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TPACK Model and Senior Secondary School Students' Performance in Chemistry in Makurdi Metropolis

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Abstract
Enhancing senior secondary school students' academic performance in Chemistry through Technological Pedagogical Content Knowledge (TPACK) Model in Makurdi Metropolis was investigated using pre-test, post-test control group quasi-experimental design. Two research questions and two hypotheses guided the study. The population of the study comprised all 954 (687 Males and 267 females) senior secondary two Chemistry students in 16 co-educational public secondary schools. A sample of 112 Chemistry students (56 males and 56 females) SS2 was drawn using multi-stage sampling procedure. Chemistry Performance Test (CPT) was validated by three experts and was used for data collection. CPT was trial tested and scores obtained were analyzed using KR-21 and yielded a reliability co-efficient of 0.95. Data was analyzed using mean and standard deviation to answer research questions while Analysis of Covariance (ANCOVA) was used to test the null hypotheses at 0.05 α-level. Findings revealed that there was significant difference in the mean academic performance scores of students taught Chemistry using TPACK Model and those taught using Discussion Teaching Method (DTM), ($F(1, 109) = 80.883$; $p = 0.001 < 0.05$). The study showed that there was no significant difference in the mean academic performance scores of male and female students taught Chemistry using TPACK Model ($F(1,54) = 3.665$; $p = 0.06 > 0.05$). The study recommends among others that Chemistry teachers should use TPACK Model for effective of Chemistry at the senior secondary school level.

Keywords: TPACK Model, Academic performance, Chemistry, gender,

Introduction

Science education plays a critical role in the social, economic, and technological advancement of any nation. Science equips leaners with the knowledge, skills and attitude necessary for innovation, problem-solving and sustainable development (Ameh & Olatunded, 2022). In developing countries such as Nigeria, science education is viewed as a strategic tool for linking industrialization and national development because it fosters creativity, rational thinking and ability to apply scientific principles to everyday life. It is a field of study which enhance the health, agriculture, transportation and education of any nation; thus, its knowledge determines how people can manipulate their environment for quality living (Samba, 2019; Nja & Ideba, 2021). Science aims to inculcate into young people the right scientific skills and attitude needed to pursue science-based careers. It enables citizens to develop competencies for effective accomplishment in career for self-reliance and national development through science education (Udu, 2018). Science education is a means for all round facet of human development and for individual to function and meaningfully fit in the society. Adejoh and Ekele (2014) confirms that science education is the aggregate of all the processes by which individuals develop interest, abilities, attitudes, knowledge and skills for the development of the society. Science education inculcates scientific literacy to individuals that are not originally part of a scientific community (Clement et al., 2017; Nja et al., 2022). This implies that appropriate delivery of science content such as Biology, Chemistry and Physics in secondary schools can enhance the excellent impartation of scientific literacy and consciousness in citizens and prepare students to explore Chemistry and other sciences.

It is important to note that the production of essential human needs such as soap of all kinds, creams, drinks, petroleum and its by-products, clothing, drugs, household utensils and chemicals for the preservation of food items as well as textiles are all products of Chemistry. It aligns with the objectives of the National Policy on Education (FRN, 2014). The place of Chemistry in the development of the scientific base of a country cannot be over emphasized (Ajayi et al.,

2019). It is a prerequisite science subject for science-based programmes like medicine, engineering, pharmacy and others. Chemistry is the study of composition, properties and reactions of matter and the use of such reactions to form new substances (Igboanugo, 2018). With the relevance of Chemistry in national building and development there is need to improve on the teaching methodology quality academic performance of students in the subject. The West African Examinations Council (WAEC) Chief Examiners' Report (2020-2023) showed that there is students' low performance in Chemistry over these years. In addition, a study conducted by Baanu et al. (2018) found out that the students' academic performance in Chemistry was low. This low academic performance in Chemistry is an indication that students have difficulty in learning and mastering the content and applying these when they are under examination conditions. That is to say that there is need for using innovative teaching strategies that enable students to be part of knowledge gained and construction (Agu & Samuel, 2018; Ajayi & Angura, 2017). Such strategies include collaborative learning, games, simulation and Technological Pedagogical Content Knowledge (TPACK) Model (Oyelekan et al., 2017). However, for the purpose of this study, TPACK Model is relevant due to its combination with technology.

TPACK Model stands for Technological Pedagogical Content Knowledge Model. A framework that describes the combination of knowledge teachers need to integrate technology into their lesson delivery. This model was developed to explain set of knowledge that teachers need to teach their students a subject effectively using technological tools in lesson delivery. These tools are laptops, projectors, smartboards, Microsoft word and Microsoft PowerPoint. Others are google classroom, WhatsApp, You-tube, Zoom, Google meet, WhatsApp videos Hyperchem and Chemsketch. All these may combine to foster students' academic performance in the subject (Celik, 2023; Zhang and Tang, 2021). TPACK Model was introduced in educational research field as theoretical framework for understanding teacher knowledge required for effective technology integration. ((Mishra, 2019; Mishra & Koehler, 2006). It is a combination of content, theory and technology within the context of educational software design that could enhance students' academic performance.

Academic performance refers to how well students are doing in school, usually measured by grades, test scores. Performance implies something that somebody has done successfully especially using his or her effort and skills (Muhammed et al., 2019). Academic performance is the level of knowledge and skills that a student has acquired through formal education. It is typically assessed through standardized tests, grades, and other measures of performance (Winship & Smith, 2016). **Academic performance** also refers to the level of knowledge, skills, and competencies that a student has attained through formal education. Chemistry classroom activities at secondary school level remain predominately teacher-centred, limiting opportunities for students' engagement, inquiry and practical exploration. As a result, students in Nigeria consistently performed poorly in Chemistry examinations. Despite the importance of Chemistry in our everyday life, there has been low performance by senior secondary students in the subject especially in the concept of redox reactions. (WAEC, 2020-2023; Kyado et al., 2021). The low performance of students in redox reactions could be based on instructional method. Based on the gaps identified, the researcher intends to investigate using suitable innovative strategies that can enhance students' academic performance in Chemistry as well as gender factors.

Gender is the physical characteristics of being male or female. It is as old as the world and has been used severally in academic discourse. It is the nature of being masculine or feminine; male or female. A number of studies have verified the influence of gender on students' performance: This had led to divergent views on the influence of gender on the students' performance in several subjects including Chemistry (Oliweh, et al., 2021). Gender disparity according to Danjuma (2015) globally militates against equitable participation of males and females in science education especially in Africa. Alam (2024) submitted that females face a number of inequitable difficulties that limit their potentials in participation in chemistry and other sciences with such background, it is pertinent to look at previous empirical studies whether teaching with TPACK Model has effect on male and female students in Chemistry**.**

Going by empirical evidence, Ukeh and Akpomiemie (2025) investigated the effect of computer animation in teaching of chemical bonding on senior secondary school students' academic achievement in Ogbia Local Government of Bayelsa State. The findings of the study revealed that students who were taught chemical bonding by integrating computer animation in the teaching process recorded increased academic performance than their counterparts who were taught with the lecture method. The test of hypotheses also showed that the mean academic performance was significant in favour of the students in the experimental group. Similarly, Eden et al. (2025) conducted a study titled:

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digital tools utilization and Chemistry students 'academic achievement in the teaching of soap production in secondary schools. Findings of the study showed that students taught with technological tools performed better than those taught with expository method did. There was a significant difference in their academic performance mean scores. However, there was no significant difference between male and female students' mean academic performance scores. It concluded that the utilization of digital tools was effective in teaching soap production. In a study by Atsuwe and Emmanuel (2024) investigated the effect of virtual laboratory application (TPACK tool) in senior secondary school students' achievement in Biology in Makurdi Local Government Area, Benue state. The results showed that students in the virtual laboratory group had significantly higher scores on the Biology Achievement Test compared to those in the traditional laboratory group. Male students in the technological tools group performed significantly better than female students.

A study by Kekeba (2025) investigated the impact of gender and the jigsaw learning strategy integrated with computer simulations (JLSICS) on chemistry learning, emphasizing student achievement and attitude in Ethiopia. The results showed that JLSICS was discovered to be more effective than Jigsaw Learning Strategy alone and Conventional Method in improving academic performance regardless of gender. The study therefore recommended that JLSICS should be used in teaching chemistry. Gongden (2022) examined the effects of gender on senior secondary school two Chemistry students' achievement and retention in chemical equilibrium using computer animation strategy (CAS) in Jos. The study revealed a significant difference between the mean academic performance scores of male and female students taught using CAS (TPACK tool) in favour of male students. The study recommended Computer Animation Strategy for teaching of Chemistry. Similarly, a study by Okunuga and Okafor (2022) investigated the impact of Virtual Chemistry Laboratory Software (VCLS) (TPACK tool) and gender on acquisition of practical skills in acid-base titrations among secondary school students in Lagos State. The findings showed that chemistry students acquired practical skills with the use of VCLS (TPACK tool). In addition, female chemistry students acquired practical skills more than their male peers did. The use of virtual laboratories (TPACK tool) is therefore highly recommended in carrying out chemistry practical in secondary schools.

Studies reviewed indicated that TPACK Model-based teaching enhances students' engagement and improve academic performance in many science concepts. However, studies on its application and effectiveness in Chemistry concepts such as redox reactions is limited. A contextual gap is evident, as most studies on innovative Chemistry teaching strategies have been conducted within Nigeria and a few outside Nigeria with little focus on Makurdi Metropolis. Given these gaps, this study seeks to investigate effect of TPACK Model on senior secondary students' academic performance in Chemistry in Makurdi Metropolis.

Statement of Problem

Ideally, education system is supposed to make individual functionally fit for a dynamic ever-changing society and meeting the ever-rising needs of a nation. However, there is a problem with the academic performance of students as reported by West African Examinations Council (WAEC) in the last four (4) years, Chemistry students have continued to exhibit low performance as at 2020 (42.94 %), 2021 (38.01%) and 2022 (38.82%) pass at credit level (WAEC). This indicated that the Chemistry at the senior secondary schools, which is supposed to give rise to excellent performance in tertiary levels of education, is poor. Ojukwu (2016) observed that Chemistry is not taught is in such a way that may give room for students improved academic performance. Agboola and Loto (2020) confirmed that teaching method is the major problem of poor academic performance and with the fact that no research concerning TPACK Model has been carried out in the study area of Makurdi Metropolis has made it possible to investigate effect of TPACK Model on senior secondary school students' academic performance in Chemistry in Makurdi Metropolis with the following specific objectives.

1. To find out the academic performance scores of students taught Chemistry using TPACK Model and those taught using Discussion Teaching Method (DTM).
2. Determine the academic performance scores of male and female students taught Chemistry using TPACK Model.

Research questions

The following research questions guided the study;

1. What is the mean difference in the academic performance scores of students taught Chemistry using TPACK Model and those taught using Discussion Teaching Method (DTM)?

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2. What is the mean difference in the academic performance scores of male and female students taught Chemistry using TPACK Model?

Hypotheses

The following hypotheses were formulated and tested at 0.05 α-level

1. There is no significant difference in the mean academic performance scores of students taught Chemistry using TPACK Model and those taught using Discussion Teaching Method (DTM).
2. There is no significant difference in the mean academic performance scores of male and female students taught Chemistry using TPACK Model.

Methodology

This study adopted quasi-experimental design of non-randomized pre-post and post-test, control group to measure effect of technological pedagogical content knowledge (TPACK) Model on secondary school students' academic performance in Chemistry in Makurdi Metropolis. The choice of this design was to establish cause-effect relationship between and among variables. (Agogo & Achor, 2019). The population for the study consists of all the 954 (Male-687 and Female-267) senior secondary two (SS2) Chemistry students in all the 16 co-educational public schools in Makurdi Metropolis of Benue State. The sample for the study consists of 112 Senior Secondary Two (SS2) Chemistry students drawn using multistage sampling procedure. Chemistry Performance Test was constructed by the researcher. The CPT was validated by three experts. It was trial tested and the scores collected were computed using Kuder-Richardson Formula 21, which yielded a reliability coefficient of 0.95. The researcher developed ten lesson plans on redox reactions concept in Chemistry. The researcher trained two Chemistry teachers as research assistants for this study. Five (5) lesson plans were delivered in accordance with the principles of TPACK Model in experimental group. The experimental group was taught using TPACK Model while the control group was taught using discussion teaching method for six weeks. In the process of experimental procedure, extraneous variables such as baseline group differences and interaction effects were statistically controlled. Meanwhile, control group were taught the same concept with five (5) lesson plans prepared in line with Discussion Teaching Method (DTM). The pre-test was administered to both experimental and control groups before treatment. Research questions were answered using mean and standard deviation while hypotheses were tested at 0.05 level of significance using ANCOVA. The choice of ANCOVA was to control the initial mean differences within and among the groups, that is pre-test before the intervention.

Results

Research Question One: What is the mean difference in the academic performance scores of students taught Chemistry using TPACK Model and those taught using Discussion Teaching Method (DTM)?

Table 1: **Mean and Standard Deviation of Academic Performance Scores of Students base on Teaching Methods.**

Method	**Sample (n)**	**Pre-test**		**Post-test**		**Gain**
		Mean	**SD**	**Mean**	**SD**	
TPACK Model	58	11.00	2.04	15.14	2.42	4.14
Discussion Teaching Method	54	10.33	2.42	11.57	2.38	1.24
Mean Difference		**0.67**		**3.57**		**2.90**

The results in Table 1 revealed that students taught Chemistry using TPACK Model had academic performance mean scores of 11.00 with standard deviation of 2.04 in the Pretest and academic performance mean scores of 15.14 with standard deviation of 2.42 in the post-test. Students taught Redox Reaction in Chemistry using Discussion teaching method had academic performance mean scores of 10.33 with standard deviation of 2.42 in the Pre-test and academic performance mean scores of 11.57 with standard deviation of 2.38 in the post-test. Table 2 further indicated that students taught Chemistry using TPACK Model had mean gain scores of 4.14 while those taught using Discussion teaching had a mean gain score of 1.24. Thus, there was a mean gain difference of 2.90 in favour of students taught Chemistry using TPACK Model. This showed that students taught using TPACK Model enhanced academic

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performance more as compared to those taught using Discussion teaching.

Research question Two: What is the difference in the mean academic performance scores of male and female students Chemistry with TPACK Model?

Table 2: Mean and Standard Deviation Academic Performance based on Gender.

Gender	Sample (n)	Pre-test		Post-test		Gain
		Mean	SD	Mean	SD	
Male	25	11.12	1.90	14.56	2.57	3.44
Female	33	10.91	2.16	15.53	2.26	4.62
Mean Difference		**0.21**		**-0.97**		**1.18**

The results in Table 2 revealed that male students taught Chemistry using TPACK Model had academic performance mean scores of 11.12 with standard deviation of 1.90 in the pre-test and academic performance mean scores of 14.56 with standard deviation of 2.57 in the post-test. Female Students who were taught Chemistry using TPACK Model had academic performance mean scores of 10.91 with standard deviation of 2.16 in the pretest and academic performance mean scores of 15.53 with standard deviation of 4.62 in the post-test. Table 4 further showed that male students taught Chemistry using TPACK Model had mean gain scores of 3.44 while female students taught using the same TPACK Model had a mean gain score of 4.62 with a mean gain difference of 1.18 in favour of the female students taught Chemistry using TPACK Model. This explained that female students taught using TPACK Model enhance academic performance more as compared to their male counterpart students taught Chemistry using the TPACK Model.

Hypothesis One: There is no significant difference in the mean academic performance scores of students taught Chemistry using TPACK Model and those taught using Discussion Teaching Method (DTM).

Table 3: ANCOVA Summary of Students' Academic Performance Scores Based on Teaching Method.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	639.011[a]	2	319.505	99.427	.000	.646
Intercept	147.687	1	147.687	45.959	.000	.297
Pretest	283.834	1	283.834	88.327	.000	.448
Teaching Method	**259.914**	**1**	**259.914**	**80.883**	**.000**	**.426**
Error	350.266	109	3.213			
Total	21159.000	112				
Corrected Total	989.277	111				

The ANCOVA statistic summary in Table 3 showed that $F(1,109) = 80.883$; $\rho = 0.001 < 0.05$. This suggests that the probability level is less than the specified alpha of 0.05. Therefore, the null hypothesis was rejected. It means that there was a significant difference in the academic performance mean scores of students taught using TPACK Model and those taught using discussion teaching method in Chemistry. This implies that TPACK Model improved students' academic performance more than discussion teaching method. The partial eta squared value of 0.426 was considered a large effect size, indicating that the TPACK Model has a substantial impact on students' academic performance. This means that approximately 42% of the variance in students' academic performance was attributed to the difference between the two teaching methods and there was a strong association between the TPACK Model and students' academic performance.

Hypothesis Two: There is no significant difference in the mean academic performance scores of male and female students taught Chemistry using TPACK model.

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Table 2: ANCOVA Summary of Students' Academic Performance Based on Gender

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	79.382[a]	2	39.691	8.574	.001	.241
Intercept	158.411	1	158.411	34.219	.000	.388
Pre-test-TPACK	66.142	1	66.142	14.288	.000	.209
Gender	**16.967**	**1**	**16.967**	**3.665**	**.061**	**.064**
Error	249.986	54	4.629			
Total	13335.000	57				
Corrected Total	329.368	56				

The ANCOVA statistic summary in Table 2 states that F (1, 54) = 3.665; ρ = 0.06 > 0.05. This specifies that the probability level is greater than the stated alpha of 0.05. Thus, the null hypothesis was not rejected. This indicates that there was no significant difference in the academic performance mean scores of male and female students taught Chemistry using TPACK Model. It means that TPACK Model is effective and has no significant gender-based disparities in learning outcomes for both males and females. The partial eta squared value of 0.064 is considered as a small effect size, indicating that male and female students perform similarly in academic performance when taught using TPACK Model. This means that approximately 6% of the variance of students' academic performance is attributed to no statistically significant difference between male and female students.

Discussion

The study investigated effect of technological pedagogical content knowledge model on senior secondary students' academic performance in Chemistry in Makurdi Metropolis. The findings revealed that TPACK Model improved academic performance of students compared to DTM. ANCOVA test showed that there was a significant difference in the academic performance mean scores of students taught Chemistry using TPACK Model and those taught using DTM. This implies that TPACK Model has significantly improved students' academic performance more than DTM. Reasons for the improved academic performance is that TPACK Model uses technological tools such as simulations, virtual laboratories, animations and YouTube videos to visualize complex redox reactions processes. This can lead to deeper understanding that improve academic performance. Another reason for this improved performance is that students learn better, when content is presented in various forms such as images, texts, videos and simulations. These multiple representation of redox reactions takes care of different learning preferences and improves academic performance of students. This study agrees with the studies of Ukeh and Akpomiemie(2025) and Eden et el.(2025) whose study showed that students taught with digital tools performed better than those taught with expository method and there was a significant difference in their academic performance mean scores. Similarly, studies by Atsuwe and Emmanuel (2024) confirmed that technological tools enhanced academic performance of students.

Findings further revealed that male students taught Chemistry using TPACK Model had improved academic performance. This explains that male students taught Chemistry using TPACK Model had better academic performance than their female counterpart taught using TPACK Model. It means that TPACK Model is effective and has significant gender-based disparities in learning outcomes for both male and female students. It suggests that both male and female students responded differently to the instructional method. This is because of persistent stereotypes that affect perception and academic performance, particularly female students experience low performance in Chemistry even when using innovative teaching strategy such as TPACK Model. In addition, male students exhibit greater familiarity and confidence in technological tools and showing more concern in abstract and problem-solving tasks. These findings disagree with Gongden (2022) and Okunuga and Okafor (2022) which showed that female students outperformed their male counterpart in mean academic performance. It confirmed that if teachers effectively integrate technological tools in chemistry lessons showing real-world applications, it enhances academic performance in Chemistry regardless of gender.

Conclusion

The study found that Technological Pedagogical Content Knowledge (TPACK) Model provides a way of improving

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students' academic performance in Chemistry.

Recommendations

Therefore, the study recommends that;

i. Chemistry teachers should use TPACK Model in lesson delivery to enhance academic performance in Chemistry.
ii. TPACK Model should be integrated in Chemistry curriculum as it aligns with science education objectives contained in the National Policy on Education (FRN, 2014).

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