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Assessing Problem-Based Metacognitive strategies on Chemistry students' Learning Styles and Achievement in Electrochemistry

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ABSTRACT

Background: Previous studies conducted have shown the effectiveness of Problem-Based Learning (PBL). This investigation was aimed at discovering the relevance and interrelationship of students' cognition (which is directly linked to PBL), metacognition and learning styles on their achievement. These are key elements in achieving adequate learning as measured by students' readiness to learn, understanding of new concepts, appropriate application of knowledge gained, retention and recall of content learned. The adoption of an innovative approach in circumventing some obvious learning intricacies and enhancing achievement through the integration of problem-based learning with metacognitive strategies necessitated this study.
Objectives: This study investigated the effectiveness of incorporating Problem-Based Learning with Metacognitive strategies on the achievement of some Chemistry students with varied learning styles preferences.
Methods: The study adopted a quasi-experimental non-randomized pretest and post-test control group design. The sample comprised 70 students drawn from Senior Secondary II chemistry class in Nasarawa State, through a multi-stage random sampling technique. Two intact classes were randomly assigned as the experimental and control group. Three validated instruments used for data collection were Electrolysis Achievement Test (EAT), Metacognition Rating Scale (MRS) and Kolb's Learning Style Inventory (KLSI-3.1). The control group was taught electrolysis with demonstration method for four weeks while the experimental group was exposed to Problem-Based Metacognitive (PBM) strategies in electrolysis (similar content) for four weeks. Three research questions raised were answered and three corresponding hypotheses formulated were tested at 0.05 level of significance. Data collected were analyzed using Means, Standard Deviations and Analysis of Covariance (ANCOVA).
Results: The result of the study showed significant difference in the mean achievement scores of students taught electrolysis with PBM strategies from those taught with the conventional method.
Conclusions: The finding reveals no significant difference in students' achievement based on their learning styles preferences and categorization (accommodating, assimilating, divergent and convergent). There was also no significant difference in the mean achievement scores of male and female chemistry students taught electrolysis using the PBM strategies.

Keywords: Learning styles, Metacognitive strategy, Achievement, Problem-Based Learning, Electrolysis

INTRODUCTION

Appropriating the relationship between students' cognition and metacognition is paramount in achieving and assessing learning and this can be measured by students' understanding, readiness to learn, appropriate application, retention and recall of learned concepts or topics. Cognition is the process of acquiring knowledge through the information received from the environment during instructional activities and is in consistent with problem-based learning approach. Metacognition refers to the ability to reflect on one's thought processes and the way one learns (Fleur and Van den Bos, 2021). Active learning, therefore occurs when students take responsibility for acquired knowledge through consciously exploring their environment, analyzing events and evaluating their learning personally. Metacognitive strategies students often engaged in include; self-questioning, meditation, reflection, awareness of strengths and weaknesses, mnemonic aids, writing down their work and, thinking aloud. Metacognition aids students' interpretation and effective application of newly acquired knowledge since the new ideas are linked to a well-founded basic framework or existing knowledge structure (Rahman, et al, 2010; Inekwe, and Zakariya, 2010).

There are different learning styles in existence which are exhibited by students when exposed to similar experiences or instructional environments. Learning style only predicts how a person's brain learns and store information (Bulter, 1988). However, there is no right or wrong style of learning because the preferred or displayed learning style of a student is independent of his achievement but a function of his metacognitive awareness and overall capabilities. Coffield, Moseley, Hall and Ecclestone, (2004) suggest that learners should develop a repertoire of styles in order to be aware of their own preferences and abilities, and use them in different instructional activities Biggs, (2001). Some learning styles are better developed and more preferred (Grasha and Yangarber – Hick, 2000). Learning style has cognitive, affective and psychological aspect. There are different classifications of learning styles based on varied perspectives. Examples of such classification are; Myers – Briggs (1962), Honey and Mumford (1982), VARK model by Niel, and classification by Kolb and Kolb (2005) among others.

Experiential learning theory constitutes the basis of Kolb's learning style model and it perceives four specific ways of learning as; Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC) and Active Experimentation (AE) which give rise to converging learners, diverging learners, assimilating learners and accommodating learners respectively. Kolb used his learning cycle as a basis for the development of these four different learning styles. Experiential learning differs from other cognitive learning theories by exploring the use of experiences in learning (Hasirci, 2006). This current study anchor on Kolbs' classification because of its direct relevance to science learning.

According to Kolb, learners in the diverging category have CE and RO as dominant learning abilities. They are best at viewing concrete situations from many different points of view. Learners in this category perform better in situations that call for general ideas such as brainstorming, they have broad cultural interests and like to gather information. They are interested in people and tend to be imaginative and emotional. In a formal learning situation, diverging learners prefer to work in groups, listen with open minds to different points of view and receive personalized feedback. While learners demonstrating assimilating style have AC and RO as dominant learning abilities, they are best at understanding a wide range of information and putting it into concise, logical form. They are less focused on people and are more interested in ideas and abstract concepts. In formal learning situations, assimilating learners prefer reading, lectures, exploring analytical models and taking time to think things through.

Though learners displaying converging styles have AC and AE as dominant learning abilities, they are best at finding practical ideas and theories. They have the ability to solve problems and make decisions based on finding solutions to questions or problems. Learners with a converging learning style prefer to deal with technical tasks and problems rather than social issues and interpersonal issues. In formal learning situations, learners in this category prefer to experiment with new ideas, simulations, laboratory assignments and practical applications. However, learners with accommodating styles have CE and AE as dominant learning abilities. They learn primarily from "hand-on " experiences, reacting flexibly so that they can find the relationships between concepts and use the understandings of these concepts to explain various phenomena.

Fatokun and Adeniji (2015) found no significant difference in students' performance in Mathematics and science, who were in different learning styles groups. Alade and Ogbo (2014) submitted that learning styles have strong influence on students' achievement. Fatokun and Eniayeju (2014) reported that learners' academic achievement is not greatly dependent on their learning styles when exposed to a similar instructional environment. Yilmaz-soylu and Akkoyunlu (2009) clarified from a study conducted, using Kolbs' learning style model, that the type of the learning style adopted by the sampled students was not significantly effective on their achievement in different learning environments. When dealing with learning styles, metacognition should be as well considered as Oriab, (2014) asserted that learning styles significantly explain and predict all sub–dimensions of metacognition.

Abarro and Asuncion (2021) believe that every student under proper training and feedback will consciously endeavour to become a self-propelling learner: a learner as reflective practitioner of his own learning. The gateway to this; is teaching for metacognition. In the views of Annevirta and Vauras (2006), metacognition is the knowledge that the learner has concerning his academic strengths and weaknesses of the cognitive resources he can apply to meet the demand of a particular task, as well as his knowledge and skills relating to how to regulate his engagement in a task in order to maximize the learning process and outcomes. The impact of metacognition strategies in young children is far-reaching and need a redress to harmonize methods of learning and the natural setting of our minds. The learning process begins with the natural setting of the mind (Bawdy, 2012).

Problem statement: Often, students' difficulty in understanding electrochemical concepts is linked to considering different concepts as isolated elements of knowledge (Fatokun and Eniayeju, 2014; Brandt, 2001), for example, the secondary school Chemistry curriculum separates Redox reaction from Electrolysis. Misconceptions due to per-conceived ideas and cultural differences equally interfere with learning (Fatokun, 2016). These usually lead to students' poor achievement and lack of interest in learning. Hence, metacognition becomes very necessary in ensuring students' deep understanding of concepts in Chemistry as well as promoting their skills in problem solving (Cook, Kennedy and McGuire, 2013).

Research Questions

What are the mean achievement scores of students taught electrochemistry with PBM strategies and those taught using conventional method?

What are the mean achievement scores of students taught electrochemistry through the PBM strategies based on the categorization of their learning styles?

What are the mean achievement scores of male and female students taught electrochemistry with PBM strategies?

Research Hypotheses

There is no significant difference in the mean achievement scores of students taught electrochemistry with PBM strategies and those taught using conventional method.

There is no significant difference in the mean achievement scores of students taught electrochemistry with PBM strategies based on the categorization of their learning styles.

There is no significant difference in the mean achievement scores of male and female students taught electrochemistry with PBM strategies based on the categorizations of their learning styles.

Methodology

Research Design

This study adopted quasi-experimental design. A non-randomized pre-test, and post-test control group was used precisely. Two intact classes of students with similar intellectual capabilities were involved as the pretest scores were used to establish their equivalence.

Population

The population of the study was 23, 524 (13,077 male and 10,447 female) Senior Secondary school (SSII) students in Nasarawa State, Nigeria.

Sample and Sampling Technique

Multi-stage random sampling was employed to obtain 70 SS II students from two intact classes who participated in the study as the experimental and control group. The pretest was administered to determine their prior knowledge and establish the equivalence of the two groups. There were 36 students in the experimental group and 34 students in the control group.

Instrumentation and Administration

Three instruments were used for data collection. The Electrochemistry Achievement Test (EAT) which consisted of 20 objective test items on electrochemistry, was developed by the researchers and validated. This was used as both pretest and posttest. Pre-test served as covariate for the study and the posttest was used to determine the achievement of the two groups.

Kolb's Learning Style Inventory (KLSI) 3.1 version was adopted to identify the various learning styles of the students. The instrument was in two parts. The first part, consisted of nine rank order of sentences in columns A – D. The second part of the KLSI was the rubric scoring after which a graph of AC – CE and AE – RO was plotted to locate the appropriate learning styles of the sampled students.

The third Instrument was the Metacognition Rating Scale (MRS), consisting of 25 items which involved different response modes representing students 'metacognition of the lessons learned.

Both the experimental group and the control groups were taught similar aspects of electrochemistry for four consecutive weeks. In the experimental group, Problem-based learning was employed but incorporated with metacognitive strategies. The students were divided into groups, learning materials were provided and series of learning tasks were slated for them to accomplish at each stage of the lessons. Students were required to study individually, assess their learning of new concepts and solve some set of problems before gathering in groups to complete their task. Each member was expected to participate actively by providing adequate justification for stated responses before arriving at collective conclusions by the group. The students were also expected to evaluate their overall learning process and analyse their learning difficulties. The teacher served as a mediator, closely monitoring each group, answering necessary questions when asked or responding with leading questions to redirect/ guide the students to the solution. The control group was taught with the demonstration method where the teacher participated actively in the teaching process.

Results

Research Question 1

What are the mean achievement scores of students taught electrochemistry with Metacognitive strategies and those taught using conventional method?

Table 1: Mean and Standard Deviation of achievement of Chemistry students taught Electrochemistry with PBM strategies and those taught using conventional method

Groups		Pre-test	Post-test
Experimental (PBM strategies)	Mean	8.42	59.64
	N	36	36
	Std. Deviation	2.781	5.658
Control (Demonstration)	Mean	8.41	52.29
	N	34	34
	Std. Deviation	2.388	5.750

Table 1 shows mean achievement scores and standard deviations of chemistry students in both the experimental and control groups. It was observed that the pre-test and post-test mean scores of students in the experimental group in were 8.42 and 59.64 respectively and their standard deviations stood at 2.781 and 5.658 respectively. Students in the control group had achievement mean scores of 8.41 and 52.29 respectively and their standard deviations were 2.388 and 5.75 respectively.

Ho_1: There is no significant difference in the mean achievements scores of students taught electrochemistry with PBM strategies and those taught using conventional method.

Table 2 shows the summary of the one-way ANCOVA result of Chemistry students' achievement scores in EAT. This result revealed that the noted difference between the mean achievement score of students taught electrochemistry using PBM strategies and those taught with conventional method is significant at 0.05 alpha levels. Since the F = ration of 28.774 was obtained with an associated exact probability value of 0.000 ($F = 28.774$, $P = .000 < \alpha = .05$) and the associated probability .000 is less than .05, the null hypothesis was rejected. Hence, there was a significant difference between the two groups in favour of the experimental group. The experimental group performed better than the control group.

Table 2: Results of ANCOVA on Chemistry Students' Achievement taught Electrochemistry using PBM Strategies and Conventional Method

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	958.761[a]	2	479.381	14.627	.000	.304
Intercept	17571.539	1	17571.539	536.137	.000	.889
Pretest	15.483	1	15.483	.472	.494	.007
Group	943.046	1	943.046	28.774	.000	.300
Error	2195.882	67	32.774			
Total	223235.000	70				
Corrected Total	3154.643	69				

Research Question 2: What are the mean achievement scores of students taught electrochemistry through the PBM strategies based on the categorizations of their learning styles?

Table 3: Mean and Standard Deviation of students' achievement scores taught electrochemistry through PBM strategies based on the categorization of their learning styles

Learning style categorization	Parameter	Pre-test	Post-test
Accommodating	Mean	6.63	59.75
	N	8	8
	Std. Deviation	2.066	6.475
Assimilating	Mean	7.60	59.20
	N	5	5
	Std. Deviation	2.608	3.421
Divergent	Mean	10.13	62.13
	N	8	8
	Std. Deviation	3.314	6.105
Convergent	Mean	8.73	58.40
	N	15	15
	Std. Deviation	2.434	5.642

Table 3 shows the mean scores and standard deviations of chemistry students' taught electrochemistry with the different learning styles. (Accommodating, Assimilating, Divergent and Convergent learning styles). The pre-test and post-test mean score for students with Accommodating style were 6.63 and 59.75 while their standard deviations were 2.066 and 6.475 respectively. The students with Assimilating style had pre-test and post-test mean scores of 7.60 and 59.20 respectively with standard deviations of 2.608 and 3.421 respectively. The students in Divergent style had mean score in pre-test and post-test as 10.13 and 62.13 respectively and the standard deviations were 3.314 and 6.105. The students in the convergent style had mean scores in pre-test and post-test of 8.73 and 58.40 and standard deviations of 2.434 and 5.642 respectively.

Ho_2: There is no significant difference in the mean achievement scores of students taught electrochemistry with PBM strategies based on the categorizations of their learning styles.

Table 4 shows no significant difference in the mean achievement scores of chemistry students taught electrochemistry with the different learning styles (Accommodating, Assimilating, Divergent and Convergent learning styles). F = ratio of 0.65 was obtained with associated exact probability value of 0.589. ($F = 0.65$, $P = .589 > \alpha$ .05).

Since the associated probability of .589 is greater than .05 set at the level of significance, the null hypothesis was not rejected. There was no significant difference in the achievement of chemistry students in the experimental group taught electrolysis with PBM strategies based on the categorizations of their learning style.

Research Question 3

What are the mean achievement scores of male and female students exposed to PBM strategies?

Table 5: Mean and Standard deviation of achievement of male and female Chemistry students exposed to PBM strategies

Gender (PBMS)		Pre-test	Post-test
Male	Mean	8.05	59.79
	N	19	19
	Std. Deviation	2.778	5.564
Female	Mean	8.82	59.47
	N	17	17
	Std. Deviation	2.811	5.928

Table 5 shows the mean achievement scores and standard deviations of male and female chemistry students exposed to PBM strategies. It was observed that the mean scores of males in pre-test and post-test were 8.05 and 59.79 respectively and their standard deviations were 2.778 and 5.564 respectively. The females' achievement mean scores in pre-test and post-test

were 8.82 and 59.47 respectively and their standard deviations were 2.811 and 5.928 respectively.

Hypothesis 3

Ho_3: There is no significant difference in the mean achievement scores of male and female students taught electrochemistry with PBM strategies.

Table 6 reveals no significant differences in the mean achievement scores of male and female chemistry students taught electrochemistry using the PBM strategies. F = ration of 0.200 was obtained with an associated exact probability value of 0.657. ($F = .200$, $P = .657 > \alpha = .05$). Since the associated probability of .657 is greater than .05 set at the level of significance, the null hypothesis was not rejected. There was no significant difference between the male and female students taught electrochemistry using the Problem-Based Metacognitive strategies.

Discussion

The first null hypothesis formulated was rejected. Table 2 shows that there was a statistically significant difference in the achievement score of students taught electrochemistry using PBM strategies and those taught with conventional method. The findings revealed the efficacy of the Problem-Based Metacognitive strategy over other comparative methods. This finding is in agreement with the results of Bogdonovic et al (2015), Narang and Saini (2013), Rahman, Jumani, Chandy, Christi and Abbasi (2010) and Inekwe and Zakariya (2010) who reported that metacognition has positive influence on academic achievement. Boniface, (2018) also confirmed that PBL promotes students' achievement in chemistry. Hence, integrating PBL with

Table 6: Mean achievement scores of male and female students taught electrochemistry with Problem-Based Metacognitive strategies

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	118.446[a]	2	59.223	1.951	.158	.106
Intercept	9852.651	1	9852.651	324.534	.000	.908
Pretest	117.533	1	117.533	3.871	.058	.105
GenderMeta	6.087	1	6.087	.200	.657	.006
Error	1001.860	33	30.359			
Total	129165.000	36				
Corrected Total	1120.306	35				

metacognitive strategies will enhance the achievement of learners. Moreover, Dinsmore and Zoellner (2018) affirmed a very strong relationship between the metacognitive and cognitive strategies when a statistical model was employed to independently examined the influence of metacognitive monitoring and control of cognitive strategies.

The second null hypothesis was not rejected. Table 4 indicates that there was no significant difference in the mean achievement scores of students taught electrochemistry with PBM strategies based on the categorizations of their learning styles. It was discovered from the study that students perform equally irrespective of their preferred learning styles. These findings are consistent with the earlier assertion by Fatokun and Adeniji (2015) and Fatokun and Enaiyeju (2014), that learners' achievement is independent of learning styles exhibited by them when exposed to a similar learning situation. Yilmaz-soylu and Akkoyunlu (2009) equally expressed that students' achievement is not affected by their preferred learning style even when exposed to different learning conditions. However, this finding contradicts the submission by Alade and Ogbo (2014) that learning styles have strong influence on students' achievement.

The third null hypothesis was not rejected. Table 6 reveals that there was no significant difference between the male and female students taught electrochemistry using the Problem-Based Metacognitive strategies. This implies that male and female students perform similarly and achieve equally. Hence, gender has no significant effect on students' exposure to PBM. This result is in consonant with Omoniyi (2016) and Okoh *et al* (2011) which affirm that both male and female students perform equally when taught chemical concepts with the PBL approach,

Conclusion

The study assessed the effect of Problem-Based Metacognitive strategies on Chemistry students' learning styles and achievement in electrochemistry. Quasi-experimental non-randomized pre-test and post-test control group design was adopted and two intact classes were randomly assigned as the experimental and control groups were involved. Three validated instruments used were Electrolysis Achievement Test, Metacognition Rating Scale and Kolb's Learning Style Inventory (3.1 version). The control group was taught electrolysis with demonstration method while the experimental group was exposed to Problem-Based Metacognitive (PBM) strategies. Three research questions raised were answered and the corresponding formulated hypotheses were tested at a 0.05 level of significance.

The result of the study reveals a significant difference in the mean achievement scores of students taught electrolysis with PBM strategies and those taught with the conventional method but there was.no significant difference in the mean achievement scores of male and female students taught electrochemistry using the PBM strategies. Also, there is no significant difference in students' achievement based on their learning styles preferences and categorization. Based on the findings, Problem-Based Metacognitive strategies are recommended to be adopted in teaching electrochemical concepts for enhancing students' problem-solving skills and metacognition. For improved achievement and other learning outcomes, PBM is advocated at the secondary school level especially, for teaching difficult chemical concepts.

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