Major/ Minor	Baseline group	30	53.1
	Investigative group	34	46.9
Age Range	16-18	19	29.7
	19-21	30	46.9
	22-24	9	14.0
	25 or more	6	9.3

As the ages of the minority (9.3%) of trainee science educators were more than 25 years, the ages of the majority (46.9 %) of trainee science educators were between 19 and 21 years.

Instrumentation

In this study, the data collected was largely based on the responses to the post-diagnostic questions. The ECT was the instrument used to collect data in this study. By comparison with various literature, the researchers developed some parts of the ECT and others adapted and reviewed by three expert chemistry lecturers. The ECT had a two-tiered, ten-question test based on the framework established by [39]. The second tier, which is centred on conceptual knowledge, was a follow up to the first tier which relied on procedural knowledge, with the respondent in the first tier selecting a justification for their preference. [39] argued that, when evaluating learner assignment, this inquiring approach can separate procedural knowledge from conceptual knowledge.

Method of Data Collection

First-year pre-service science teachers pursuing chemistry as a teaching subject took part in the study. In this investigation, the groups were formed based on the students' performance in their chemistry courses as well as their availability as they offer other courses apart from chemistry. At the end of the day, one group represented the baseline class whereas the other represented the investigative class. In the first week of October 2018, before instruction started during the second week of October 2018, the ECT was conducted as a pre-test. Similarly, in the second week of November 2018, the post-test was conducted after treatment. The researchers trained one chemistry lecturer (more than ten years teaching experience) on how to use the CCTs. The other was asked to use the Lecture Method, as this is the most common way of teaching that the students are used to. The post-test on ECT was conducted utilising a pencil and paper exam on electrochemistry conceptions.

For this investigation, the researchers produced three texts, one for each of electrolyte cells, electrode potentials, and galvanic cells. According to [31], conceptual change texts are very efficient in improving students' alternative conceptions, and in this study, they were intended to improve learner involvement and understanding. The researchers' designed conceptual change texts are composed of five sections and they were developed based on the criteria of "frustration", "intelligibility", "plausibility" and "fruitfulness" in Posner et al's proposed conceptual change framework. Pre-service science teachers were advised to be presented with the five sections separately so that they would not read the responses in the following section and change their responses accordingly.

To start the teaching-learning process, worksheets, which comprise the initial step of the conceptual change texts, were distributed by the lecturer in the investigative class to each of the pre-service science teachers. The learners were then instructed to follow the directions carefully. After the text was distributed, the instructor asked each student to read the text in silence and to answer the problem individually. The students were also told that they are free to ask questions for clarification. Following this, the pre-service science teachers discussed the subject with the lecturer as a facilitator, offering them the chance to rectify their alternative conceptions, if any, and find a suitable response where applicable. The lecturer did not specifically correct the mistakes of the students but motivated them by giving clues to uncover the explanations for their mistakes [40]. The initial component of the texts focused on identifying any potential preconceptions that learners might have and creating a discrepancy that is dissatisfaction. This permits the lecturer to comprehend how the understanding of a learner is influenced by using a conceptual change text.

Analysis of Data

Means and standard deviations of descriptive statistics were utilised to address research question one, by examining the extent to which instructional methods have impacted the conceptual understanding of electrochemistry by pre-service science teachers. Research question 2 was analysed using a Scatter plot and the Test for homogeneity of regression slopes whereas the oneway ANCOVAwas used to analyse research question 3. The purpose was to evaluate whether the conceptual understanding of electrochemistry by pre-service science teachers differs as far as the teaching approach is concerned.

RESULTS AND DISCUSSIONS

Results

It was observed that there were no noticeable outliers in evaluating the results. Similarly, Levene's homogeneity test for variance at p<05 was also not violated. Post-test marks were measured for pre-service science teachers and a higher score suggested that alternate ideas were eradicated compared with a lower score. In marking the scripts, a student scored zero if Tier 1 is answered correctly but Tier 2 is answered wrongly; scored 0.5 if Tier 1 is wrongly answered but Tier 2 is answered correctly, and 1 if both Tiers 1 and 2 are answered correctly. Mean and standard deviation were used by the researchers to find out whether the use of CCTs impacts on pre-service teachers' conceptual understanding. Table 5 did not include the interaction term in the results of the ANCOVA, as it has already been verified in both Figure 1 and Table 4.

Research Question 1: What effect do conceptual change texts as a teaching technique have on the comprehension of electrochemistry concepts by pre-service science teachers?

Research question one was addressed using mean and standard deviation for student teachers. Utilising CCTs and LM respectively, results of Baseline and Investigative classes' post-test scores on Table 2 show that the post-test score for the CG (46.33± 5.86) was less than the post-test score (59.41 ± 7.46) for the EG.

Table 2: Mean and Standard Deviation for CG and EG

Technique of Teaching	Mean	Standard deviation	N
Baseline (CG)	46.33	5.862	30
Investigative (EG)	59.41	7.464	34
Total	53.28	9.395	64

This could indicate that CCTs enhanced the achievement of the concept of electrochemistry in EG over CG. A post hoc analysis with a Bonferroni adjustment on the ECT was conducted as a follow up to the one-way between-group analysis of variance, ANCOVA, as shown in Table 3. This was to establish if the mean differences are indeed statistically relevant.

Table 3: Investigative and Baseline Classes' Pairwise Assessment

Technique of Teaching		Mean Difference	Std Error	Sig.
Baseline	Investigative	-10.650	1.728	.0005
Investigative	Baseline	10.650	1.728	.0005

From the foregoing, it is clear that the post-test results from the CG were lower than that of the EG (Table 3), with a mean difference of -10,650 ($p<.001$). The pairwise comparison showed that there was a substantial difference in the conceptual understanding of electrochemistry between the mean CG and EG post-test results.

Research Question 2: What is the interaction effect between CG and EG, and the teaching method regarding pre-service science teachers' understanding of electrochemistry?

An interaction effect is when two or more independent variables have a combined effect that is considerably higher (or significantly less) than the sum of their parts on at least one dependent variable. Interaction effects are crucial in any survey research because they show how two or more independent variables interact to influence the dependent variable. Incorporating an interaction term effect into an analytic model allows the researcher to visualize and comprehend the link between the dependent and independent variables more clearly. It also contributes to a better understanding of the dependent variable's variability [41].

Thus, for each type of the independent variable, CG and EG, the pre-test was assumed to have a linear connection with the post-test for all groups of the independent variable (teaching method). Hence, a scatterplot of post-test versus pre-test, grouped on teaching technique, was plotted as shown in Fig. 1.

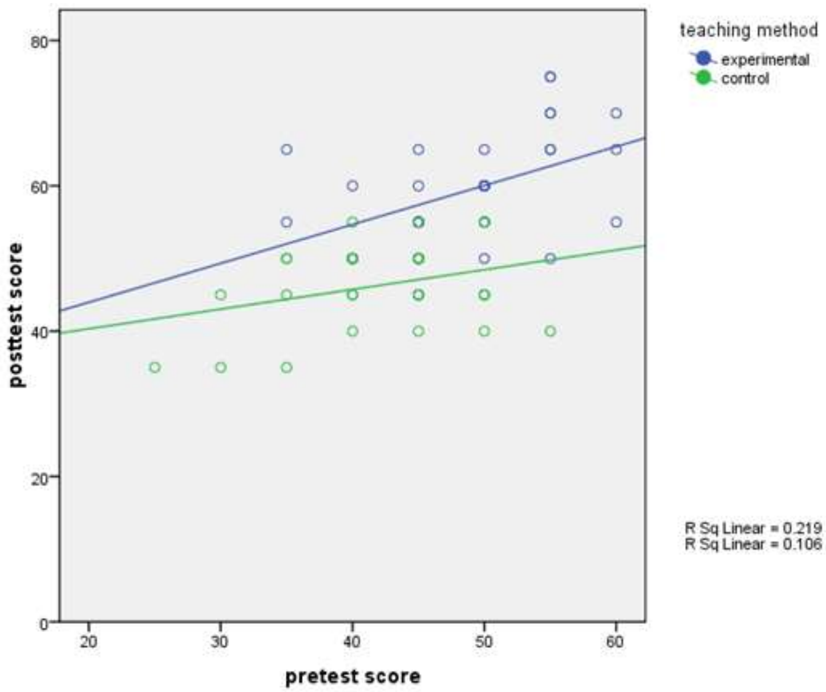

Figure 1. *Scatterplot of post-test against pre-test grouped on teaching method*

Figure 1 depicts the linear relationship between pre-test and post-test scores for all types of interventions, as determined by evaluating the scatterplot visually. Besides, deciding if there is a statistically significant interaction effect, "teaching method*pre-test", the interaction effect was statistically significant. This shows that pre-service science teachers who were instructed with CCTs are similar to those who were instructed with LM.

Test for homogeneity of regression slopes for CG and EG was conducted (Table 4) to ascertain the significance of the interaction term. By performing a general linear model univariate analysis for this purpose, the interacting term did not imply statistically significant accuracy of the regression slopes, F(1,60) = .007, p = .238. The results can be observed on Table 4 considering (tm*pre).

Table 4: Investigative and Baseline Groups' Test for homogeneity of regression slopes

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3222.986[a]	3	1074.329	27.571	.000	.349
Intercept	1556.112	1	1556.112	39.935	.000	.310
tm	1.504	1	1.504	.039	.845	.039
pre	445.256	1	445.256	11.427	.001	.254
tm * pre	55.354	1	55.354	1.421	.238	.007
Error	2337.951	60	38.966			
Total	187250.000	64				
Corrected Total	5560.938	63				

a. R Squared = .580 (Adjusted R Squared = .559)

Research Question 3: What is the difference between post-test mean scores of CG and EG regarding pre-service science teachers' understanding of electrochemistry?

Table 5 summarizes the findings of ANCOVA conducted by the researchers. The kind of instruction used for teaching was the independent variable, specifically CCTs or LM whereas the dependent variable was pre-service science teachers' post-test scores, with pre-test scores as covariate. The post-test scores denoted the conceptual understanding of electrochemistry exhibited by pre-service science teachers.

Table 5: ANCOVA Summary on Conceptual Understanding of CG and EG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3167.632[a]	2	1583.816	40.368	.000	.570
Intercept	1612.134	1	1612.134	41.090	.000	.402
pre	441.596	1	441.596	11.255	.001	.156
tm	1490.678	1	1490.678	37.994	.000	.384
Error	2393.305	61	39.235			
Total	187250.000	64				
Corrected Total	5560.938	63				

a. R Squared = .570 (Adjusted R Squared = .556)

The post-test results showed a statistically significant difference between the treatments, F(1,61)= 41,090, p<.0005, partial 5-02=.384, after accounting for pre-test scores. The strength of the connection between teaching technique and understanding of the concepts of electrochemistry was high from Table 5. The teaching approach contributed 38.4% of the dependent variable variance when the pre-test as a covariate was tested.

Discussion

Testing the alternative ideas of pre-service science teachers regarding the conceptual understanding of electrochemistry was the main objective of the research. It was also intended to evaluate the effectiveness of conceptual change texts and to compare and contrast the influence of teaching on students' comprehension of electrochemistry conceptions with CCTs and LM. The post-test mean scores of pre-service science teachers from CG and EG were analysed using an ANCOVA analysis. According to the findings, there was a statistically significant difference between the post-test mean scores of pre-service teachers studying using LM and those studying using CCTs in terms of their understanding of electrochemistry. Hence, pre-service science teachers representing the investigative group have done better than the CG pre-service science teachers on post-test (ECT) ratings, which suggest that CCTs have been more efficacious in addressing alternative ideas [29] and conceptual understanding of electrochemistry for pre-service science teachers [28, 29]. Other researches support these conclusions [42], [30, 31], which demonstrates that CCTs have been more effective for the conceptual understanding of electrochemistry by science teacher trainees.

Pre-service science teachers were supposed to recollect elementary information in a traditional setting, where chemistry teaching depended on conceptual understanding, which are empirical facts. For example, CCTs have advocated the creation of procedural knowledge, based on the teaching technique for conceptual change, and this is understood as information needed to execute the exact tasks. Pre-service science teachers in the EG employed CCTs to objectively analyse their logic and alternative concepts linked to theoretical notions of electrolytic, galvanic, and electrode potentials. These factors could have influenced pre-service science teachers' post-test performance disparities. Pre-service science teachers in the CG couldn't answer subsequent questions in a rational manner. Following CCTs, however, EG pre-service science teachers employed their methodological skills adopting their understanding of basic electrochemical principles and obtained meaningful learning.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The primary purpose of this study was to see how pre-service science teachers' electrochemistry achievement was affected by a conceptual change teaching strategy involving the use of conceptual change texts. The current investigation utilised CCTs and LM to teach the sub-topics of galvanic cells, electrode potentials, and electrolytic cells in electrochemistry to pre-service science teachers at the University of Ghana. The study revealed that the respondents have many misconceptions related to electrochemistry, particularly about electrolytic cells, and these alternative concepts affect their conceptual understanding of electrochemistry. The quest for methods to rectify these alternate concepts to accomplish meaningful learning thus became obvious. The results of this study show that employing CCTs assisted pre-service science teachers in rectifying their alternate conceptions, as pre-service science teachers who used CCTs fared better than those instructed with LM when evaluating post-test scores on conceptual understanding of electrochemistry.

Galvanic cells were better understood by pre-service science teachers than electrolytic cells. It's possible that the lecturers during instructional period concentrated more on the algorithmic challenges linked to electrolytic cells. This study is part of major research that verified several of the alternate concepts found in literature. However, the purpose of this investigation was on evaluating whether the conceptual understanding of electrochemistry by pre-service science teachers of conceptual change texts could be enhanced. As a result, nothing has been reported in this article on the alternative conceptions confirmed from literature. The worry is that if pre-service science teachers' alternate conceptions of these are not eradicated, they will carry it over to the classroom after graduating. One other disturbing issue is that it seems the alternative conceptions of these teachers were incorporated into the subconsciousness when they were at senior high school.

Despite this assertion, the teaching strategy for conceptual improvement failed to some degree, as some post-test outcomes revealed that the EG still had some alternate concepts. Pre-service science teachers had more concepts related to galvanic cells compared to electrolytic cells. The logic could be that the teachers focused more on the algorithmic problems related to electrolytic cells in the class. This study is part of major research that verified several of the alternate concepts found in literature. However, the purpose of this investigation was on evaluating whether the conceptual understanding of electrochemistry by science teacher trainees of conceptual change texts could be enhanced. As a result, nothing has been reported in this article on the alternative conceptions confirmed from literature. The worry is that if science teacher trainees' alternate conceptions of these are not eradicated, they will carry it over to the classroom after graduating. One other disturbing issue is that it seems the alternative conceptions of these teachers were incorporated into the sub-consciousness when they were at senior high school.

Recommendations

A cursory look at randomly sampled chemistry notes given to pre-service science teachers by their instructors shows the difficulty they encounter in extracting concepts from the notes given, which is mostly in power point presentation. It has been observed that the achievement of learners is independent of how copious their notes are but how conceptual comprehension is achieved. Discussions may be conducted on the growth of teacher training programs to plan and implement CCTs in classrooms to enhance the program's progress. Although the study of the technique is critical to implementing this method in classrooms, it is equally important and invaluable to train senior high school science teachers on this technique.

LIMITATIONS

Sampling methodology was the most important weakness of the analysis because intact groups were utilized during the sampling process. Therefore, generalizability is likely to be reduced.

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