A quasi-experimental study of two technology-supported constructivist models training programmes and pre-service teachers' teaching quality and students' learning outcomes in chemistry

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ABSTRACT

The study investigated the effect of two technology-supported constructivist learning models training programmes (Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme and Technology-Supported Vee Heuristic (TS-VH) training programme) on pre-service teachers' teaching quality and students' learning outcomes in Chemistry. Quasi-experimental research design was adopted in this study. The instruments used for data collection were Pre-Service Teachers' Teaching Quality Inventory (PTTQI) and Chemistry Learning Outcomes Test (CLOT). Using multi-stage sampling technique, a sample of 9 pre-service teachers and 127 students drawn from 3 schools in Anyigba Local Government Area of Kogi State, Nigeria was selected for the main study. Descriptive statistics of mean and standard deviation scores were used to answer the research questions while the null hypotheses were tested using the inferential statistics of analysis of covariance. The study revealed that, the difference among the mean teaching quality scores of pre-service chemistry teachers as rated by students taught chemistry using TS-PEOE training programme, TS-VH training programme and those taught without training programme was statistically significant {F1, 125 =14.801, P<0.05}. Thus, chemistry teachers should adopt the use of the two technology-supported constructivist learning models training programmes so as to improve their teaching quality, ultimately leading to higher students learning outcomes in Chemistry.

Keywords: *TS-PEOE training programme, TS-VH training programme, Teaching quality, Learning outcomes and Chemistry.*

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Highlights of this paper

- The purpose of the research was to investigate the effect of two technology-supported constructivist learning models (TS-PEOE and TS-VH training programs) on pre-service teachers' teaching quality and students' learning outcomes using a quasi-experimental research design.
- TS-PEOE and TS-VH training programmes were the independent variables, and their effects on the dependent variables (pre-service teachers' teaching quality and students' learning outcomes) were measured by administering instruments to a sample of 127 SS2 students offering chemistry, drawn from three schools in Anyigba, using a purposive sampling method.
- The difference between the mean teaching quality ratings and learning outcome scores, as rated or scored by students taught chemistry using TS-PEOE, TS-VH, and those without a training program, was found to be statistically significant, respectively, $F_{1, 126} = 287.004$, $p_{1, 126} = 111.001$, $p<0.05$.

1. INTRODUCTION

Science education is expected to equipped learners with scientific knowledge and skills needed in the fast-changing world. Recently, science education is marked by an active shift towards improving pedagogical methods to meet various learning needs and predilection and to efficiently engage students and improve their learning experiences. Within this factor, this research probes into the exploration of constructivist instructional models as a potential way to upgrade teaching quality, students' learning outcome, and learning experiences through effective teacher training programmes. Constructivist learning models allows learner's active participation and understanding of learning process. By implication, high quality learning takes place when the learner's misconceptions are investigated and used during instruction. Higher teaching quality is core to enhance students learning outcome in schools. A good teaching quality is an effective instruction that promotes learners' active participation and learning outcome (Cihanoglu, 2018). Thus, there is need for teachers to maintain high quality teaching since good teaching quality, is important for a meaningful learning outcome.

Constructivist views learning as a creative process in which the learner is allow to create an internal exemplification and interpretation of understanding and experience. Learning is an engage process in which experience has a significant role to play in comprehending and grasping the objective(s) of such concept (Amineh & Hanier, 2015). Khalid and Azeem (2017) opines that a constructivist teacher assists the students through real-world problem-solving and inquiry-based learning tasks with which students plan and trial their thinking, draw conclusions and inferences, and communicate their understanding collaboratively with peer/teacher in a classroom. Constructivism promotes communication and interaction skills by creating a classroom situation that stresses collaboration and exchange of ideas. In a constructivist classroom, students learn how to express their ideas plainly as well as to collaborate on activities efficiently by participating in peer tasks. Students also exchange ideas and learn to conclude with others and to assess their contributions in a socially satisfactory manner.

Ebube (2020) and Ajala (2021) concluded that most chemistry teaching seems to be passive learning as students only listen to what teacher teaches without actively participating in the learning process. The teaching methods adopted by many teachers might not guarantee effective students' interest and learning that allows them to construct scientific understanding. By implication, chemistry teachers need to be equipped with effective pedagogical skills possibly through constructivist training programmes so as to learn how to develop instructions that could allow students to develop their own cognition. A constructivist training programme is an independent, systematically organized learning experience with a logical and clearly set of steps, objectives and evaluation basis (Gaetana, 2019). A constructivist training programme support students to construct what they learn, know and pave the way for their active participation in the learning process and as a result uplift the teaching quality.

Technology-supported science teaching provide students the exceptional opportunity to make the teaching and learning process collaborative, objective, clear, simple, interesting, engaging and effective. It is obligatory to enhance the skill level and increase the resourcefulness and adoptability of teachers through training. In this study, training is a knowledge acquisition process that involves the development or mastering of specific skills by teachers to equipped them, and ultimately enhancing their teaching quality. Training is the systematic course of action by which people learn knowledge and skill for a specific intention. Hence, to keep on using technological tools in teaching and learning, science teachers need to continually enhance their technological pedagogical knowledge in delivering meaningful learning instruction through adoption of technology-supported constructivist models. Thus, the study investigated the effectiveness of two technology-supported constructivist learning models training programmes namely Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme and Technology-Supported Vee Heuristic (TS-VH) training programme on pre-service teachers' teaching quality and students' learning outcomes in Chemistry.

The technique of Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) was modified from PEOE by the researchers to emphasize the use of technology tools in teaching and learning process. TS-PEOE is a constructivist instructional model where students in a small setting make predictions for a task and clarify the basis for their predictions, then conduct and observe a experiment using technology tools and are required to compare their observations with their predictions, thereby enhancing conceptual understanding of scientific knowledge. Therefore, TS-PEOE training programme is an structured procedure or guide used by teacher learn the needed skills or knowledge for a purpose of teaching chemistry effective, and ultimately facilitating students' active involvement in the teaching/learning process.

Technology-Supported Vee Heuristic (TS-VH) is a constructivist instructional model where students in a group setting are involved in aligned and sustained attempts in the creation of a V-shaped diagram using technology tools to constitute key elements (ideas) that are composed in the knowledge framework with two sides namely the theoretical (thinking side) on the left and methodological (doing side) on the right in order to monitor their learning activities and assess the outcome of these activities, thereby uplifting understanding of scientific knowledge. Therefore, TS-VH training programme is a coordinated procedure or guide used by teacher learn the needed skills or knowledge for a purpose of teaching chemistry effective, and ultimately facilitating students' active engagement in the teaching/learning process.

1.1. Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) Training Programme Guide

The training was to make pre-service teachers conversant with the TS-PEOE. During the training period each of the pre-service chemistry teachers were made to do micro-teaching for a minimum of forty minutes on any selected chemistry concept. The pre-service teachers were critiqued and corrections made were necessary. The training manual was as follows:

Day One: (3 hours)

Stage 1: The researchers explained to the pre-service chemistry teacher the purpose of the research. Explained the seven-step format for TS-PEOE steps for classroom activities. The main TS-PEOE phases which include introduction/checking previous knowledge; grouping/elicitation of students' ideas; introducing the experiment using technology tools; Predict; Explaining the predictions; Observe (carry out laboratory activities using technology tools); and Explaining the observations was explained to the pre-service teachers.

Stage 2: The pre-service chemistry teachers were given the relevant training guide for each TS-PEOE steps. In-class instruction was done by the pre-service chemistry teachers, and a predict-explain-observe-explain

technology-based activity which lasted for 80 minutes. Instructions for the activity were given to the students prior to the activity and each group were given a TS-PEOE worksheet and a pen to writes down their group decision on each phase of the TS-PEOE worksheet, using the steps outlined. The guidelines or steps for effective TS-PEOE activity was followed.

1. Predict phase: The captain or recorder for the group, writes down their prediction(s) as agreed upon by the group on the PEOE worksheet.
2. Explain phase: The captain or recorder for the group, writes down the explanation for their prediction(s) as agreed upon by the group on the PEOE worksheet.
3. Observe phase: Students carried out laboratory activities using technology tools as directed by the pre-service chemistry teacher. The captain or recorder for the group, writes down their observation(s) as agreed upon by the group on the TS-PEOE worksheet.
4. Explain phase: The group captain or recorder for the group, writes down the explanation for their observation(s) as agreed upon by the group on the TS-PEOE worksheet.

Stage 3: The researcher discussed the model lesson design with pre-service chemistry teachers using the selected chemistry concepts. The uniqueness of the TS-PEOE was also emphasized. Questions were asked and answered.

Assignment: Each of the pre-service teachers was given assignment to develop their own chemistry lesson plans for selected topics using the TS-PEOE steps.

Day Two: (2 hours)

Stage 4: Application phase. The pre-service teachers did a mock teaching using TS-PEOE steps to presents any selected chemistry concept. The researcher observed, as constructive criticisms and correction were also made. Questions were asked and answered.

Stage 5: The pre-service chemistry teachers were trained on the administration of data gathering instruments. That is, they were trained on the administration of the pre-test and post-test and how to score the test items. Questions were asked and answered.

1.2. Technology-Supported Vee Heuristic (TS-VH) Training Programme Guide

Day One: (3 hours)

Stage 1: The researchers explained to the pre-service chemistry teachers the purpose of the research. The researcher further explained that following the steps for effective construction of Technology-Supported Vee Heuristic (TS-VH). The main TS-VH phases which include formation of group/pooling of ideas, group brainstorming (thinking), group carrying out learning task (doing) using technology tools, presentation of group Vee diagram using technology tools, and summary and final class Vee diagram were explained to the pre-service teachers.

Stage 2: The pre-service teachers were given the relevant training guide for each TS-VH steps. There was an in-class instruction done by the pre-service teachers, and a Vee diagramming using technology tools activity was done which lasted for 80 minutes. Instructions for the activity were given to the students prior to the activity and each group were given a laptop with Canva installed (Canva is a graphic design tools that allows students to construct presentations, graph, diagram, posters, infographics and so on) to construct Vee diagram, using the outlined steps. The guidelines or steps for effective VH technology-based activity was followed.

a. Draw a V-shaped diagrams and place the focus question at the top center.

b. Input the key theories that form the basis of the investigation and write them at the top left side of the Vee.
c. Input the relevant principles and key concepts that are important in this investigation and put them in the appropriate spaces on the left side of the Vee diagram.
d. At the bottom point of the Vee diagram, identify and input the objects/event.
e. Experiment are conducted using technology tool (experiment mini-video are sourced by the pre-service teacher from multimedia platform such as YouTube or Glogster), students record the information or data generated or collected at the bottom right of the Vee diagram. This can be done using words, symbols or drawings.
f. Complete the right side of the Vee diagram by recording the knowledge claim, transformations, construct and records.

Stage 3: The researcher discussed the model lesson plans with pre-service teachers using the selected Chemistry concepts. The uniqueness of the TS-VH was also emphasized. Questions were asked and answered.

Assignment: Each of the pre-service teachers was given assignment to develop their own chemistry lesson plans for selected topics using the TS-VH steps.

Day Two: (2 hours)

Stage 4: Application phase. The pre-service teachers did a mock teaching using TS-VH steps to presents any selected chemistry concept. The researchers observed, as constructive criticisms and correction were also made. Questions were asked and answered.

Stage 5: The pre-service teachers were trained on the administration of data gathering instruments.

1.3. Purpose of the Study

The purpose of this study was to investigate the effect of two technology-supported constructivist learning models training programmes on pre-service chemistry teachers' teaching quality and students' learning outcomes in Chemistry. Specifically, the study:

1. Ascertain the effect of Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme, Technology-Supported Vee Heuristic (TS-VH) training programme and without training programme on teaching quality of pre-service teachers as rated by students.
2. Determine the effect of TS-PEOE training programme, TS-VH training programme and without training programme on students' learning outcome in chemistry.

1.4. Research Question

The following research questions guided this study:

1. What is the mean teaching quality rating differences among pre-service chemistry teachers as rated by students taught chemistry using Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme, Technology-Supported Vee Heuristic (TS-VH) training programme and those taught without training programme?
2. What is the mean learning outcomes scores differences among students taught chemistry using TS-PEOE training programme, TS-VH training programme and those taught without training programme?

1.5. Research Hypotheses

The following null hypotheses were formulated and tested in this study:

1. The difference in the mean teaching quality rating of pre-service chemistry teachers as rated by students taught chemistry using Technology-Supported Predict-Explain- Observe-Explain (TS-PEOE) training

programme, Technology-Supported Vee Heuristic (TS-VH) training programme and those taught without training programme is not statistically significant.

2. The difference in the mean learning outcome scores of students taught chemistry using TS-PEOE training programme, TS-VH training programme and those taught without training programme is not statistically significant.

2. METHODOLOGY AND EXPERIMENTAL PROCEDURE

A quasi-experimental research design was adopted in this study. The study area is Anyigba, Kogi State, Nigeria. Anyigba is a town in Dekina Local Government Area of Kogi State located between latitudes $7^{0}15$'N - $7^{0}29$'N and longitudes $7^{0}11$'E - $7^{0}32$'E and with an average altitude of 385 meters above sea level and total land mass area of 420 Sq. Km^{2} and has an estimated population of 189, 976 (National Population Commission (NPC), 2016). The major ethnic groups in Anyigba are Igala, Ebira, Gbagyi, Okun (Yoruba), Bassa, Nupe, Ogori, Igbo, Idoma, Hausa and so on. The population for this study comprises all the 49 pre-service chemistry teachers from department of Science Education, Prince Audu Abubakar University, Anyigba. In other words, the pre-service chemistry teachers here are all students in the final year of bachelor of Science degree of Chemistry and Education from Prince Audu Abubakar University, Anyigba. The population also comprises all the students offering chemistry in senior secondary school two in Anyigba, numbering 6,837 students from all the 56 approved senior secondary schools in Anyigba (Kogi State Secondary Education and Teaching Service Commission (STETSCOM), 2022). The sample of this study was made up of 9 pre-service chemistry teachers and 127 SS2 students that were drawn from 9 schools using purposive sampling technique. The instruments used was Pre-service Teachers' Teaching Quality Inventory (PTTQI) and Chemistry Learning Outcomes Test (CLOT).

Pre-service Teachers' Teaching Quality Inventory (PTTQI) was a researcher made 20 items questionnaire which was intended to help students assess the extent of the pre-service teachers teaching quality in chemistry. PTTQI is a 4-point Likert modified rating scale with 4 response options. The options are Very High Extent (VHE), High Extent (HE), Moderate Extent (ME) and Low Extent (LE). PTTQI is a 4-point Likert Scale with number indicators as 4 (VHE), 3 (HE), 2 (ME) and 1 (LE). Chemistry Learning Outcomes Test (CLOT) was developed from the chemistry concept expected to be taught since the target of the study is to improve the students' learning outcome. The test instrument consists two sections. Section A consists bio-data information of the respondents, while section B consisted 30 multiple choice objective items with four options (A, B, C, D) drawn from chemistry concepts to which respondents are expected to provide the correct answers by selecting the correct option.

Before the pre-service teachers training, the developed two constructivists models integrated with technology training programmes were validated by science education experts. Upon validation, three pre-service teachers were trained by the researcher using Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme guide. Likewise, three pre-service teachers were also trained using Technology-Supported Vee Heuristic (TS-VH) training programme guide and three pre-service teachers were not trained. This lasted for 1 week and after the training, the pre-service teachers developed lesson plans using the knowledge of TS-PEOE and TS-VH training programmes experienced respectively while those without training also developed lesson plan using the same chemistry topics.

The lesson plan developed by the pre-service teachers, Pre-service Teachers' Teaching Quality Inventory (PTTQI) and Chemistry Learning Outcomes Test (CLOT) were face validated by presenting them to three experts in science education/Measurement and Evaluation. The items were scrutinized by these expects. Corrections and suggestions arising from these experts were used to review the training programmes and the instruments. Upon

validation, the instruments were trial-tested to establish the reliability by administering PTTQI and CLOT to a randomly selected 37 SS2 students of a senior secondary school which is not part of the schools selected for this study. Pre-PTTQI and Pre-CLOT were administered and after 1 week of 6 periods of teaching, the PTTQI and CLOT was administered. Cronbach Alpha was used to ascertain the reliability index of PTTQI which gave reliability value of 0.89. The internal consistency of CLOT was tested using Kuder-Richardson (KR-21) formula which yielded a reliability value of 0.97. This indicate that the instruments are reliable (Ajayi, 2023).

Three intact classes were randomly assigned to experimental 1 group (pre-service teacher taught chemistry using the experience of TS-PEOE training programme), experimental 2 group (Pre-service teacher taught chemistry using the experience of TS-VH training programme), and Control group (Pre-service teacher taught chemistry without training programme) during the main study. Thereafter, Pre-service Teachers' Teaching Quality Inventory (PTTQI) and Chemistry Learning Outcomes Test (CLOT) were administered as pre-test by the pre-service teachers. This lasted for one week before actual teaching commences. During lessons, the pre-service teachers taught the experimental group I chemistry topics such as alkane, ethene, alkyne and alkanol using the experience of TS-PEOE training programme. The experimental group 2 were taught the same chemistry topics using the experience of TS-VH training programme while the control group were taught the same topics without any training programme. This lasted for three weeks. At the end of these actual teaching periods, the pre-PTTQI and pre-CLOT were reshuffled and administered as post-test which lasted for one week. Descriptive statistics of mean and standard deviation scores were used to answer the research question, while the inferential statistic of Analysis of Covariance (ANCOVA) were used to test the null hypotheses at 0.05 level of significance.

3. RESULTS

3.1. Research Question One

What is the mean teaching quality rating differences among pre-service chemistry teachers as rated by students taught chemistry using Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme, Technology-Supported Vee Heuristic (TS-VH) training programme and those taught without training programme? The answer to research question one is represented on Table 1 and Figure 1 respectively.

Table 1. Mean teaching quality and standard deviation rating as rated by students taught chemistry using TS-PEOE and TS-VH and without training programme.

Group	N	PRE- PTTQI		POST- PTTQI		Mean gain within group
		$\bar{x}$	δ	$\bar{x}$	δ	
TS-PEOE	44	1.17	0.23	3.72	0.31	2.55
Without training programme	45	1.15	0.19	2.16	0.23	1.01
Mean diff. between groups		0.02		1.56		1.54
TS-VH	38	1.16	0.22	3.61	0.24	2.45
Without training programme	45	1.15	0.19	2.16	0.23	1.01
Mean diff. between groups		0.01		1.45		1.44
TS-PEOE	44	1.17	0.23	3.72	0.31	2.55
TS-VH	38	1.16	0.22	3.61	0.24	2.45
Mean diff. between groups		0.01		0.11		0.10

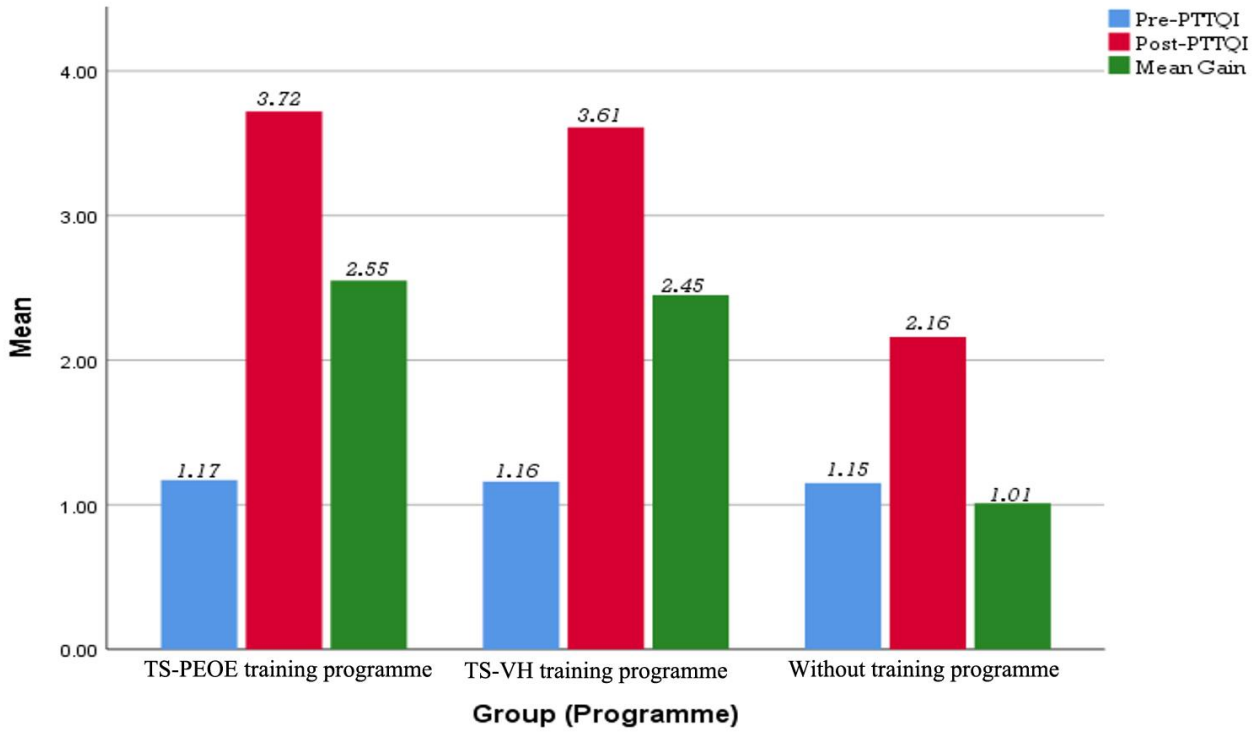

Figure 1. Pre- PTTQI, Post-PTTQI and mean gain rating in effect of TS-PEOE training programme, TS-VH training programme and without training programme on pre-service chemistry teaching quality.

The summary of the Pre-PTTQI and Post-PTTQI mean teaching quality rating differences among pre-service chemistry teachers as rated by students taught chemistry using Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme, Technology-Supported Vee Heuristic (TS-VH) training programme and those taught without training programme is represented in Figure 1. However, the data in Table 1 show that the overall mean difference between the TS-PEOE training programme and without training programme groups was 1.54 in favour of pre-service teachers that taught chemistry using the knowledge or experience of TS-PEOE training programme. This implies that pre-service teachers that taught chemistry using TS-PEOE training programme had higher teaching quality than pre-service teachers that taught without training programme. Similarly, the overall mean difference between the TS-VH training programme and without training programme groups was 1.44 in favour of pre-service teachers that taught chemistry using the knowledge of TS-VH training programme. This implies that pre-service teachers that taught chemistry using the experience of TS-VH training programme had higher teaching quality than pre-service teachers that taught without training programme. In the same vein, the overall mean difference between the TS-PEOE training programme and TS-VH training programme was 0.10. This difference though small is in favour of pre-service teachers that taught chemistry using TS-PEOE training programme. This implies that pre-service teachers that taught chemistry using the experience of TS-PEOE training programme had slightly higher teaching quality than pre-service teachers that taught using TS-VH training programme.

3.2. Research Question Two

What is the mean learning outcomes scores differences among students taught chemistry using TS-PEOE training programme, TS-VH training programme and those taught without training programme? The answer to research question two is presented on Table 2 and Figure 2 respectively.

Table 2. Mean learning outcome and standard deviation scores of students taught Chemistry using TS-PEOE, TS-VH and without training programme.

Group	N	PRE- CLOT		POST- CLOT		Mean gain within group
		$\bar{x}$	δ	$\bar{x}$	δ	
TS-PEOE	44	9.17	1.28	27.82	1.61	18.65
Without training programme	45	9.15	1.17	14.26	1.23	5.11
Mean diff. between groups		0.02		13.56		13.54
TS-VH	38	9.16	1.24	24.91	1.57	15.75
Without training programme	45	9.15	1.17	14.26	1.23	5.11
Mean diff. between groups		0.01		10.65		10.64
TS-PEOE	44	9.17	1.28	27.82	1.61	18.65
TS-VH	38	9.16	1.24	24.91	1.57	15.75
Mean diff. between groups		0.01		2.91		2.90

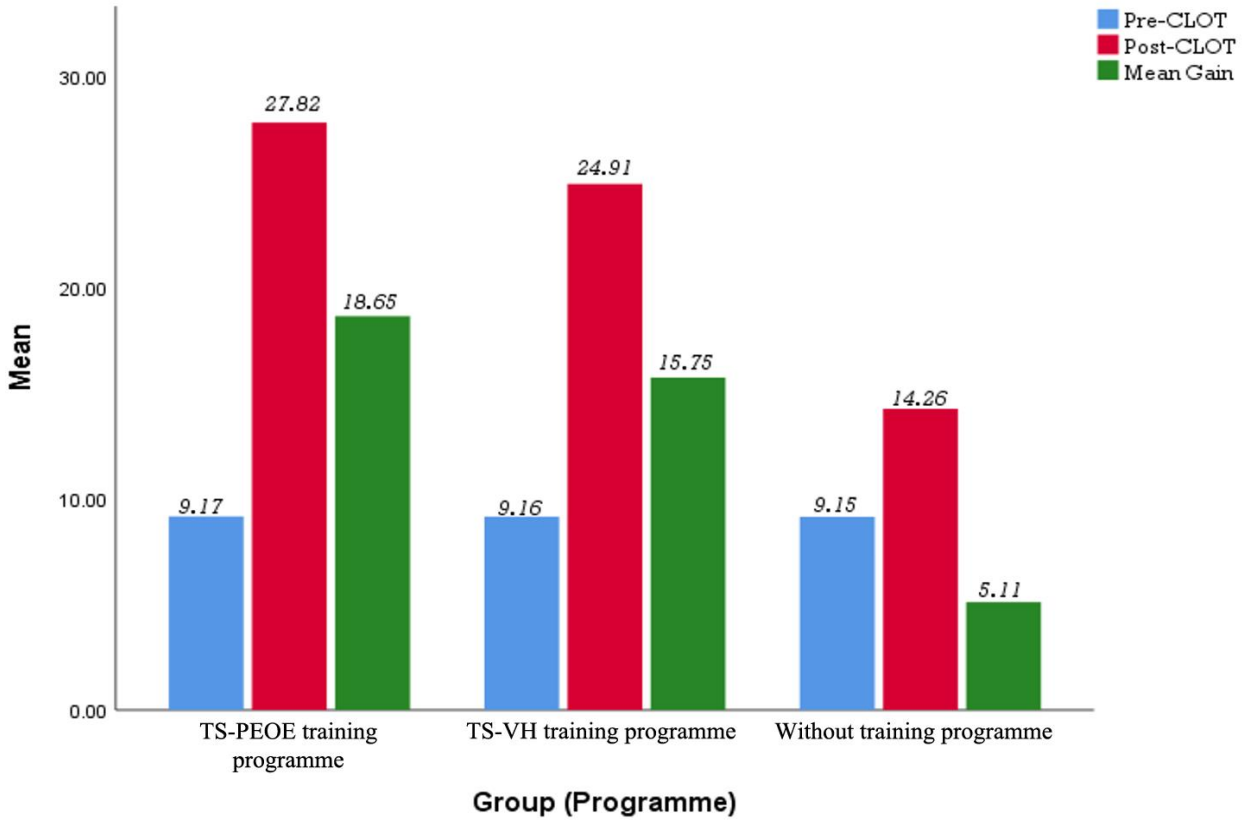

Figure 2. Pre- CLOT, Post-CLOT and mean gain in effect of TS-PEOE training programme, TS-VH training programme and without training programme on students learning outcomes in chemistry.

The summary of the Pre-CLOT and Post-CLOT mean learning outcome scores differences among students taught chemistry using Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme, Technology-Supported Vee Heuristic (TS-VH) training programme and those taught without training programme is represented in Figure 2. Thus, the data in Table 2 show that the overall mean learning outcome difference between the TS-PEOE training programme and without training programme groups was 13.54 in favour of students taught chemistry by pre-service teachers using experience of TS-PEOE training programme. This implies that students that taught chemistry using the experience of TS-PEOE training programme had higher learning outcome than students taught by pre-service teachers without training programme experience. Similarly, the overall mean difference between the TS-VH training programme and without training programme groups was 10.64 in favour of students taught chemistry using the experience of TS-VH training programme. This implies that

students taught chemistry by pre-service teachers using the experience of TS-VH training programme had higher learning outcome than students taught without training programme. In the same vein, the overall mean difference between the TS-PEOE training programme and TS-VH training programme was 2.90. This difference though relatively small is in favour of students taught by pre-service teachers using the experience of TS-PEOE training programme.

3.3. Hypothesis One

The difference in the mean teaching quality rating of pre-service chemistry teachers as rated by students taught chemistry using Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme, Technology-Supported Vee Heuristic (TS-VH) training programme and those taught without training programme is not statistically significant. The answer to hypothesis one is presented on Table 3.

Table 3. ANCOVA result for mean teaching quality ratings as rated by students taught chemistry using TS-PEOE, TS-VH and without training programme.

Source	Type III sum of squares	*df*	Mean square	F	Sig.	Partial eta squared
Corrected model	9855.904[a]	3	3285.301	69.007	0.000	0.378
Intercept	1772.009	1	1772.009	128.099	0.000	0.503
TPr PTTQI	165.309	1	1665.309	163.704	0.000	0.059
Group	3925.883	2	1962.942	287.004	0.000	0.729
Error	4004.003	123	22.575			
Total	20201.100	127				
Corrected total	19980.007	126				

Note: a. R squared = 0.042 (Adjusted R squared= 0.035).

Table 3 presents the ANCOVA result for mean teaching quality ratings of pre-service teachers as rated by students taught chemistry using the experience of TS-PEOE training programme, TS-VH training programme and without training programme. The data in Table 3 reveal that the observed mean difference in the teaching quality scores among the groups was significant $\{F_{2,\ 126}=287.004,\ P<0.05\}$. Hence, the null hypothesis that there is no significant difference in the mean teaching quality scores of pre-service chemistry teachers as rated by students taught chemistry using TS-PEOE training programme, TS-VH training programme and those taught without training programme was rejected. This implies that there is a significant difference in the mean teaching quality scores of pre-service teachers as rated by students taught chemistry using the experience of TS-PEOE, TS-VH and those taught without training programme. Meanwhile, the effect size was 0.729 as indicated by the corresponding partial eta squared value is considered as large effect size. This implies that, 72.9% of the difference or variance in the teaching quality scores among the groups was explained by the training programmes. Hence, the difference in the teaching quality scores among the groups has a large statistical effect size.

Table 4. Bonferroni post Hoc comparison for mean teaching quality ratingd as rated by students' chemistry using TS-PEOE, TS-VH and without training programme (WTP).

(I) Group	(J) Group	Mean difference (I-J)	Std. error	Sign.
TS-PEOE	WTP	1.549*	0.022	0.000
TS-VH	WTP	1.524*	0.022	0.000
TS-VH	TS-PEOE	-0.025	0.022	0.101

Note: * p < 0.1.

Table 4 shows Bonferroni post-hoc comparison for mean teaching quality ratings as Rated by Students' taught Chemistry using TS-PEOE training programmes, TS-VH training programmes and Without Training Programme (WTP). The results reveal that the mean difference (I-J) between TS-PEOE and without training programme is 1.549* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean teaching quality ratings between the students taught Chemistry by pre-service teachers using the experience of TS-PEOE training programme and those taught using without training programme in favour of students in TS-PEOE class. Likewise, the results reveal that the mean difference (I-J) between TS-VH and without training programme is 1.524* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean teaching quality ratings between the students taught Chemistry using the experience of TS-VH training programme and those taught using without training programme in favour of students in TS-VH class. However, the paired comparison of TS-PEOE and TS-VH showed a mean difference of -.025 and this is not significant at $p>0.05$. This indicates no significant difference in the mean teaching quality ratings of pre-service teachers as rated by students taught chemistry using the experience of TS-PEOE and TS-VH training programmes

3.4. Hypothesis Two

The difference in the mean learning outcome scores of students taught chemistry using TS-PEOE training programme, TS-VH training programme and those taught without training programme is not statistically significant. The answer to hypothesis two is presented on Table 5.

Table 5. ANCOVA result for mean learning outcomes scores of students taught chemistry using TS-PEOE, TS-VH and without training programme.

Source	Type III sum of squares	*df*	Mean square	F	Sig.	Partial eta squared
Corrected model	14959.001[a]	3	4986.334	97.001	0.000	0.392
Intercept	2272.009	1	2272.009	101.009	0.000	0.201
TPr^{CLOT}	1775.009	1	1775.009	153.001	0.000	0.151
Group	4305.883	2	2152.942	111.001	0.000	0.801
Error	1117.103	123	47.001			
Total	19901.000	127				
Corrected total	21110.001	126				

Note: a. R squared = 0.042 (Adjusted R squared= 0.035).

Table 5 presents the ANCOVA result for mean learning outcome scores of students taught chemistry using the experience of TS-PEOE training programme, TS-VH training programme and without training programme. The data in Table 5 reveal that the observed mean difference in the learning outcome scores among the groups was significant $\{F_{2,\ 126}=111.001,\ P<0.05\}$. Hence, the null hypothesis that there is no significant difference in the mean learning outcome scores of students taught chemistry using TS-PEOE training programme, TS-VH training programme and those taught without training programme was rejected. This implies that there is a significant difference in the mean learning outcome scores of students taught chemistry using the experience of TS-PEOE training programme, TS-VH training programme and those taught without training programme. Meanwhile, the effect size was 0.801 as indicated by the corresponding partial eta squared value is considered as large effect size. This implies that, 80.1% of the difference or variance in the learning outcome scores among the groups was explained by the training programme. Hence, the difference in the learning outcome among the groups has a large statistical effect size.

Table 6. Bonferroni post hoc comparison for mean learning outcome scores of students' taught Chemistry using TS-PEOE, TS-VH and without training programme (WTP).

(I) Group	(J) Group	Mean difference (I-J)	Std. error	Sign.
TS-PEOE	WTP	13.751*	0.451	0.000
TS-VH	WTP	12.236*	0.453	0.000
TS-VH	TS-PEOE	-1.515	0.467	0.173

Note: * $p < 0.1$.

Table 6 shows Bonferroni post-hoc comparison for mean learning outcomes scores of students' taught Chemistry using TS-PEOE, TS-VH and without training programme. The results reveal that the mean difference (I-J) between TS-PEOE training programme and without training programme is 13.751* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean learning outcomes scores between the students taught Chemistry by pre-service teachers using the experience of TS-PEOE training programme and those taught using without training programme in favour of students in TS-PEOE class. Likewise, the results reveal that the mean difference (I-J) between TS-VH and without training programme is 12.236* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean learning outcomes scores between the students taught Chemistry using the experience of TS-VH training programme and those taught without the experience of any training programme. However, the paired comparison of TS-PEOE and TS-VH training programme showed a mean difference of -1.515 and this is not significant at $p>0.05$. This indicates no significant difference in the mean learning outcome scores of students taught chemistry using the experience of TS-PEOE and TS-VH training programmes.

4. DISCUSSION OF FINDINGS

The study was on quasi-experimental study of two technology-supported constructivist models training programmes and pre-service teachers' teaching quality and students' learning outcomes in chemistry. The finding of this study revealed that there was a significant difference in the mean teaching quality scores of pre-service chemistry teachers as rated by students taught chemistry using the experience of TS-PEOE, TS-VH and those taught without training programme. The post-hoc comparison for the teaching quality scores revealed that pre-service teachers that taught chemistry using the experience of TS-PEOE training programme had significantly higher teaching quality than their counterparts that taught the same chemistry concept without having any experience of training programme. Likewise, the finding also revealed that teachers that pre-service teachers that taught chemistry using the experience of TS-VH training programme acquired had significantly higher teaching quality than their counterparts that taught the same chemistry concept without having any experience of training programme. However, the post-hoc comparison for the teaching quality among the pre-service teachers further revealed that the difference in the teaching quality scores between pre-service teachers as rated by students taught chemistry using the experience of TS-PEOE and TS-VH training programmes acquired respectively was not statistically significant. The likely reason for this outcome may be connected to the fact that the two constructivist models integrated with technology training programme helped the pre-service teachers to know how to make students explore concept and generate investigation. Furthermore, the fact that the use of TS-PEOE and TS-VH training programme respectively provides formats for teachers to see and understand how knowledge is developed through the process of reflecting on what learner know and the investigation they should undertake using technology tools enhance their teaching quality compared to methods that only promotes passive learning. This finding agrees with Gernale, Aranes, and Duad (2017) findings that students' achievement and attitudes towards

science improved significantly using constructivist approach. In the same vein, the finding is in line with Ajayi, Achor, and Otor (2019) findings that teachers improved significantly in their teaching quality in science education using Kolb's and 5E learning constructivist models compared to those using traditional teaching method.

The finding of this study revealed that there was a significant difference in the mean learning outcome scores of students taught chemistry using the experience of TS-PEOE, TS-VH and those taught without training programme. The post-hoc comparison for the learning outcome scores revealed that students taught chemistry by pre-service teachers using the experience of TS-PEOE training programme had significantly higher learning outcome than their counterparts that were taught without having any experience of training programme. Likewise, the finding also revealed that students taught chemistry by pre-service teachers using the experience of TS-VH training programme acquired had significantly higher learning outcome than their counterparts taught without having any experience of training programme. However, the post-hoc comparison for the learning outcome among the students further revealed that the difference in the learning outcome scores between students taught chemistry using the experience of TS-PEOE and TS-VH training programmes acquired respectively was not statistically significant. The likely reason for this outcome may be connected to the fact that the two constructivist models integrated with technology helped the learners to explore concept and generate investigation. The students are given the chance to express their schema and experience the ideas behind the activity to satisfy their curiosity and thinking process. Furthermore, the models exposed the students to various learning experiences from which students made reflective reasoning observation and as such acquire the necessary skills involved in the learning process. This finding agrees with Arslan and Emre (2021) and Özcan and Uyanık (2022) findings that Predict-Observe-Explain (POE) is an effective strategy in improving students' academic achievement, scientific process skills and attitude towards science than conventional teaching method. Though PEOE was not integrated with technology.

5. CONCLUSION

The use of knowledge acquired through Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme and Technology-Supported Vee Heuristic (TS-VH) training programme improved pre-service teachers' teaching quality in chemistry than those without training programme. It was found that the students taught chemistry by pre-service teachers using the knowledge acquired through the two technology-supported constructivist models training programmes had higher learning outcome than those taught by pre-service teachers without training programme. The following recommendations were made:

1. Pre-service and serving chemistry teachers should adopt Technology-Supported Predict-Explain-Observe-Explain (TS-PEOE) training programme and Technology-Supported Vee Heuristic (TS-VH) training programme and ensure active participations in other related pedagogical training programmes so as to enhance their teaching quality.
2. Ministry of Education and professional bodies such as Science Teachers Association of Nigeria (STAN) should organize conference or workshops to popularize and sensitize teachers on the integration of TS-PEOE and TS-VH models into classroom instructions so as to improving students learning outcomes in Chemistry.

REFERENCES

Ajala, H. L. (2021). Conceptual change pedagogy and population education in secondary schools. *Knowledge Review, 3*(2), 1-6.

Ajayi, O. V. (2023). A review on primary sources of data and secondary sources of data. *European Journal of Education and Pedagogy, 2*(3), 1-7. https://doi.org/10.5281/zenodo.15328022

Ajayi, V. O., Achor, E. E., & Otor, E. E. (2019). Improving teaching quality in science education using Kolb's learning model and 5E learning model. *Journal of Research in Curriculum and Teaching, Benue State University, Makurdi, 11*(1), 1–13. https://doi.org/10.5281/zenodo.13341806

Amineh, R. J., & Hanier, D. A. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages, 1*(1), 9-16.

Arslan, J., & Emre, M. N. (2021). *Innovative models of teaching* (6th ed.). Boston: Atlyn and Bacon.

Cihanoglu, M. O. (2018). Teaching quality of teachers in Procedia. *Social and Behavioural Science, 46*, 4529-4533.

Ebube, K. K. (2020). *Effects of constructivist instructional model on senior secondary school students' achievement and retention in Chemistry*. Unpublished PhD Thesis, University of Nigeria, Nsukka.

Gaetana, E.E. (2019). *Excellent classroom management and attention*. McGraw Hill: Wadsworth Publishing Company.

Gernale, J.P., Arañes, F.Q., & Duad, V. (2017). Effects of predict-observe-explain (POE) approach on students' achievement and attitudes towards science. *The Normal Lights, 9*(2), 1-20.

Khalid, A., & Azeem, M. (2012). Constructivist vs traditional: Effective instructional approach in teacher education. *International Journal of Humanities and Social Science, 2*(5), 170-177.

Kogi State Secondary Education and Teaching Service Commission (STETSCOM). (2022). *List of approved senior secondary schools and enrollment statistics in Anyigba*. Lokoja, Nigeria: Kogi State Ministry of Education.

National Population Commission (NPC). (2016). *Population and housing census of Nigeria: 2016 census report*. Abuja, Nigeria: National Population Commission.

Özcan, G., & Uyanık, G. (2022). The effects of the Predict–Observe–Explain (POE) strategy on academic achievement, attitude, and retention in science learning. *Journal of Pedagogical Research, 6*(3), 103–111.