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Is there any possibility of enhancing students' metacognitive awareness in chemistry in Ekiti state, Nigeria using predict-explain-observe-explain and vee heuristic strategies? A field report

Victor Oluwatosin Ajayi and Emmanuel Edoja Achor

Abstract
The study was to investigate if there any possibility of enhancing students' metacognitive awareness in Chemistry in Ekiti State, Nigeria using Predict-Explain-Observe-Explain and Vee Heuristic Strategies. The instrument used for data collection was Metacognitive Awareness Inventory (MAI). Cronbach Alpha was used to ascertain the reliability index of MAI which gave reliability value of 0.84. The target population of this study was 14,753 which was the population of SSII chemistry students in study area. A sample of 308 students comprising 174 boys and 134 girls drawn from 9 schools within 9 Local Government Areas (LGA) out of 16 LGA in the Ekiti State, Nigeria selected using multi-stage sampling techniques. Two research questions and two null hypotheses guided the study. The research questions were answered using Mean and Standard Deviation scores while the null hypotheses were tested at 0.05 level of significance using Analysis of Covariance (ANCOVA). The study revealed that PEOE and VH strategies significantly improved students' metacognitive awareness [$F_{2, 301}$=3742.616, P<0.05] than discussion method. It was also found that there was no significant interaction effect of treatments and gender on the mean metacognitive awareness [$F_{2, 301}$ = .600, P>0.050] of students in Chemistry. It was recommended among others that since PEOE and VH strategies were found to be effective strategies for enhancing students' metacognitive awareness in Chemistry; Chemistry teacher's trainee should be trained on the use of PEOE and VH strategies and serving teachers should use it.

Keywords: Students' metacognitive awareness, predict-explain-observe-explain, vee heuristic strategy and discussion method

Introduction
Many of the developed nations have been able to achieve their status of development through science and technology (Ajayi, 2019) [4]. Nigeria as a developing nation looks forward to be one among the twentieth most scientifically, technologically and economically developed nations of the world. This aspiration has rekindled the desire for science education in Nigeria. Science education is the field of science that is concerned with sharing of science content, some social science, and the process of teaching science pedagogy in order to provide expectations for the development of understanding part of the scientific community. In cognizance with the importance of science and technology in Nigeria, Science subject such as Chemistry is taught in secondary schools to prepare a base for meaningful scientific and technological development. Chemistry is an experimental science that systematically studies the composition, properties and activities of organic and inorganic substances and various elementary forms of matter (Senese, 2013) [18].

Chemistry being a core science subject at the senior secondary school level of education is expected to serve as a base for scientific and technological knowledge that will enable the child to fit into the scientifically and technologically progressive society. Despite this expectation, low metacognitive awareness of students appears to have persisted. Olorunyomi (2016) stressed that learners are not aware of their metacognition in the study of Chemistry at all levels of education in Nigeria. This is often blamed on factors such as lack of Chemistry facilities, teachers' use of inappropriate teaching strategies and lack of qualified teachers' among other factors. Most Nigerian Chemistry teachers use discussion method most frequently in their classrooms which has not yielded expected results. Consequently, the poor strategy to teaching invariably translates to students' poor metacognitive awareness. According to Chatzipanteli, Grammatikopoulus and Gregoriadis (2014), metacognitive awareness is a teachable skill using effective metacognitive strategies. Similarly, Alexander

and Jetton (2015) [5] opined that, metacognitive processing is expressed through effective metacognitive instructional strategies which are procedural, purposeful, effortful, willful, essential and facilitative in nature. Metacognitive strategies are regarded as high order executive skills that make use of knowledge of cognitive processes and involve thinking about the learning process, planning for learning, monitoring the learning task, and evaluating how well one has learned (Chamot & Kupper, 2011; Wenden, 2013) [8, 19]. Individuals, who are aware of their metacognitive skills, behave more strategically and productively, make plans, organize and monitor their learning better than individuals who are unaware about their metacognitive skills. Metacognitive awareness is vital to successful learning of chemistry because it lets individuals to better regulate their cognitive skills and to determine weaknesses that can be corrected by constructing new cognitive skills.

Awareness and understanding of the process of learning help an individual to take control of one's learning (Gassner, 2009) [11].

Becoming aware of what happens in one's mind and one's thinking process may help individuals to have more control over their cognitive process and lead it toward being more effective.

This assertion calls for the need to find metacognitive strategies such as Predict-Explain-Observe-Explain (PEOE) and Vee Heuristic (VH) instructional strategies that have the potentials to equip learners to think about their cognition, monitor their learning activities and evaluate the results of these activities and thereby enhancing their conceptual understanding of scientific knowledge and problem solving abilities. The technique of Predict-Explain-Observe-Explain (PEOE) was modified from Predict-Observe-Explain (POE) by Rickey and Stacey (2015) to emphasize that the students need to explain their predictions to make their beliefs explicit. POE is a strategy which involves learners in writing down their predictions before doing the activity and the predictions are then followed by an activity in which learners observe their predictions and acclaim on whether or not their predictions were correct or incorrect.

Chris (2016) also presented a template of PEOE with a space for explanation of students' prediction. Students should know that their beliefs are important. PEOE is named to emphasize the importance of students' explanation. Ajayi (2019) [4] explain that, PEOE is an instructional strategy where learner make predictions for an event and explain the reasons for his predictions, then conduct and observe a laboratory experiment and are required to compare his observations with his predictions in order to monitor his learning activities, thereby enhancing conceptual understanding of scientific knowledge and problem solving abilities.

A Vee heuristic diagram is a V-shaped diagram showing the relationships between conceptual or theoretical and methodological framework and the resultant knowledge or value claims of a concept.

Vee Heuristic (VH) strategy is the process of creating a V-shaped diagram to represent key elements (ideas) that are contained in the structure of knowledge with two sides namely the theoretical or conceptual side (thinking side) on the left and methodological side (doing side) on the right in order to enhance conceptual understanding of scientific knowledge (Gowin, 2010) [12]. Vee Heuristic strategy is a tool that helps in seeing the interplay between what is known and what needs to be known or understood. The Vee heuristic diagram has two sides; The left hand side represents the philosophy, theories, principles and concepts that guide learners in selecting or constructing objects or event and the right hand side highlights the knowledge and value claims as well as data recording and transforming procedures and placed in the middle of the Vee heuristic diagram is the focus question and events or objects to be observed in the learning process. Metacognition awareness is often thought of as thinking about thinking (Schraw, 2012) [16].

Metacognitive awareness is refers to as the knowledge and control of cognitive processes. In other words, it is the knowledge about cognition and control of cognition. Metacognitive awareness is not only thinking about thinking, but also regulating and executing cognition (Coutinho, 2014) [9]. Metacognitive awareness refers to as thought about one's own thoughts and cognitions. Metacognition awareness is generally further grouped into two aspects of the concept; the knowledge of cognition and the regulation of cognition (Bruning, Schraw, & Ronning, 2012) [16].

Knowledge of cognition has been defined as knowledge that has been memorized regarding the goals and strategies of individuals in their efforts to accomplish tasks (Desoete & Veenman, 2011) [10].

Knowledge of cognition can further be thought of as involving declarative, procedural, and conditional types of knowledge (Schraw & Moshman, 2012) [16]. Metacognitive regulation or regulation of cognition refers to activities that control one's thinking and learning. Regulation of cognition contains three regulatory skills such as planning, monitoring comprehension and evaluation (Çetin, 2015) [7]. The components of metacognitive awareness are shown in Figure 1.

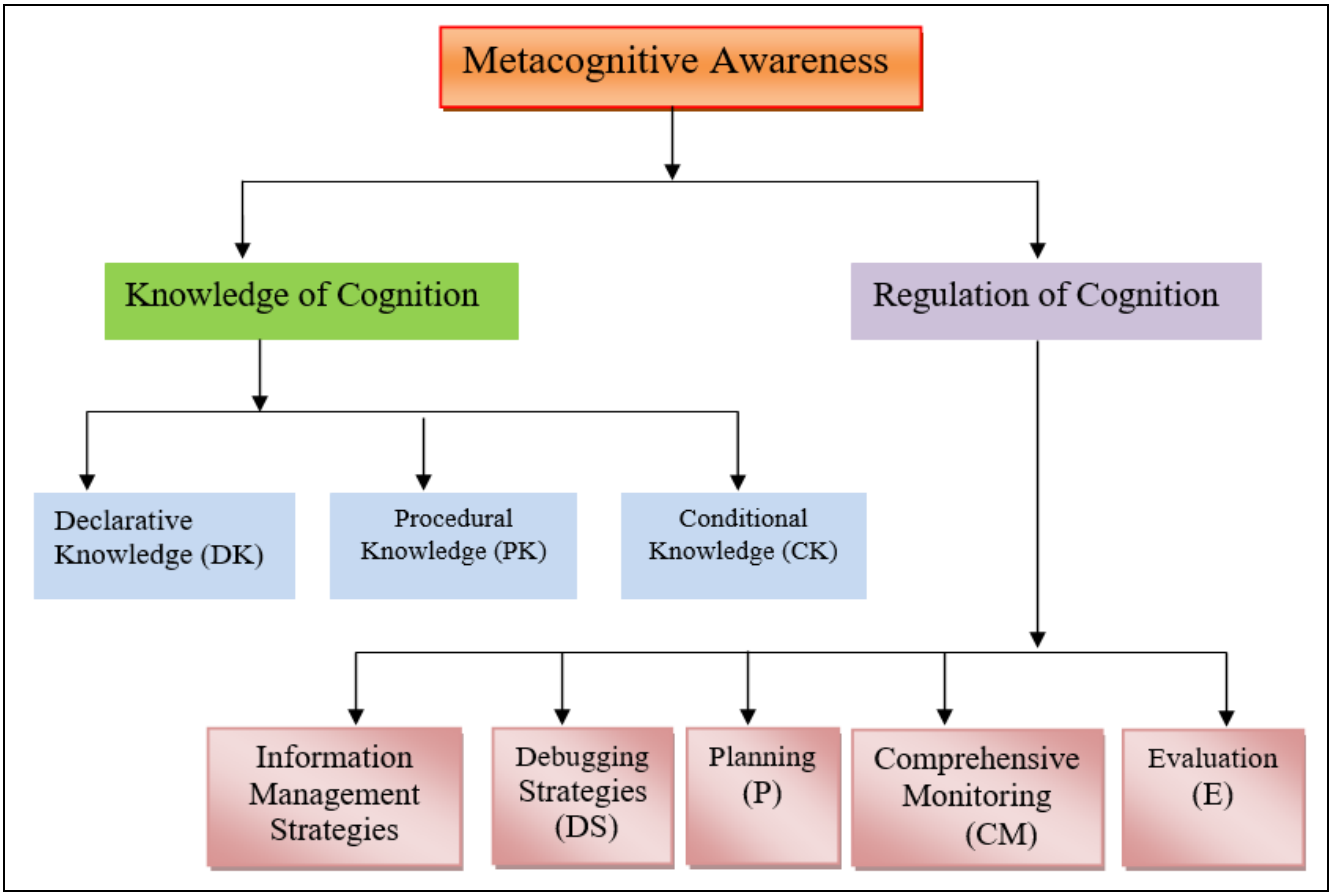

Fig 1: Metacognitive Awareness Components (Ajayi, 2019) [4]

Schraw (2013) [17] revealed that learners who are aware of their metacognition perform better than unaware learners. The author recognized high metacognitive awareness as an indicator of better performance since it allows learners to plan, sequence, and regulate their learning in a way that improve performance. Consequently, Olorundare (2015) [14] revealed that students' low metacognitive awareness is often attributed to poor teaching methods such as lecture and discussion methods adopted by teachers. Thus, the teacher's role is to carefully plan and use innovative teaching strategies that will train students to be consciously aware about their own thinking and teach them how to regulate it to ensure that they become more responsible in developing their own learning. Developing lessons that enhance students' participation and metacognition when engaging in Chemistry activities are anticipated to uplift metacognitive awareness. It is on this note that, this study investigated the effects of Predict-Explain-Observe-Explain and Vee Heuristic instructional strategies on students' metacognitive awareness in Chemistry.

Purpose of the Study

The purpose of this study was to investigate if there any possibility of enhancing students' metacognitive awareness in Chemistry in Ekiti State, Nigeria using Predict-Explain-Observe-Explain and Vee Heuristic Strategies. Specifically, the study:

1. Determined the effects of PEOE strategy, VH strategy and discussion method on students' metacognitive awareness in Chemistry.
2. Ascertained the interaction effects of treatments and gender on students' metacognitive awareness in Chemistry.

Research Questions

The following research questions guided the study

1. What are the mean metacognitive awareness scores of students taught Chemistry using PEOE strategy, VH strategy and discussion method?
2. What is the mean interaction effect of treatments and gender on students' metacognitive awareness in Chemistry?

Hypotheses

The following null hypotheses were tested

1. There is no significant difference in the mean metacognitive awareness scores of students taught Chemistry using PEOE strategy, VH strategy and discussion method.
2. There is no significant interaction effect of treatments and gender on the mean metacognitive awareness scores of students in Chemistry.

Research Design and Procedure

The study adopted a quasi-experimental non-randomized pre-test, post-test control group design. This design was adopted because it is not possible to have complete randomization of the subject as this may disrupt school organization. The study area was Ekiti State, Nigeria. The target population of this study was 14,753 which was the population of SSII chemistry students in study area. A sample of 308 students comprising 174 boys and 134 girls drawn from 9 schools within 9 Local Government Areas (LGA) out of 16 LGA in the Ekiti State, Nigeria selected using multi-stage sampling techniques. An instrument known as Metacognitive Awareness Inventory (MAI) was used for data collection. MAI was adopted from Lai (2011)

[13] and Schraw and Dennison (2012) [16]. Lai (2011) [13] organized the different types of knowledge of cognition into three types and listed three (3) main terminologies to represent the different types of knowledge of cognition. In the same vein, Schraw and Dennison (2012) [16] also enumerated five (5) terminologies in regulation of cognition. MAI is a forty-item inventory which is expected to determine the frequency of students' metacognitive awareness during chemistry classes. MAI is a 4-Likert scale with number indicators as 4 (always aware), 3 (frequently aware), 2 (sometimes aware), and 1 (never aware) which was used in the knowledge of cognition while the regulation of cognition has number indicators of 4 (always), 3 (frequent), 2 (sometimes), and 1 (never). Each subcategory comprises five (5) statements.

The instrument was face validated by presenting them to five experts in Science Education and one lecturer that is knowledgeable in test and measurement in the Department of Curriculum and Teaching, Benue State University, Makurdi and one expert in test and measurement in the College of Agricultural and Science Education, Department of Educational Foundations and General Studies, Federal University of Agriculture, Makurdi. The experts were asked to assess the instrument in terms of scope of coverage, content relevance, ambiguity, and vagueness of expression. Corrections and suggestions arising from these experts were used to review the instrument and the instructional packages. Metacognitive Awareness Inventory (MAI) upon validation was trial-tested to establish the reliability of the instrument. Cronbach Alpha was used to ascertain the reliability index of MAI which gave reliability value of 0.84.

Before the commencement of the actual treatment, the researcher used one week for the training of the Chemistry teachers who served as research assistants. Intact classes were assigned to experimental and control groups after which Metacognitive Awareness Inventory (MAI) was administered as pre-test by the researcher with the assistance of the sampled schools Chemistry teachers. This lasted for one week before actual teaching commences. During lessons, the teachers taught the experimental group I and experimental group II Chemistry topics using predict-explain-observe-explain and Vee heuristic instructional strategy respectively in line with lessons procedure prepared by the researcher. The control group were also taught the same Chemistry topics using the discussion lesson plans. This lasted for six weeks. At the end of these actual teaching periods, the pre- MAI was reshuffled and administered as post-test which lasted for one week. The pre-test score constituted the covariant of the post-test scores. Mean and Standard Deviation scores were used to answer the research questions while Analysis of Covariance (ANCOVA) was used to test the null hypotheses.

Results

Presentations in this section are based on research questions and null hypotheses

Research Question One

What are the mean metacognitive awareness scores of students taught Chemistry using PEOE strategy, VH strategy and discussion method? The answer to research question one is contained on Table 1.

Table 1: Mean Metacognitive Awareness and Standard Deviation Scores of Students taught Chemistry using PEOE strategy, VH strategy and discussion method

Group	N	PRE- MAI		POST- MAI		Mean Gain within Group
		$\bar{x}$	δ	$\bar{x}$	δ	
PEOE strategy	104	1.38	0.22	3.86	0.15	2.48
Discussion	103	1.33	0.20	2.16	0.14	0.83
Mean diff. between Groups		0.05		1.70		1.65
VH strategy	101	1.36	0.17	3.83	0.18	2.47
Discussion	103	1.33	0.20	2.16	0.14	0.83
Mean diff. between Groups		0.03		1.67		1.37
PEOE strategy	104	1.38	0.22	3.86	0.15	2.48
VH strategy	101	1.36	0.17	3.83	0.18	2.47
Mean diff. between Groups		0.02		0.03		0.01

Source: Field Survey, 2019

Table 1 reveals the mean metacognitive awareness and standard deviation scores of students taught Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM) on a paired comparative basis. The data in table 4 show that the mean difference between students in PEOE and DM groups was 1.65 in favour of PEOE. This implies that students in PEOE group had higher metacognitive awareness than students in DM group. Similarly, the mean difference between students in VH and DM groups was 1.37 in favour of VH Strategy. This implies that students in VH group had higher metacognitive awareness than those in DM group. In the same vein, the mean difference between students in PEOE and VH groups was 0.01. This difference though small is in favour of PEOE. This implies that students in PEOE group had slightly higher metacognitive awareness than their counterparts in VH group.

Research Question Two

What is the mean interaction effect of treatments and gender on students' metacognitive awareness in Chemistry? The answer to research question two is presented on figure 1.

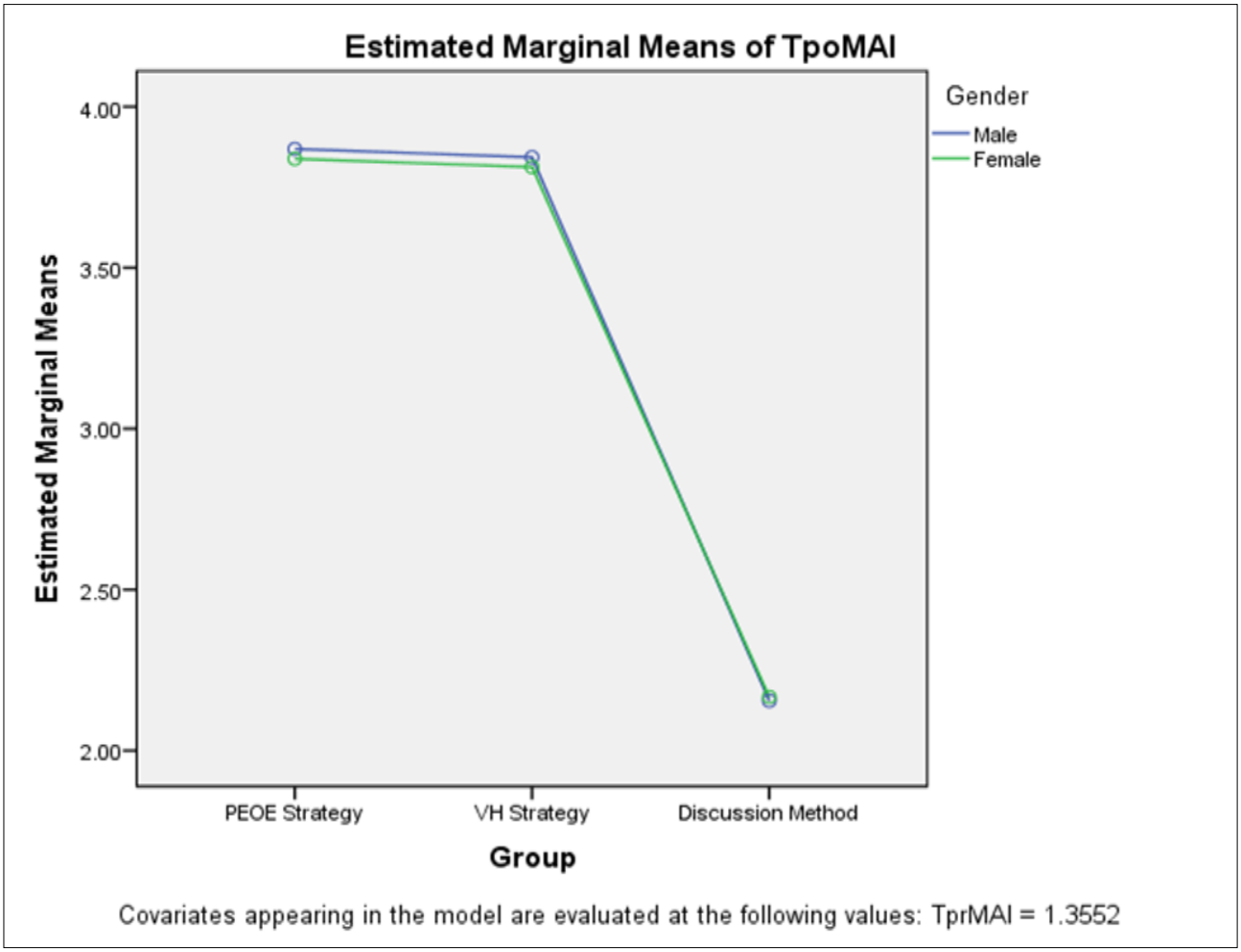

Fig 1: Interaction plot of treatments and gender on students' metacognitive awareness in Chemistry

Figure 1 presents a graph of the interaction of treatments and gender on the mean metacognitive awareness scores of students in Chemistry. The graph lines for gender did not intercept which suggests that there was no interactive effect of treatments and gender on students' metacognitive awareness in Chemistry.

Hypothesis One

There is no significant difference in the mean metacognitive awareness scores of students taught Chemistry using PEOE strategy, VH strategy and discussion method. The analysis of hypothesis one is contained on Table 2.

Table 2: Two-Way ANCOVA for Mean Metacognitive Awareness Scores of Students taught Chemistry using PEOE, VH and Discussion

Source	Type III sum of squares	*df*	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	194.499[a]	5	32.417	1282.860	.000	.962
Intercept	65.585	1	65.585	2595.466	.000	.896
TPrMAI	.009	1	.009	.337	.562	.001
Group	189.144	2	94.572	3742.616	.000	.961
Group*Gender	.030	2	.015	.600	.550	.004
Error	7.606	301	.025			
Total	3515.955	308				
Corrected Total	202.105	307				

a. R squared = .962 (Adjusted R Squared= .962)

***Source*:** Field Survey, 2019

Table 2 presents the two-way ANCOVA result for mean metacognitive awareness scores of students taught Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The data in table 2 reveal that the observed mean difference in the metacognitive awareness scores among the groups was significant [$F_{2,\ 301}$=3742.616, P<0.05]. Hence, the null hypothesis that there is no significant difference in the mean metacognitive awareness scores of students taught Chemistry using PEOE strategy, VH strategy and DM was rejected. This implies that there is a significant difference in the mean metacognitive awareness scores among the groups. Meanwhile, the effect size was 0.961 which Cohen (1988) in Pallant (2014) considered as large effect size. This implies that, 96.1% of the difference in the metacognitive awareness scores among the groups was explained by the treatments. Hence, the difference in the metacognitive awareness scores among the groups has a large statistical effect size.

Table 3: Bonferroni Post Hoc Comparison for Mean Metacognitive Awareness Scores of Students' taught Chemistry using PEOE, VH and DM

(I)	(J)	Mean Difference (I-J)	Std. Error	Sign.
Group	Group			
PEOE	DM	1.693*	.022	.000
VH	DM	1.667*	.022	.000
VH	PEOE	-.026	.022	.767

Source: Field Survey, 2019

Table 3 shows Bonferroni post-hoc comparison for mean metacognitive awareness scores of students' taught Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The results reveal that the mean difference (I-J) between PEOE and DM is 1.693* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean metacognitive awareness scores between the students taught Chemistry using PEOE and those taught using DM in favour of PEOE. Likewise, the results reveal that the mean difference (I-J) between VH and DM is 1.667* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean metacognitive awareness scores between the students taught Chemistry using VH strategy and those taught using DM in favour of VH. However, the paired comparison of VH and PEOE showed a mean difference of -.026 and this is not significant at $p>0.05$. This indicates no significant difference in the mean metacognitive awareness scores between students taught using PEOE and VH strategies.

Hypothesis Two

There is no significant interaction effect of treatments and gender on the mean metacognitive awareness scores of students in Chemistry. The data analysis of Table 2 is used to explain hypothesis 2.

The data analysis of Table 2 is used to explain hypothesis 2. The table presents a two-way ANCOVA for metacognitive awareness of students taught Chemistry using Predict-Explain-Observe-Explain (PEOE) strategy, Vee Heuristic (VH) strategy and discussion method (DM). The table also presents the interaction effect of instructional strategies and gender. The data in Table 2 reveals that there is no significant interaction effect of treatments and gender on the mean metacognitive awareness scores of students in Chemistry [$F_{2, 301} = .600$, $P>0.050$]. The null hypothesis is therefore not rejected. Meanwhile, the effect size was 0.004 which Cohen (1988) in Pallant (2014) considered as small effect size. This implies that, only 0.4% of the interaction in the metacognitive awareness scores among groups was explained by treatments and gender. Hence, the interaction of treatments and gender on students' metacognitive awareness has small statistical effect size.

Discussion of Findings

The study investigated if there any possibility of enhancing students' metacognitive awareness in Chemistry in Ekiti State, Nigeria using Predict-Explain-Observe-Explain and Vee Heuristic Strategies. The findings of this study revealed that students taught Chemistry using Predict-Explain-Observe-Explain (PEOE) Strategy had significantly higher metacognitive awareness than their counterparts taught using discussion method. This is in line with Bajar-Sales, Avilla and Camacho (2015) finding that PEOE significantly enhance students' metacognitive awareness when compared to conventional teaching approach. In another related study, Karamustafaoğlu, and Mamlok-Naaman (2015) investigated students' understanding of electrochemistry concepts using Predict-Observe-Explain (POE) strategy. Though the strategy used did not emphasize the important of students' explanation for their prediction. Yet, the finding of study revealed that, POE significantly enhanced students' understandings than lecture method.

The likely explanation for this outcome may be attributed to the fact that the PEOE strategy helped the learners to explore concept and generate investigation. Furthermore, the students are given the chance to express their schema and experience the science ideas behind the activity to satisfy their curiosity and thinking processes compared to the discussion method. Therefore, if PEOE strategy is implemented in classroom, it will enhance students' capacities to accomplish Chemistry task and control their thinking processes.

It was found that students taught using Vee Heuristic (VH) strategy had significantly higher metacognitive awareness than those taught using discussion method. This finding agrees with Mutai, Changeiywo and Okere (2014) who found that VH strategy was more effective in enhancing students' conceptual understanding and metacognition in the topic of moments in Physics than conventional teaching method. The likely explanation for this outcome may be attributed to the fact that the use of VH strategy provides a format for students to understand the nature of knowledge and construction processes of knowledge. VH strategy is a powerful metacognitive tool as it aid students to make explicit connections between prior and newly acquired information compared to discussion method that only promotes passive learning. Therefore, if VH strategy is implemented in classroom, it will enable students to understand how concepts and processes are meaningfully learned through student-directed, constructivist, and inquiry-based learning, thereby, improving their metacognitive awareness.

The study revealed that students taught Chemistry using Predict-Explain-Observe-Explain (PEOE) had slightly higher metacognitive awareness than their counterparts using Vee Heuristic (VH) strategy but ANCOVA test shows that the difference was no significant. This implies that, the difference in the metacognitive awareness of students taught Chemistry using PEOE and VH strategies was not statistically significant. There was a scarcity of studies on comparison between PEOE and VH strategies on students' metacognitive awareness in science subjects before. However, the likely explanation for this outcome may be connected to the fact that both PEOE and VH strategies are used to help develop a cognitive structure that enable students to see how scientific knowledge is developed through the process of reflecting on what they know and the investigation they undertake. Thus, if either PEOE or VH strategy is implemented in classroom, it will enhance students' capacities to accomplish Chemistry task and control their thinking processes.

The finding of this study also revealed that there is no significant interaction between strategies and gender on mean metacognitive awareness scores of students in Chemistry. This implies that either Predict-Explain-Observe-Explain (PEOE) or Vee Heuristic (VH) strategy is superior to the discussion method irrespective of gender in

fostering students' metacognitive awareness. Treatment interaction according to Abonyi cited in Ajayi (2019) [4] generally implies that different learners with different characteristics may profit more from one type of instructional method than from another and that therefore it may be possible to find the best match of learners' characteristic and instructional method in other to maximize learning outcomes. In this case, there is no need for separation of instructional method for male and female since either PEOE or VH strategy could be used successfully for the three groups.

Conclusion

It is evident from the findings of this study that the use of both Predict-Explain-Observe-Explain (PEOE) strategy and Vee heuristic (VH) strategy enhanced students' metacognitive awareness in Chemistry than the use of discussion method. There was no interaction effect between treatments and gender on students' metacognitive awareness in Chemistry. This implies that there is no need for separation of instructional strategy for male and female since either PEOE strategy or VH strategy could be used successfully

Recommendation

The following recommendations were made:

1. Chemistry teacher's trainee should be train on the application of Predict-Explain-Observe-Explain (PEOE) strategy and Vee heuristic (VH) strategy and serving teachers should employ the use of PEOE and VH strategies in teaching to enhance students' metacognitive awareness in Chemistry.
2. The curriculum developers should use PEOE and VH strategies to develop and refine the Chemistry curriculum in general and Chemistry in particular.
3. Ministry of Education, school administrators and professional bodies such as Association of Science Educators (ASE) and Science Teachers Association of Nigeria (STAN) should organize conferences or seminars and workshops to popularize and sensitize chemistry teachers on the integration of PEOE and VH instructional strategies in teaching Chemistry.

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