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Enhancing Students' Self-Confidence and Critical Thinking Ability in Identifying Physical and Chemical Changes Using Technology-Assisted Constructivist Approaches

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Abstract

Purpose: This study examined the effectiveness of technology-assisted constructivist approaches—namely, the Predict-Explain-Observe-Explain (PEOE) and Invitation-Exploration-Proposing Explanation-Taking Action (IEPT) models—in enhancing senior secondary students' self-confidence and critical thinking in identifying physical and chemical changes. **Methodology:** A quasi-experimental, non-randomized pre-test, post-test control group design was employed. Instruments used were the Physical and Chemical Changes Self-Confidence Scale (PCCSS) and the Critical Thinking Ability Test (CTAT), both validated by subject experts. The study population consisted of 5,543 SS1 Chemistry students in Dekina Local Government Area, Kogi State, Nigeria. A sample of 228 students from six schools was selected through multi-stage sampling. Four research questions and four null hypotheses guided the study. Data were analyzed using mean, standard deviation, and Analysis of Covariance (ANCOVA). **Findings:** Results indicated statistically significant differences in students' mean self-confidence and critical thinking scores across the PEOE, IEPT, and traditional discussion groups [$F(2, 227) = 2325.074$, $p < .05$; $F(2, 227) = 209.004$, $p < .05$]. However, no significant interaction effects were found between instructional method and gender on students' self-confidence or critical thinking scores [$F(2, 227) = .085$, $p > .05$; $F(2, 227) = .225$, $p > .05$]. **Significance:** The study concludes that technology-assisted constructivist strategies significantly improve students' cognitive and affective engagement in Chemistry. It is recommended that Chemistry educators integrate the PEOE and IEPT models to foster deeper understanding, self-confidence, and critical thinking in distinguishing between physical and chemical changes.

Keywords: Critical Thinking Ability, Physical and Chemical Changes, Self-Confidence, Technology-Assisted PEOE, Technology-Assisted IEPT.

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Introduction

Chemistry teaching in general aims at equipping the learners with appropriate scientific and innovative knowledge which will enable them to explore their surroundings and become more creative and self-reliant for national development (Ajayi, 2019). Chemistry is central to many of the scientific fields of human endeavors. Chemistry is a science-based subject taught to students in their senior secondary school classes focused at educating students about the fundamental principles of chemistry, including the properties, composition, chemical reactions and its applications.

Physical changes which is the main focus of this study involve the alterations in size, shape, state or other physical properties of a substance whereas chemical changes involve the formation of new substances with different chemical compositions and properties. West African Examination Council (WAEC) Chief Examiners' report (2022/2023) on Chemistry result indicates that students have difficulty distinguishing between physical and chemical change, despite formal teaching, and the distinction is somewhat arbitrary. Thus, understanding of the differences between purely physical processes such as melting, evaporation and boiling and the changes that take place in chemical reactions, particularly the idea that new substances are formed necessitated the selection of the topic (identifying physical and chemical changes) for this study.

Understanding physical and chemical changes is important for various fields, including chemistry, materials science and everyday life, as it enables us to predict and control the behaviour of substances. Hence, effective teaching of identifying physical and chemical changes should be given more serious attention. The important of chemistry to national development cannot be over-emphasized. Yet, self-confidence of students in chemistry in has been reported very poor in Nigeria (Ahmed, 2022). Students with low self-confidence may fear failure or judgment, leading to avoidance of classroom participation.

Students with low self-confidence students can create a negative self-fulfilling prophecy, where students don't put forth their best critical thinking ability to solve problems. The importance of students' self-confidence and it's imparted on their critical thinking ability should be given more serious attention. Thus, creating a supportive and inclusive classroom that promote self-confidence and critical thinking is very important. Ahmed (2022) concluded that students' low self-confidence that, they don't have the ability needed to complete the cognitive-ability test or task has been attributed to the ineffective teaching methods such as discussion or lecture method adopted by teachers. Self-confidence is an attitude about your skills and capabilities. In other words, self-confidence is a feeling of assurance in one's own capabilities and judgment. High Self-confident students have a strong belief in their capabilities and make decisions based on their own judgment, rather than relying on external validation. On the other hand, low self-confident students is always full of self-doubt, passive and submissive (Al-Hebaish, 2020).

Self-confidence may facilitate or debilitate students' critical thinking ability. This is because students who possess high self-confidence are likely to have high critical thinking ability due to their confidence. Critical thinking ability is the capacity to analyze information objectively, evaluate arguments, and form well-reasoned judgment or conclusion. Critical thinking ability is essential for problem-solving (identify and resolve complex problem effectively). Students' low or weak critical thinking abilities can manifest as a reliance on rote memorization, difficulty analyzing information, and struggle with problem-solving and independent thought. Demirhan and Besoluk (2019) lament the inability of science teachers to teach students in a way that they will 'think outside the box' to be able to solve problem on

their own. Thinking outside the box could enable learners cope with future challenges which could be in other areas of human endeavors.

In the same vein, Foong (2019) lamented that the poor students' critical thinking has often been blamed on poor teaching method such as discussion method. Considering, critical thinking is one of several learning and innovative skills necessary to prepare students for post-secondary education and professional disciples. There is need for learning paradigm to shift from low level thinking skills to learning higher order thinking skills such as prediction, evaluation and syntheses. Thus, preparing the students to become successful individuals, chemistry teachers need to ensure that their teaching is effective. Thus, developing lesson using innovative approaches that involve students' active participation when engaging in identifying physical and chemical changes activities are anticipated to uplift self-confidence and critical thinking ability. Consequently, considering the fast speed of change and innovation in knowledge, the integration of technology tools during teaching and learning processes seems necessary.

Technology plays a large role in providing a more engaged learning environment, boosts collaboration and support learning. The use of technology in teaching has revolutionized the way chemistry educators present information and engage students, leading to more effective and immersive learning experiences. The use of technology makes the teaching process objective, clear, simple, interesting, engaging and effective. Thus, the researcher adapted the integration of technology tools to constructivist instructional approaches to emphasize on the use of technology in classroom. This assertion calls for the need to find innovative approaches such as Technology-assisted Predict-Explain-Observe-Explain (PEOE) approach and Technology-assisted Invitation, Exploration, Proposing-Explanation and Taking action (IEPT) approach that may have the potentials to equip students to think about their cognition, interact, monitor their learning activities and evaluate the results of these activities and thereby enhancing their conceptual understanding and may invariable enhance self-confidence and critical thinking ability.

The technique of Technology-assisted Predict-Explain-Observe-Explain (PEOE) was modified from Predict-Observe-Explain (POE) by the researchers to emphasize that the students need to explain their predictions to make their beliefs explicit and foster interaction using technology tools. Technology-assisted PEOE involves integrating simple technology tools such as educational mini-lesson video, computer-based puzzles, and multimedia etcetera to the approach. Thus, technology-assisted PEOE is a constructivist instructional approach where learners in a small group setting make predictions for an event and explain the reasons for their predictions, then watch, listen, and observe a laboratory experiment or activities using technology tools and are required to compare their observations with their predictions, thereby enhancing conceptual understanding of scientific knowledge.

Technology-assisted Invitation, Exploration, Proposing-Explanation and Taking action (IEPT) approach was adapted from IEPT approach by the researcher to foster students' interaction and engagement using technology tools. It involves integrating simple technology tools such as video mini-lesson, computer-based puzzles, and multimedia etcetera to IEPT approach. In conclusion, Technology-Enhanced IEPT approach is a four-step constructivist instructional approach where students are engaged actively in constructing knowledge through exploration of activities using technology tools, discussion and evaluation of the results of these activities thereby enhancing conceptual understanding. In other words, this approach arranges learning experience through Invitation (Invitation involves recognition of the problem), exploration using technology tools, proposing explanation and Taking action as that

students have the opportunity to construct their understanding of a concept. Technology-Enhanced IEPT approach is a teaching approach adopted by a teacher to teach through technology based-activity in which the students participate thoroughly and bring about efficient learning experience. It is an approach in which the child is actively engaged both mentally and physically. Technology-Enhanced IEPT is a form of approach that encourages thoughtful reflection on technology-based activity explored.

Gender has to do with socially constructed differences which lead to forms of inequality such that the male is regarded as superior and all-knowing and the female as inferior and incompetent. Gender inequality in chemistry has remained a perennial problem of global scope. The differences between boys and girls in relation to chemistry learning outcomes have received a lot of attention in recent years. Some studies indicate that boys achieve better (Samuel et al., 2023), either no difference (Ajayi & Audu, 2023; Nwafor et al., 2024) or girls outperform boys (Ifagbemi, 2021) have been demonstrated. Studies on gender differences continued to yield inconsistent results and it has usually been attributed to unequal exposure of males and females to learning instructions relevant to chemistry learning.

Purpose of the Study

The purpose of the study was to find out if technology-assisted constructivist approaches could enhance students' self-confidence and critical thinking ability in identifying physical and chemical changes. Specifically, the study was set out to:

1. Find out the effects of Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method on students' self-confidence in identifying physical and chemical changes.
2. Ascertain the interaction effect of treatments and gender on students' self-confidence in identifying physical and chemical changes.
3. Find out the effects of Technology-assisted PEOE, Technology-Enhanced IEPT approaches and discussion method on students' critical thinking ability in identifying physical and chemical changes.
4. Ascertain the interaction effect of treatments and gender on students' critical thinking ability in identifying physical and chemical changes.

Research Question

The following research questions guided this study

1. What are the mean self-confidence ratings difference among students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method?
2. What is the interaction effect of treatments and gender on students' self-confidence rating in identifying physical and chemical changes?
3. What are the mean critical thinking ability scores difference among students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method?
4. What is the interaction effect of treatments and gender on students' critical thinking ability scores in identifying physical and chemical changes?

Hypotheses

The following null hypotheses guided the study:

1. There is no significant difference in the self-confidence ratings of students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method.
2. There is no significant interaction effect of treatments and gender on the self-confidence ratings of students in identifying physical and chemical changes.
3. There is no significant difference in the critical thinking ability scores of students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method.
4. There is no significant interaction effect of treatments and gender on the critical thinking ability scores of students in identifying physical and chemical changes.

Method

Quasi-experimental research design was adopted in this study. The study area is Dekina LGA, Kogi State, Nigeria. Dekina LGA of Kogi State is located in the middle belt area of Kogi State, on the A233 highway. Dekina LGA is between latitudes 7^0 41'41" N and longitudes 7^0 01'20" E with a total land mass area of 2461 Km^2 (950 Sq. ml) and has an estimated population of 260, 312. The major ethnic groups in Dekina are Igala, Ebira, Gbagyi, Okun (Yoruba), Bassa, Nupe, Ogori, Igbo, Idoma, and Hausa. The major rural area in Dekina LGA is Abocho, Adumu Egume, Dekina Town, Emewe, Odu I, Oganenigu, Anyigba and Okura Olafia. The major ethnic groups in Dekina are Igala, Ebira, Gbagyi, Okun (Yoruba), Bassa, Nupe, Ogori, Igbo, Idoma, and Hausa. The population for this study was made up of 5543 Senior Secondary one student in the 39 government-approved Senior Secondary Schools in Dekina LGA. A sample of 228 Senior Secondary 1 students was purposively sampled from 6 schools out of the 24 SSS in Dekina LGA. The instruments used for data collection are Physical and Chemical Changes Self-Confidence Scale (PCCSS) and Critical Thinking Ability Test (CTAT)

Physical and Chemical Changes Self-Confidence Scale (PCCSS) was a researcher made 25-item questionnaire which was intended to help students express their level of confidence in answering questions or solving problem related to identifying physical and chemical changes. PCCSS is a 4-point Likert modified rating scale with 4 response options. The options are Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD). PCCSS is a 4-points Likert-Scale with number indicators as 4 (SA), 3 (A), 2 (D) and 1 (SD). Critical Thinking Ability Test (CTAT) was adapted from Watson and Glizer (2022) Critical Thinking Ability Test. Critical Thinking Ability Test (CTAT) was modified to include physical and chemical changes concept. The test items looked at individual's ability to make correct inferences, recognize assumptions, make deductions, come to conclusion, interprets and evaluate arguments. Thus, the critical thinking test adapted in this study is based on recognizing assumptions, evaluating arguments and drawing conclusion. CTAT is a 30 multiple choice tests made of short statements and conclusions to be answered within 30 minutes. Students were to read through the statements carefully and come out with definite conclusions.

The instructional lesson plans, Physical and Chemical Changes Self-Confidence Scale (PCCSS) and Critical Thinking Ability Test (CTAT) were face validated by presenting them to three experts in Chemistry Education/Measurement and Evaluation. Upon validation, the reliability of the instruments

was established by administering PCCSS and CTAT to a randomly selected 49 SS1 students of a senior secondary school which is not part of the schools used for the main study. After 1 week of 4 periods of teaching, the PCCSS and CTAT were administered. Cronbach Alpha was used to ascertain the reliability index of PCCSS which gave reliability value of 0.89. The internal consistency of CTAT which yielded a reliability value of 0.97 was tested using Kuder-Richardson (KR-21) formula. During the main study, six chemistry teachers were trained by the researcher using Technology-assisted Predict-Explain-Observe-Explain (PEOE) lesson plan and Technology-assisted Invitation, Exploration, Proposing-Explanation and Taking action (IEPT) lesson plans and discussion lesson plans respectively and this lasted for 1 week. After the training, two intact classes were assigned randomly to experimental group 1 (Technology-assisted PEOE group), experimental group 2 (Technology-assisted IEPT group) and Control group (Discussion group).

Before actual teaching commences, Physical and Chemical Changes Self-Confidence Scale (PCCSS) and Critical Thinking Ability Test (CTAT) were administered as pre-test by the chemistry teachers and this lasted for one week. During lessons, the teachers taught the experimental group 1 identifying physical and chemical changes using Technology-assisted PEOE lesson plan, the teachers taught the experimental group 2 identifying physical and chemical changes using Technology-assisted IEPT lesson plan, while, the control group were taught the same experimental group 2 identifying physical and chemical changes topics using discussion lesson plan. This lasted for three weeks. At the end of these actual teaching periods, the pre-test was reshuffled and administered as post-test which lasted for one week. Mean and standard deviation scores was used to answer the research questions while Analysis of Covariance (ANCOVA) was used to test the null hypotheses.

Results and Discussions

Research Question 1

What are the mean self-confidence ratings difference among students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method? Table 1 presented the answer to research question one.

Table 1

Mean Self-Confidence and Standard Deviation Scores of Students Taught Identifying Physical and Chemical Changes using Technology-Assisted PEOE, Technology-Assisted IEPT and Discussion Method

Group	N	PRE- PCCSS		POST- PCCSS		Mean Gain within Group
		$\tilde{x}$	δ	$\tilde{x}$	δ	
Technology-Assisted PEOE	79	1.27	0.23	3.72	0.17	2.45
Discussion	76	1.24	0.19	2.46	0.14	1.22

Mean diff. between Groups		0.03		1.26		1.23
Technology-Assisted IEPT	73	1.26	0.24	3.61	0.15	2.35
Discussion	76	1.24	0.19	2.46	0.14	1.22
Mean diff. between Groups		0.02		2.26		2.24
Technology-Assisted PEOE	79	1.27	0.23	3.72	0.17	2.45
Technology-Assisted IEPT	73	1.26	0.24	3.61	0.15	2.35
Mean diff. between Groups		0.01		0.11		0.10

Source: Field Survey, 2025

Table 1 reveals the mean self-confidence and standard deviation scores of students taught identifying physical and chemical changes using Technology-Assisted Predict-Explain-Observe-Explain (PEOE) approach, Technology-Assisted Invitation, Exploration, Proposing-Explanation and Taking action (IEPT) approach and discussion method (DM) on a paired comparative basis. The data in Table 1 show that the overall mean difference between students in Technology-Assisted PEOE and DM groups was 1.23 in favour of Technology-assisted PEOE. This implies that students in Technology-assisted PEOE group had higher self-confidence than students in DM group. Similarly, the overall mean difference between students in Technology-Assisted IEPT and DM groups was 1.22 in favour of Technology-assisted IEPT approach. This implies that students in Technology-assisted IEPT group had higher self-confidence than those in DM group. In the same vein, the overall mean difference between students in Technology-Assisted PEOE and Technology-assisted IEPT groups was 0.10. This difference though small is in favour of Technology-assisted PEOE approach. This implies that students in Technology-assisted PEOE group had slightly higher self-confidence than their counterparts in Technology-assisted IEPT group. In conclusion, students taught using Technology-assisted PEOE had slightly higher self-confidence than those taught using Technology-Assisted IEPT approach. Meanwhile, students taught identifying physical and chemical changes using Technology-assisted IEPT approach had higher self-confidence than those taught using discussion method.

Research Question 2

What is the interaction effect of treatments and gender on students' self-confidence rating in identifying physical and chemical changes? Research question two is presented on Figure 1.

Figure 1

Interaction bar chart of treatments and gender on students' self-confidence in identifying physical and chemical changes

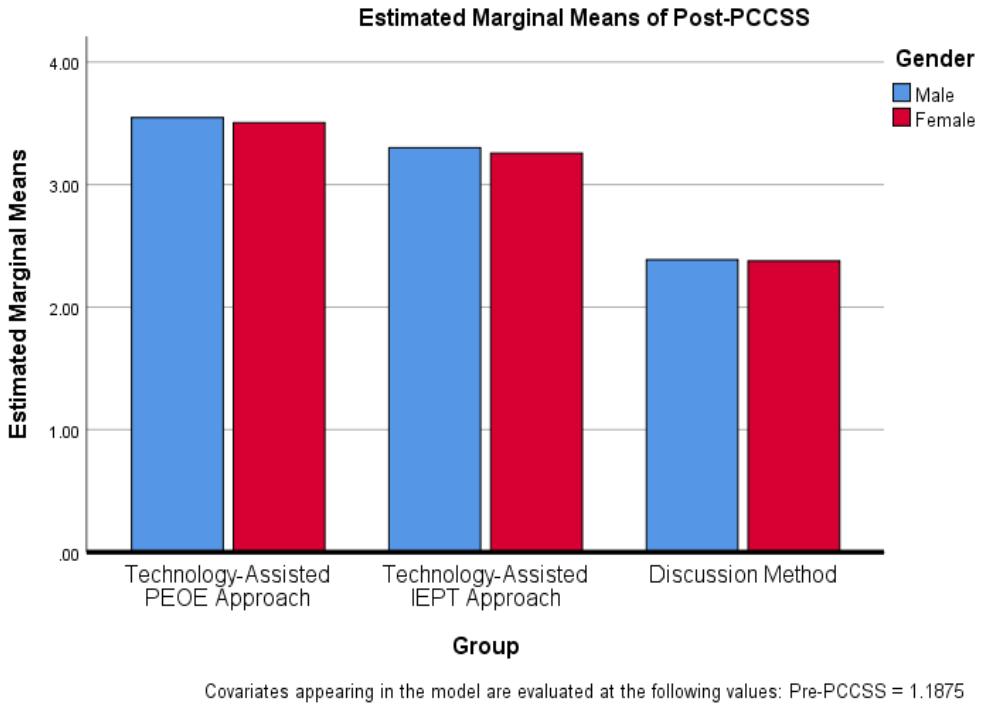

Figure 1 presents a bar chart of the interaction effect of treatments and gender on the mean self-confidence rating of students in identifying physical and chemical changes. The bar charts of each treatment are roughly the same height for both genders. In other words, the lines connecting the tops of the bars are roughly parallel which suggests that the treatment effect is consistent across genders. Hence, interaction effect of treatments and gender on students' self-confidence in identifying physical and chemical changes was very minimal.

Research Question 3

What are the mean critical thinking ability scores difference among students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method? Table 2 presented the answer to research question three.

Table 2

Mean Critical Thinking Ability and Standard Deviation Scores of Students Taught Identifying Physical and Chemical Changes using Technology-Assisted PEOE, Technology-Assisted IEPT and Discussion Method

Group	N	PRE- CTAT		POST- CTAT		Mean Gain within Group
		$\tilde{x}$	δ	$\tilde{x}$	δ	
Technology-Assisted PEOE	79	8.38	2.27	27.77	2.98	19.39
Discussion	76	8.34	2.22	14.59	2.40	6.25
Mean diff. between Groups		0.04		13.18		13.14
Technology-Assisted IEPT	73	8.35	2.24	22.99	2.55	14.64
Discussion	76	8.34	2.22	14.59	2.40	6.25
Mean diff. between Groups		0.01		8.40		8.39
Technology-Assisted PEOE	79	8.38	2.27	27.77	2.98	19.39
Technology-Assisted IEPT	73	8.35	2.24	22.99	2.55	14.64
Mean diff. between Groups		0.03		4.78		4.75

Source: Field Survey, 2025

Table 2 reveals the mean critical thinking ability and standard deviation scores of students taught identifying physical and chemical changes using Technology-Assisted Predict-Explain-Observe-Explain (PEOE) approach, Technology-Assisted Invitation, Exploration, Proposing-Explanation and Taking action (IEPT) approach and discussion method (DM) on a paired comparative basis. The data in Table 2 show that the overall mean difference between students in Technology-Assisted PEOE and DM groups was 13.14 in favour of Technology-assisted PEOE. This implies that students in Technology-assisted PEOE group had higher critical thinking ability than their counterparts in DM group. Similarly, the overall mean difference between students in Technology-Assisted IEPT and DM groups was 8.39 in favour of

Technology-assisted IEPT approach. This implies that students in Technology-assisted IEPT group had higher critical thinking ability than their counterparts in DM group. In the same vein, the overall mean critical thinking ability difference between students in Technology-Assisted PEOE and Technology-assisted IEPT groups was 4.75. This difference though small is in favour of Technology-assisted PEOE approach. This implies that students in Technology-assisted PEOE group had slightly higher critical thinking ability than those in Technology-assisted IEPT group. In conclusion, students taught using Technology-assisted PEOE had slightly higher critical thinking ability than those taught using Technology-Assisted IEPT approach. Meanwhile, students taught identifying physical and chemical changes using Technology-assisted IEPT approach had higher critical thinking ability than those taught using discussion method.

Research Question 4

What is the interaction effect of treatments and gender on students' critical thinking ability scores in identifying physical and chemical changes? Research question four is presented in Figure 2.

Figure 2

Interaction bar chart of treatments and gender on students' critical thinking ability in identifying physical and chemical changes

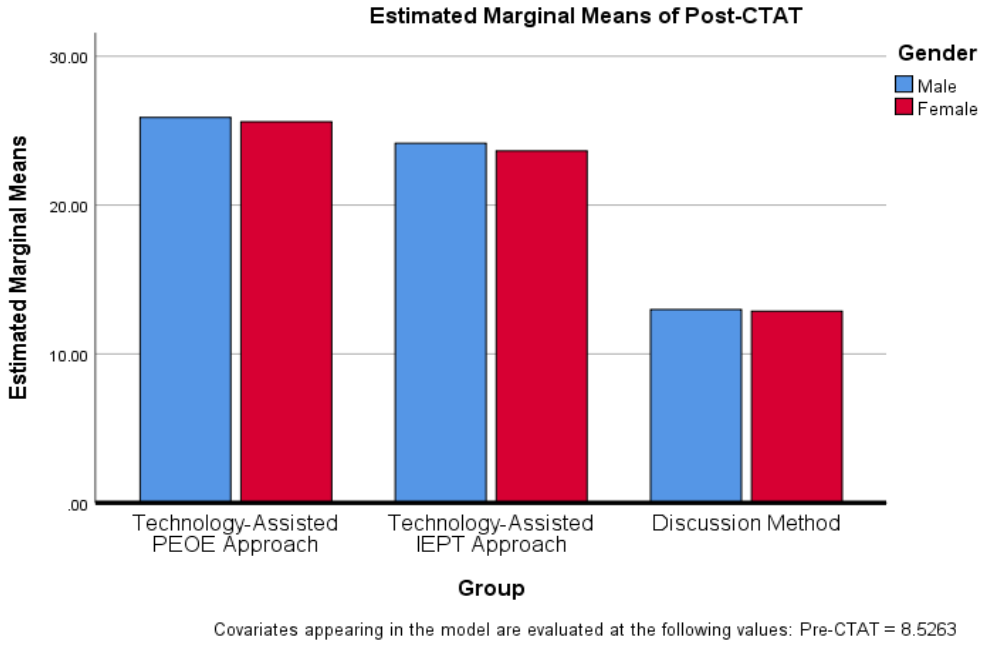

Figure 2 presents a bar chart of the interaction effect of treatments and gender on the mean critical thinking ability scores of students in identifying physical and chemical changes. The bar charts of each treatment are roughly the same height for both genders. In other words, the lines connecting the tops of the bars are roughly parallel which suggests that the treatment effect is consistent across genders. Hence, interaction effect of treatments and gender on students' critical thinking ability in identifying physical and chemical changes was very minimal.

Hypothesis 1

There is no significant difference in the self-confidence ratings of students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method. Table 3 presented the test result of null hypotheses one.

Table 3

Two-Way ANCOVA for Mean Self-Confidence Rating of Students Taught Identifying Physical and Chemical Changes using Technology-Assisted PEOE, Technology-Assisted IEPT and Discussion Method

Source	Type III sum of squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	287.839[a]	6	47.973	1101.097	.000	.902
Intercept	78.039	1	78.039	2017.009	.000	.833
TPr[PCCSS]	.179	1	.179	.344	.484	.000
Group	225.001	2	112.500	2325.074	.000	.819
Gender	.032	1	.032	.718	.311	.004
Group*Gender	.048	2	.024	.085	.711	.001
Error	17.903	221	.081			
Total	2213.000	228				
Corrected Total	174.007	227				

R squared = .142 (Adjusted R Squared= .135). Source: Field Survey, 2025

Table 3 presents the two-way ANCOVA result for mean self-confidence rating of students taught identifying physical and chemical changes using Technology-Assisted Predict-Explain-Observe-Explain (PEOE) approach, Technology-Assisted Invitation, Exploration, Proposing-Explanation and Taking action (IEPT) approach and discussion method (DM). The data in Table 3 reveal that the observed mean difference in the self-confidence rating among the groups was significant [$F_{2, 227}$=2325.074, P<0.05]. Hence, the null hypothesis that there is no significant difference in the mean self-confidence ratings of students taught identifying physical and chemical changes using Technology-assisted PEOE approach, Technology-assisted IEPT approach and DM was rejected. This implies that there is a significant difference in the mean self-confidence scores among the groups. Meanwhile, the effect size was 0.819 as indicated by the corresponding partial eta squared value is considered as large effect size. This implies that, 81.9% of the difference or variance in the self-confidence ratings among the groups was explained by the treatments. Hence, the difference in the self-confidence rating among the groups has a large statistical effect size.

Table 4

Bonferroni Post Hoc Comparison for Mean Self-Confidence Ratings of Students' Taught Identifying Physical and Chemical Changes using Technology-Assisted PEOE, Technology-Assisted IEPT and DM

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sign.
Technology-Assisted PEOE	DM	1.789*	.019	.000
Technology-Assisted IEPT	DM	1.754*	.019	.000
Technology-Assisted IEPT	Technology-Assisted PEOE	-.035	.019	.128

Source: Field Survey, 2025

Table 4 shows Bonferroni post-hoc comparison for mean self-confidence ratings of students' taught identifying physical and chemical changes using Technology-Assisted PEOE, Technology-Assisted IEPT and Discussion method (DM). The results reveal that the mean difference (I-J) between Technology-Assisted PEOE, and DM is 1.789* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean self-confidence ratings between the students taught identifying physical and chemical changes using Technology-assisted PEOE and those taught using DM in favour of students in Technology-assisted PEOE class. Likewise, the results reveal that the mean difference (I-J) between Technology-Assisted IEPT and DM is 1.754* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean self-confidence ratings between the students taught identifying physical and chemical changes using Technology-Assisted IEPT and those taught using DM in favour of students in Technology-Assisted IEPT class. However, the paired comparison of Technology-Assisted IEPT and Technology-Assisted PEOE showed a mean difference of -0.035 and this is not significant at $p>0.05$. This indicates no significant difference in the mean self-confidence ratings between students taught using Technology-Assisted PEOE and Technology-Assisted IEPT instructional approaches

Hypothesis 2

There is no significant interaction effect of treatments and gender on the self-confidence ratings of students in identifying physical and chemical changes. The data analysis of Table 3 is used to explain hypothesis 2.

The table presents a two-way ANCOVA for self-confidence of students taught identifying physical and chemical changes using Technology-Assisted PEOE, Technology-Assisted IEPT and Discussion method (DM). The table presents the interaction effect of instructional strategies and gender. The data in Table 3 reveals that there is no significant interaction effect of treatments and gender on the mean self-confidence ratings of students in identifying physical and chemical changes [$F_{2, 227} = .085$, $P>0.050$]. The null hypothesis is therefore not rejected. Meanwhile, the effect size was 0.001 as indicated by the corresponding partial eta squared value which is considered as small effect size. This implies that, only 0.1% of the interaction in the self-confidence rating among groups was explained by treatments and gender. Hence, the interaction of treatments and gender on students' self-confidence has small statistical effect size.

Hypothesis 3

There is no significant difference in the critical thinking ability scores of students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method. Table 6 presented the test result of null hypotheses one.

Table 5

Two-Way ANCOVA for Critical Thinking Scores of Students Taught Identifying Physical and Chemical Changes using Technology-Assisted PEOE, Technology-Assisted IEPT and Discussion Method

Source	Type III sum of squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	16585.001[a]	6	2764.166	98.909	.000	.792
Intercept	14322.009	1	14322.009	425.099	.000	.513
TPr^{CTAT}	346.379	1	346.379	15.344	.000	.049
Group	11555.003	2	57 77.501	209.004	.000	.769
Gender	29.362	1	29.362	1.001	.264	.001
Group*Gender	6.911	2	3.455	.225	.111	.002
Error	9914.003	22	1 44.859			
Total	39291.001	22	8			
Corrected Total	19780.005	22	7			

R squared = .032 (Adjusted R Squared= .045). Source: Field Survey, 2025

Table 5 presents the two-way ANCOVA result for mean critical thinking ability scores of students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method (DM). The data in Table 5 reveal that the observed mean difference in the critical thinking ability scores among the groups was significant [$F_{2, 227}$=209.004, P<0.05]. Hence, the null hypothesis that there is no significant difference in the mean critical thinking ability scores of students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT approaches and discussion method (DM) was rejected. This implies that there is a significant difference in the mean critical thinking ability scores among the groups. Meanwhile, the effect size was 0.769 as indicated by the corresponding partial eta squared value is considered as large effect size. This implies that, 76.9% of the difference or variance in the critical

thinking scores among the groups was explained by the treatments. Hence, the difference in the critical thinking ability scores among the groups has a large statistical effect size.

Table 6

Bonferroni Post Hoc Comparison for Mean Critical Thinking Ability Scores of Students' Taught Identifying Physical and Chemical Changes using Technology-Assisted PEOE, Technology-Assisted IEPT and DM

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sign.
Technology-Assisted PEOE	DM	11.389*	.432	.000
Technology-Assisted IEPT	DM	11.101*	.439	.000
Technology-Assisted IEPT	Technology-Assisted PEOE	-0.288	.441	.251

Source: Field Survey, 2025

Table 6 shows Bonferroni post-hoc comparison for mean critical thinking scores of students taught identifying physical and chemical changes using Technology-Assisted PEOE, Technology-Assisted IEPT and Discussion method (DM). The results reveal that the mean difference (I-J) between Technology-Assisted PEOE, and DM is 11.389* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean critical thinking scores between the students taught identifying physical and chemical changes using Technology-assisted PEOE and those taught using DM in favour of students in Technology-assisted PEOE class. Likewise, the results reveal that the mean difference (I-J) between Technology-Assisted IEPT and DM is 11.101* and this is significant at $p<0.05$. This implies that there is a significant difference in the mean critical thinking scores between the students taught identifying physical and chemical changes using Technology-Assisted IEPT and those taught using DM in favour of students in Technology-Assisted IEPT class. However, the paired comparison of Technology-Assisted IEPT and Technology-Assisted PEOE showed a mean difference of -0.288 and this is not significant at $p>0.05$. This indicates no significant difference in the mean critical thinking scores between students taught using Technology-Assisted PEOE and Technology-Assisted IEPT instructional approaches.

Hypothesis 4

There is no significant interaction effect of treatments and gender on the critical thinking ability scores of students in identifying physical and chemical changes. The data analysis of Table 5 is used to explain hypothesis 4.

The table presents a two-way ANCOVA for critical thinking scores of students taught identifying physical and chemical changes using Technology-Assisted PEOE, Technology-Assisted IEPT and Discussion method (DM). The table presents the interaction effect of instructional strategies and gender. The data in Table 3 reveals that there is no significant interaction effect of treatments and gender on the mean critical thinking scores of students in identifying physical and chemical changes [$F_{2, 227} = .225$, $P>0.050$]. The null hypothesis is therefore not rejected. Meanwhile, the effect size was 0.002 as indicated by the corresponding partial eta squared value which is considered as small effect size. This implies that,

only 0.2% of the interaction in the critical thinking ability scores among groups was explained by treatments and gender. Hence, the interaction of treatments and gender on students' critical thinking scores has small statistical effect size.

The study investigated if technology-assisted constructivist teaching approaches such as Technology-assisted Predict-Explain-Observe-Explain (PEOE) and Technology-assisted Invitation, Exploration, Proposing-Explanation and Taking action (IEPT) approaches could enhance senior secondary students' self-confidence and critical thinking ability in identifying physical and chemical changes in Dekina Local Government Area (LGA) of Kogi State, Nigeria. Finding of this study revealed that the difference in the self-confidence rating among students taught identifying physical and chemical changes using Technology-assisted PEOE approach, Technology-assisted IEPT approach and discussion method was statistically significant. The post-hoc comparison for the self-confidence rating among the groups revealed that students taught identifying physical and chemical changes using Technology-assisted PEOE had higher self-confidence than their counterparts taught using discussion method. This is in line with Teerasong et al. (2016), Ajayi (2019) and Ajayi et al. (2025) findings that students improved significantly in their academic performance and cognitive engagement in Basic Science and Chemistry respectively when taught using PEOE (though technology tools were not integrated with the approach in the reviewed studies) compared to those taught using conventional teaching method. The likely explanation for this outcome may be connected to the fact that the Technology-assisted PEOE approach helped the learners to explore concept and generate investigation through engaging, understandable, hand-on technology tools, and near reality visual simulations when compared to the discussion method.

The post-hoc comparison for the self-confidence rating among the groups also revealed that students taught identifying physical and chemical changes using Technology-assisted IEPT approach had significantly higher self-confidence than their counterparts taught using discussion method. This finding agrees with Ajayi (2023) and Agamber and Ajayi (2024) who found that students taught Social Studies and Biology using IEPT approach respectively (though technology was not integrated with the approach in the reviewed studies) had higher academic performance than those taught using lecture teaching method. The likely explanation for this outcome may also be connected to the fact that the use of Technology-assisted IEPT approach provides a format for students to construct their knowledge about a concept. Students can see how scientific knowledge is developed through the process of reflecting on what they know and the investigation they undertake using technology tools. The post-hoc comparison for the self-confidence rating among the groups further revealed that the difference between students taught identifying physical and chemical changes using Technology-assisted PEOE and those taught using Technology-assisted IEPT approach was not statistically significant. There was a scarcity of studies on comparison between Technology-assisted PEOE and Technology-assisted IEPT approaches on students' self-confidence in science subjects before. However, the likely explanation for this outcome may be attributed to the fact that both Technology-assisted PEOE and Technology-assisted IEPT approaches are used to help students develop a cognitive structure that enable meaningful learning using technology tools.

Finding of this study revealed that the difference in the critical thinking ability scores among students taught identifying physical and chemical changes using Technology-assisted PEOE, Technology-assisted IEPT and discussion method was statistically significant. The post-hoc comparison for the critical thinking ability scores among the groups revealed that students taught identifying physical and chemical changes using Technology-assisted PEOE approach had significantly higher critical thinking

ability than their counterparts taught using discussion method. This is in line with Bajar-Sales et al. (2015) and Ajayi (2019) finding that PEOE (though technology tools were not used in the reviewed studies) significantly enhance students' metacognitive awareness and engagement respectively when compared to lecture teaching method. The likely explanation for this outcome may be attributed to the fact that the Technology-assisted PEOE helped the learners to explore concept and generate investigation using technology tools. 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 using technology tools and hands on activities compared to the discussion method.

The post-hoc comparison for the critical thinking ability scores among the groups also revealed that students taught identifying physical and chemical changes using technology IEPT approach had significantly higher critical thinking ability than those taught using discussion method. This finding agrees with Mutai et al. (2014) and Ajayi (2023) who found that IEPT approach (though technology tools was not used in the reviewed studies) was more effective in enhancing students' conceptual understanding and academic performance in the topic of moments in Physics and Social Studies than conventional teaching method respectively. The likely explanation for this outcome may be attributed to the fact that the use of technology IEPT strategy provides a format for students to understand the nature of knowledge and construction processes of knowledge using technology tools. The post-hoc comparison for the critical thinking ability scores among the groups further revealed that the difference between students taught identifying physical and chemical changes using Technology-assisted PEOE and those taught using Technology-assisted IEPT was not statistically significant. This reason for this higher critical thinking ability by students taught using Technology-assisted PEOE and Technology-assisted IEPT could be that they were able to reflect on, interpret and search for solutions through exposure to real situations using technology tools when compared to students taught using discussion group.

The study revealed that the interaction effect between approach and gender on the self-confidence and critical thinking ability of students in identifying physical and chemical changes is very minimal but ANCOVA test shows that the interaction effect was not significant respectively. This implies that there was no significant interaction between approaches and gender on self-confidence and critical thinking ability of students in identifying physical and chemical changes. Hence, either Technology-assisted PEOE approach or Technology-assisted IEPT approach can be used successfully irrespective of gender in fostering students' self-confidence and critical thinking ability. In this case, there is no need for separation of instructional approach for male and female students, since either Technology-assisted PEOE approach or Technology-assisted IEPT could be used successfully for the three groups.

Conclusions

The future of Technology-assisted constructivist instructional approaches in science teaching gleam with immense assurance and stirring prospects. As technology advances, the view expands, leading us nearer to a world where technology tools not only improve but transforms the way we approach chemistry learning. It was concluded that the students taught identifying physical and chemical changes using Technology-assisted PEOE and Technology-assisted IEPT constructivist instructional approaches had higher self-confidence toward answering or solving problems related to identifying

physical and chemical changes and also had higher critical thinking ability respectively than those taught using discussion method. Thus, recommendations were made:

1. Chemistry teachers should be encouraged to employ the use of technology-assisted PEOE and technology-assisted IEPT instructional approaches during teaching/learning process in other to enhance students' self-confidence and critical thinking ability in identifying physical and chemical changes;
2. Professional bodies such as STAN and Ministry of Education should organize workshops to sensitize basic science teachers on the use technology-assisted PEOE and technology-assisted IEPT instructional approaches in classroom instructions so as to enhance students' self-confidence and critical thinking ability.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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APPENDIX

	TECHNOLOGY-ASSISTED PEOE WORKSHEET FOR PHYSICAL AND CHEMICAL CHANGES
	Group_____ Date_____
Predict (P) (What do you think will happen?) 	(a) If you hand squeeze a piece of paper, what do you think will happen? ..... & is it a physical or chemical change and why …….. (b) If you mix baking soda and vinegar in a test tube, what do you think will happen? ……& is it a physical or chemical change and why …….. (c) What do you think is difference between physical or chemical change …….. …….. ……... (d) Mention any changes you have observed in your environment? …….....
Explain (E) (Why do you think that will happen) 	Write down the explanation(s) for the prediction(s) as agreed upon by the group *Expected answer* (a) The paper is still made of the same material, just in a different form. Therefore, it is a physical change. (b) Undergoes an acid-base reaction that produces carbon dioxide, gas, water and sodium acetate (c) Physical changes involve changes in appearance or state, while chemical changes involve the formation of new substances.
Observe (O) using **Technology Tools** (What actually happened?) 	(a) Watch and listen to the 5-minites educational mini-video which are designed to help you provide answers to the challenging questions. (The educational mini-video can be designed and made available both offline and online by the teacher. The researcher adopted educational mini-video on physical and chemical changes designed by NGS: https://youtu.be/oLxjsO4mT14?si=meenVeSIPnq0wiQ2) (b) Conduct a hands-on experiment or activities to investigate some examples of physical and chemical change.
Explain **(E)** (Why did that happen?)	Based on the technology-assisted activities explored, provide answers to the following questions: (a) Define the terms physical and chemical changes? (b) Identify three examples of physical and chemical changes in everyday life? (c) Explain the difference between physical and chemical changes

	

	TECHNOLOGY-ASSISTED IEPT WORKSHEET FOR PHYSICAL AND CHEMICAL CHANGES
	Group_____ Date_____
Invitation (I) 	(a) Define the terms physical and chemical changes? (b) Identify three examples of physical and chemical changes in everyday life? (c) Explain the difference between physical and chemical changes
Exploration (E) using **Technology Tools** 	(a) Watch and listen to the 5-minites educational mini-video which are designed to help you provide answers to the challenging questions. (The educational mini-video can be designed and made available both offline and online by the teacher. The researcher adopted educational mini-video on physical and chemical changes designed by NGS: https://youtu.be/oLxjsO4mT14?si=meenVeSIPnq0wiQ2) (b) Conduct a hands-on experiment or activities to investigate some examples of physical and chemical change.
Proposing-Explanation **(P)** 	Based on the technology-assisted activities explored, provide answers to the following questions: (a) Define the terms physical and chemical changes? …… …… /…… (b) Identify three examples of physical and chemical changes in everyday life? …… …… …… (c) Explain the difference between physical and chemical changes? …… …… /……

Taking-Action **(T)** 	Provide instances of the application; You had understood identifying physical and chemical changes. Therefore, mention at three evidences of physical changes? …… …… Mention at five evidences of chemical changes? …… ……