
EFFECT OF HERRMANN WHOLE BRAIN MODEL ON PHYSICS STUDENTS' ACADEMIC ACHIEVEMENT AND RETENTION IN CURRENT ELECTRICITY IN SENIOR SECONDARY SCHOOLS IN PORT HARCOURT METROPOLIS, NIGERIA

¹Oigiangbe, J. E. J., ²Adolphus, T. and ³Naade, N. B.

^{1,2,3}Department of Science Education, Faculty of Education, Rivers state University, Nkpolu-Oroworukwo

Corresponding author: Jerry.Oigiangbe@renaissanceafrica.com

Citation: Oigiangbe, J. E. J., Adolphus, T. & Naade, N. B. (2026). Effect of Herrmann whole brain model on physics students' academic achievement and retention in current electricity in senior secondary schools in Port Harcourt metropolis, Nigeria. *Journal of Science, Technology, and Education (JSTE)*; www.nsjkste.com/ 10(1), 1-17.

Abstract

The Study determined the effect of the Herrmann Whole Brain Model on Physics students' academic performance and retention in electricity in senior secondary schools in Port-Harcourt Metropolis, Nigeria. The study adopted a non-randomized pre-test posttest control group quasi-experimental design. Five thousand eight hundred and thirty-seven physics students in thirty-six public secondary schools in Port Harcourt Port-Harcourt Metropolis formed the population of the study. One hundred and seventy-five physics students in four intact classes selected from two schools formed the sample for the study. Two research questions and two hypotheses were used and formulated respectively to guide the study. The instrument used in data collection was titled "Electricity Performance Test in Resistor". Face and content validity of the instrument were carried out by experts in physics education and measurement and evaluation. Kuder-richardson-20 method of reliability was employed. A reliability coefficient of 0.84 was

obtained. Item analysis was done to determine the psychometric features of each test item. The research questions were answered using descriptive statistics of mean standard deviation and the corresponding null hypotheses were tested using Analysis of Covariance at 0.05 level of significance. Results from the study revealed that there was a statistically significant difference between the mean achievement scores of the experimental and control groups to the advantage of students in the experimental group. Also, students in the experimental group had higher retention than students exposed to instruction through the lecture method, although the difference in their mean retention score was not statistically significant. Based on the result, it was recommended among others that teachers should employ the Herrmann Whole Brain Model approach in teaching electricity and other science topics as it has the capability to enhance students' understanding and performance of complex concepts.

Keywords: Herrmann whole brain; teaching strategy; electricity; resistor; achievement

Introduction

Science is a field of study which uses rigorous methodology that involves hypothesis formulation, experimentation, data analysis, and theory development to carry out investigations towards understanding and predicting natural phenomena. Furthermore, science involves the systematic investigation of natural laws and processes, and the application of scientific knowledge to solve practical problems towards improving human life (Brown, 2015). Science plays significant role in the society. It enables individuals to understand natural phenomena, and expand the frontiers of human knowledge. Through scientific inquiry, insight is gained into the fundamental laws governing the physical, chemical, and biological systems, aiding informed decisions and development of innovative solutions (Mbajiorgu, 2014). Science serves as a foundation for technological advancements that have revolutionized our lives. From modern transportation and communication systems to medical treatments and energy production, many of the conveniences and advancements we enjoy today are a direct result of scientific discoveries and research. Science fuels innovation, drives technological breakthroughs, and paves the way for new

inventions that improve our quality of life (Albahari, *et al.*, 2018).

The contribution of science is also felt in economic growth and development. Scientific research and innovation contribute to the creation of new industries, products, and services, fostering job opportunities and economic prosperity. Also, scientific advancements in areas like agriculture, energy production, and manufacturing enhance productivity and efficiency, leading to improved living standards (Adolphus, 2020; Anaeto, *et al.*, 2016).

Physics is a fundamental aspect of science which studies the properties of matter and energy, as well as their interrelationships. It encompasses various domains, including mechanics, optics, electricity, and thermodynamics, and is deeply rooted in mathematical principles. Physics aims to understand natural phenomena for the benefit of humanity (Lanzinger, 2022). Electricity, being an aspect of Physics deals with the phenomena associated with electric charges at rest and in motion. It is one of the most important and widely studied branches of physics and it has many applications in electronic devices as well as massive power generation systems. An understanding of electricity is crucial for explaining many natural phenomena and forms the basis for

numerous technological advancements. Electricity has a number of different aspects including electrostatics, current electricity and electromagnetism. Physics has applications in electronics, power generation and distribution, telecommunication, medical imaging and renewable energy among others (Etkina, Gentile, & Van Heuvelen, 2013). Current electricity deals with electric charges in motion. It covers areas such flow of electric charge, resistance, Ohm's Law which relates voltage, current, and resistance in a circuit (Serway & Jewett, 2018). Studies have shown that this is one aspect of physics that students find difficult to grasp (Naade et al, 2018)

Science teachers are trained teachers that are saddled with responsibilities of providing science instruction to students Science teachers create lesson plans; evaluate student performances; and teach using lectures, technology and hands-on learning experiences. They also model expected behavior to establish and maintain an orderly, disciplined classroom. Science teachers are key factor to be considered when talking about the development of science education in any nation (Ajemba, Ahmed, Ogunode & Olatunde- Aiyedun, 2021). Science teachers need to use different strategies as there is no single universal approach for specific class. Many science teachers still hold to chalk and talk method which is not

appropriate for science teaching in this age. Effective science instruction is crucial for fostering scientific literacy, critical thinking, and problem-solving skills among students. However, many secondary school science teachers face significant challenges in delivering instruction that meets the diverse learning needs of students. These challenges often result in suboptimal student engagement, understanding, and performance in science subjects (Parane, 2023).

Students in secondary schools exhibit a wide range of learning styles and cognitive preferences. Traditional teaching methods, which often focus on lecture-based instruction and rote memorization, may not address the varied ways in which students process and comprehend information. This mismatch between teaching methods and student learning preferences can lead to disengagement, lack of motivation, and poor academic outcomes in science. The traditional teaching methods in science education are usually teacher-centered and content-focused, emphasizing the transmission of factual knowledge rather than the development of critical thinking and problem-solving skills (Isa, Mammam, Badar & Bala, 2020). These methods may not foster deep conceptual understanding or the ability to apply scientific knowledge in real-world contexts. As a result, students may struggle to

grasp complex scientific concepts and lose interest in pursuing further studies or careers in science (Bigozzi, Tarchi, Fiorentini, Falsini & Stefanelli, 2018).

There is a growing recognition of the need for instructional strategies that cater to the diverse cognitive styles of students and promote active, meaningful learning. One such strategy is the Herrmann Whole Brain Model. This model suggests that effective learning and problem-solving involve engaging all four quadrants of the brain: analytical, sequential, interpersonal, and imaginative (Yusuf, Atadoga, Falalu & Mustapha, 2019). This model emphasizes the integration of different thinking styles to enhance learning and retention. Learning is analytical if it is precise, and straight to the point, informative, theory and logical based. Learning is sequential if it is well organised, adopts consistent approach among others. Learning is considered interpersonal if it encourages group efforts, knowledge sharing and provides opportunity for hands on among others. Learning is said to be imaginative if it is experimenting, fun-based and explorative among others (De Boer, Steyn & Du Toit, 2001).

The Herrmann Whole Brain Model has been successfully applied in various educational settings to improve teaching and learning outcomes (Bawaneh, Zain, Saleh & Abdullah,

2012). In encouraging teachers to design instruction that addresses the full spectrum of cognitive styles, this model promotes a more inclusive and effective learning environment (Smit & du Toit, 2016). The literature shows that the Herrmann Whole Brain Model has positive contribution to learning outcomes among students. For example, Bawaneh, et al (2012) reported that the model enhances students' understanding and is gender friendly learning model. According to Hughes, Hughes and Hodgkinson (2016), the Herrmann Whole Brain Model (HWBM) encourages utilization of a range of methodologies and strategies towards enhancing learning among students. However, there is limited research on the application of the Herrmann Whole Brain Model specifically in secondary schools' science subjects in Port-Harcourt.

The Herrmann Whole Brain Model, also known as the Herrmann Brain Dominance Instrument (HBDI), is a cognitive model that categorizes thinking preferences into four distinct quadrants, representing different modes of thinking and information processing (Herrmann, 1996). This model posits that while individuals can use all four quadrants, they tend to have preferences for certain thinking styles, which influence their learning, communication, and problem-solving approaches (Herrmann & Herrmann-Nehdi, 2015). The model was

developed by Ned Herrmann in the late 1970s while he was working as a manager at General Electric (GE). Herrmann's interest in brain research and creativity led him to combine theories from split-brain research and the triune brain model to create a metaphorical four-quadrant model of brain function (Herrmann, 1991). The model was initially used for organizational development at GE but quickly gained popularity in various fields, including education, business, and personal development (Herrmann-Nehdi, 2002).

The aim of the Herrmann Whole Brain Model is to provide a framework for understanding and leveraging cognitive diversity. It seeks to help individuals and organizations recognize and utilize different thinking styles to enhance creativity, problem-solving, and communication (Herrmann, 1996). In education, the model aims to improve learning outcomes by encouraging educators to design instruction that engages all thinking preferences, thereby catering to diverse learning styles (De Boer, Steyn, & Du Toit, 2001).

Previous research showed that the Herrmann Whole Brain Teaching Model (HWBTM) has positive effect on learning outcomes across different contexts and subjects. Bawaneh, Zain, and Saleh (2012) found that HWBTM had significant positive influence on Jordanian

eight graders' understanding of simple electric circuits compared to conventional teaching. The study however showed no gender-based differences. Musa (2021) similarly found that HWBTM enhanced academic performance and retention in Physics among secondary school students in Kaduna State, Nigeria. There was also no significant gender effect. In the Philippines, Escultura and Ricafort (2022) and Bucayong et al. (2019) found that students exposed to the HWBTM showed greater improvements in understanding wave topics and electric circuits, respectively, than those taught through traditional teaching method. The study by Sontillano (2018) also confirmed that HWBTM significantly enhanced Algebra performance among special education students in General Emilio Aguinaldo National High School. Stratton and Farmer (2023) found exposure to the HWBTM enhanced students' motivation in reading and writing among elementary students in Tennessee. Abrenica and Casuncad (2022) also obtained similar result in academic gains in Chemistry performance and student engagement using the HWBTM. Furthermore, Ahmed and Susmitha (2024) surveyed Indian Physics teachers and found strong positive perceptions of the model's effectiveness in enhancing learning competence, achievement, behavior, and engagement. Despite these promising findings, there is a limited empirical

study on the application of HWBTM in Physics education in secondary schools in Rivers State, Nigeria. The present study therefore sought to address this gap, thereby contributing to the broader body of knowledge.

Statement of the Problem

The literature shows that students' performance in Physics has not been encouraging. For example, Okwu and Charles (2018) reported that performances of students in Physics in secondary school has less than 50% in the last decade. Similar report was published by WAEC chief examiner of 2020. According to the report, the physics students had low performance in Physics and this was among others attributed to inadequate teaching methods employed in teaching Physics (Hassan & Mohammed, 2024). In today's education system, students exhibit diverse learning preferences and cognitive styles which are sometimes not addressed by traditional teaching methods, which primarily focuses on logical and analytical thinking (Hughes & Hodgkinson, 2016) This one-size-fits-all approach can negatively impact students' academic performance, particularly for those who may excel in creative, relational, or intuitive learning environments. The Herrmann Whole Brain Model (HWBM) offers a more inclusive and comprehensive approach to learning by recognizing the importance of

engaging all four quadrants of the brain—analytical, sequential, interpersonal, and imaginative (Yusuf, Atadoga, Falalu & Mustapha, 2019). Despite the potential benefits of this model, there is limited empirical research on its effectiveness on students' performance in electricity in Physics in secondary schools in Port-Harcourt. Therefore, there is a pressing need to investigate whether the HWBM can enhance students' academic achievement in this context. It was in a bid to address this issue that the present study was intended.

Purpose of the Study

The purpose of the study was to determine the effect of Herrmann Whole Brain Model on Physics students' academic achievement and retention in electricity in senior secondary schools in Port-Harcourt Metropolis, Nigeria. Specifically, the study intends to.

1. determine the achievement of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis?
2. find out the retention of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught lecture method in secondary schools in Port Harcourt Metropolis?

Research Questions

1. What is the mean achievement scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis?
2. What is the mean retention scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis?

Hypothesis

1. There is no significant difference in the mean achievement scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis.
2. There is no significant difference in the mean retention scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis.

Methodology

The research design adopted for this study was a quasi-experimental design. Precisely, the non-

randomized, pretest-posttest control group design. The study was conducted in Port Harcourt Metropolis in Rivers State, Nigeria. The area was chosen to enable the researcher to have enough time to supervise the experiment properly; the area is accessible at all time of the year. The population of the study consists of all 5837 Physics students from 36 public senior secondary schools in Port-Harcourt Metropolis. This number comprises 2976 students from Port-Harcourt City and 2861 from Obio/Akpor (Nominal Roll from each of the schools). One school was purposively selected from each Local Government Area in Port Harcourt Metropolis, making it two schools in total used for the study. The criteria for the selection include:

- (1) Schools that had an adequately equipped science laboratory.
- (2) Schools having at least two professional physics teachers with at least five years of teaching experience.

Four intact classes were randomly selected and used in the two schools since each of the schools had two arms (SS1A & SS1B). In each school, there was an experimental class and one control class. A total of 175 Physics Students from the four intact classes in the two schools form the sample for the study.

The research instrument for data collection was titled “Electricity achievement Test in Resistor” (EATR). The instrument was composed of 20 questions covering the content area and testing the various level of understanding. The instrument was subjected to face and content validation by experts in Physics education. The instrument was further subjected to item analysis to determine the item difficulty index, discrimination index, effectiveness of distracters to verify the psychometric features of each test items. A reliability coefficient of 0.84 and 0.78 were established using Kuder-Richardson-20 method of reliability to ascertain the stability and internal consistency of the instrument respectively. These values were considered good enough to use the instrument.

Two instructional methods were used for the study. Herrmann whole brain teaching strategy was used in teaching the experimental group, while the lecture method was used in teaching the control group. The pre-test was administered to the intact classes in the selected schools to establish the equivalence of the participants in the study. The teachers in the respective schools were trained for one week on how to follow the

various steps in the new model in teaching the students. Before treatment, a pre-test was administered to the students. The experiment lasted for four (4) weeks; an equivalent form of the pre-test was administered by the teachers to the student as post-test. Data collected from the pre-test and post-test were kept separately for analysis. Then two weeks after the posttest, the test was administered again to ascertain student’s retention ability. This procedure was followed in both experimental and control classes. The research question was answered using descriptive statistics of mean and the corresponding null hypothesis was tested using inferential statistics of ANCOVA at $p \leq 0.05$ level of significance. Data collected from the pre-test in both groups were subjected to a pre-test analysis to ascertain the equivalence of both groups before treatment. The result showed a significance difference in the pre-test mean scores of both groups. This justifies the use of ANCOVA in testing the hypothesis as to statistically take care of the significant difference in both groups.

Results

Research Question 1: What is the mean achievement scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis?

Table 1: Means Scores in Physics for HWBM and Lecture Methods

Group	Pretest			Posttest		Mean Gain
	N	Mean	S.D.	Mean	S.D.	
Control	92	26.47	11.62	48.04	13.85	21.57
Experimental	83	29.22	14.04	60.90	17.15	31.68
Mean Difference		2.75		12.86		10.11

Table 1 shows the mean achievement scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using the traditional teaching method in secondary schools in Port Harcourt Metropolis. It shows a pre-test mean score of 26.47 for the control group and a pre-test mean score of 29.22 for the experimental group. This shows a mean difference of 2.75 in favour of the experimental group. This slight difference in the mean scores of the two groups could be attributed to extraneous variables. It also shows a posttest mean score of 48.04 for the control group and a posttest mean score of 60.90 for the

experimental group. This shows a mean difference of 12.86 in favour of the experimental group. This difference in the mean scores of the two groups is an indication that students exposed to instruction using the HWBM performed better than those exposed to instruction in electricity using the traditional lecture method. Furthermore, the mean difference between the pretest score and posttest scores for the control group is 21.57 while that for the experimental group is 31.68. This further shows that students taught using HWBM achieved better than students taught using lecture method.

Research Question 2: What is the mean retention scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis?

Table 2: Difference in Retention Scores of Students Taught Using HWBM and Lecture Methods

Method	N	Posttest		Postposttest		Retention
		Mean	SD	Mean	SD	
HWBM	83	60.90	17.15	54.40	16.24	-6.51
Lecture	92	48.04	13.85	38.91	14.62	-9.13

Table 2 shows the retention mean scores in electricity of students taught using HWBM and lecture methods. As shown, the HWBM method group had a mean score of 60.90 at the posttest level and 54.40 at the postposttest level. This is an indication that there was a slight decrease as evident by retention score of -6.51. The posttest mean score of the students taught using lecture method was 48.04 as against postposttest mean score of 38.91. This indicates that there was a

decrease of -9.13 in the mean score for this group. This shows that the decrease in mean score between posttest mean score of the lecture method group was higher than that of the HWBM group. This suggests that the students exposed to instruction using the Hermann Whole Brain Model teaching approach had a slightly higher retention in electricity than their counterparts exposed to instruction using lecture method.

Hypothesis 1: There is no significant difference in mean scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis.

Table 3: ANCOVA for Effect of HWBM and Lecture Methods on Electricity Performance

Sources of Variance	Sum of Squares	df	Mean Square	F	p-value	Effect Size
Corrected Model	22787.449 ^a	2	11393.724	75.420	.000	.467
Intercept	34801.092	1	34801.092	230.365	.000	.573
pretest	15571.075	1	15571.075	103.072	.000	.375
Method	5055.511	1	5055.511	33.465	.000	.163
Error	25983.980	172	151.070			
Total	561775.000	175				
Corrected Total	48771.429	174				

a. R Squared = .467 (Adjusted R Squared = .461)

Table 3 shows the ANCOVA for test of hypothesis one. As shown, $F(1,172) = 33.465$, $p < 0.05$. Based on this, the hypothesis was rejected. This implies that there was a significant difference between the mean scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using the traditional teaching method in secondary schools in Port Harcourt Metropolis.

Hypothesis 2: There is no significant difference in the mean retention scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis.

Table 4: ANCOVA for Difference in Retention between Experimental and Control Groups

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1544.329 ^a	2	772.164	257.085	0.000
Intercept	1.725	1	1.725	0.574	0.450
post_test	1125.839	1	1125.839	374.838	0.000
Method	35.717	1	35.717	11.892	0.001
Error	516.608	172	3.004		
Total	17039.000	175			
Corrected Total	2060.937	174			

a. R Squared = .749 (Adjusted R Squared = .746)

The result in Table 4 shows the ANCOVA for test of hypothesis two. As shown, $F(1,172) = 11.892$, $p < 0.05$. Based on this, the hypothesis was rejected. This implies that there was a significant difference between the mean

retention scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using the traditional teaching method in secondary schools in Port Harcourt Metropolis.

Discussion of Findings

The first research question sought to ascertain the difference in the mean scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using the traditional teaching method in secondary schools in Port Harcourt Metropolis. The result showed that students exposed to instruction using the HWBM performed better than those exposed to instruction in electricity using the traditional lecture method. The test of

hypothesis one showed that there was a significant difference between the mean scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using the traditional teaching method in secondary schools in Port Harcourt Metropolis.

This result was expected and not surprising. Applying the Herrmann Whole Brain Model approach for teaching the concept of electricity

by the teacher may have enhanced clarity of ideas among the students in the experimental group which may have culminated to their better performance than the students exposed to the same topic through lecture method. This result agrees with the result gotten by Bawaneh, Zain and Saleh (2012) who investigated the effect of Herrmann Whole Brain Teaching Method over conventional teaching method on eight graders in their understanding of simple electric circuits in Jordan. Bawaneh, Zain and Saleh (2012) found that Herrmann Whole Brain Teaching Method was more successful than the conventional teaching method in fostering students' understanding of simple electric circuits. The result further corroborates that of Musa (2021) who investigated the effects of Herrmann's Whole-Brain Model on retention and academic performance among secondary school physics students in Zaria education zone Kaduna, Nigeria. Musa (2021) found a significant difference in performance in favour of students exposed to the Herrmann's Whole-Brain Model.

The second research question sought to find out the difference between the retention scores of students taught electricity using the Herrmann Whole Brain Model teaching method and those taught using lecture method in secondary schools in Port Harcourt Metropolis. The result showed that students exposed to instruction

using the Herrmann Whole Brain Model teaching approach had a slightly higher retention in electricity than their counterparts exposed to instruction using lecture method. The test of hypothesis two showed that there was no significant difference in the mean retention score of students in electricity when taught using the Herrmann Whole Brain Model and lecture method. This result further buttresses the result of the first research question and hypothesis. As the students exposed to instruction in electricity had significant higher performance than their counterparts exposed to same instruction through lecture method, so also their retention was higher. This result aligns with the view of Boyatzis (2008) that the whole-brain learning enhances academic performance, particularly when it comes to complex subjects like mathematics and science. The result corroborates the result of Ahmed and Susmitha (2024) who investigated Physics teachers' perception of the effectiveness of the Whole Brain instructional strategies. The result by Ahmed and Susmitha (2024) revealed that teachers perceived that students' learning competency increases while implementing the Whole Brain teaching strategy. Such increase in learning competencies may have contributed to the higher retention by the students exposed to the HWBM approach in the present study.

Conclusions

Based on the findings of the study, the following conclusions were drawn. The Herrmann Whole Brain Model (HWBM) teaching approach significantly improved students' achievement in electricity compared to the traditional lecture method. This improvement suggests that HWBM enhances clarity and understanding of complex concepts like electricity. It was further concluded that students taught using the HWBM had a higher retention of electricity concepts compared to those taught using the traditional lecture method. This suggests that the HWBM promotes deeper understanding and longer-lasting learning.

Recommendations

Based on the result of the study, the following recommendations were made.

1. Teachers should employ the Herrmann Whole Brain Model approach in teaching electricity and other science topics as it has the capability to enhance students' understanding and performance of complex concepts.
2. Stakeholders in the educational sector, such as Ministry of Education, Schools Board and school heads should promote the HWBM as it helps in retention amongst students and improves academic achievement in sciences.
3. Schools should implement the HWBM in teaching to improve students' retention of concepts, especially in subjects requiring long-term recall, such as physics and mathematics.

REFERENCES

- Abrenica, J., & Casuncad, J. D. (2022). Effectiveness of whole brain teaching style in enhancing the academic performance of Grade 11 Students in General Chemistry I. *SEAQIS Journal of Science Education*, 2(01), 9-18.
- Adetunji, O. J., Oba, F. J., & Ilesanmi, O. P. (2017). Science and technology: A catalyst for improving human health in developing countries. *Journal of Scientific Research & Reports*, 14(5), 1-8.

- Adolphus, T. (2020). The role of science education in skills acquisition and youth empowerment in Nigeria. *International Journal of Research Publications*, 65(1), 9-18.
- Ahmed, J. A., & Susmitha, P. S. (2024). Perception of secondary school physics teachers on Whole Brain Instructional strategies (WBIS). *Journal of Research in Humanities and Social Science*, 12(6), 80-82.
- Ajemba, H. E., Ahmed, F. M., Ogunode, N. J., & Olatunde-Aiyedun, T. G. (2021). Problems facing science teachers in

- public secondary schools in Nigeria and way forward. *International Journal of Discoveries and Innovations in Applied Sciences*, 1(5), 118-129.
- Albahari, A., Barge-Gil, A., Pérez-Canto, S., & Modrego, A. (2018). The influence of science and technology park characteristics on firms' innovation results. *Papers in regional science*, 97(2), 253-280.
- Anaeto, F. C., Asiabaka, C. C., Ani, A. O., Nnadi, F. N., Ugwoke, F. O., Asiabaka, I. P., Anaeto, C. A., & Ihekeronye, N. (2016). The roles of science and technology in national development. *Direct Research Journal of Social Science and Educational Studies*, 3(3), 38-43.
- Bawaneh, A. K. A., Abdullah, A. G. K., Saleh, S., & Yin, K. Y. (2011). Jordanian students' thinking styles based on Herrmann Whole Brain Model. *International Journal of Humanities and Social Science*, 1(9), 89-97.
- Bawaneh, A. K. A., Zain, A. N. M., & Saleh, S. (2012). The effect of Herrmann whole brain teaching method on students' understanding of simple electric circuits. *European Journal of Physics Education*, 2(2), 1-23.
- Bigozzi, L., Tarchi, C., Fiorentini, C., Falsini, P., & Stefanelli, F. (2018). The influence of teaching approach on students' conceptual learning in physics. *Frontiers in psychology*, 9, 2474.
- Bonney, E. A., Amoah, D. F., Micah, S. A., Ahiamenyo, C., & Lemaire, M. B. (2015). The relationship between the quality of teachers and pupils academic performance in the stma junior high schools of the western region of Ghana. *Journal of Education and practice*, 6(24), 139-150.
- Brown, G. M. (2015). Science and technology education in Nigeria: A historical perspective. *SCSR Journal of Educational Research*, 1(1), 33-41.
- Bucayong, C. O., Teofilo, M. V. C., Benben, V. Y., & Ladesma, J. O. (2019). Students' perceptions and learning gains using whole brain teaching strategy in the stem strand of K to 12 Education. *CMU Journal of Science*, 23(1), 31-38.
- De Boer, A., Bothma, T., & Du Toit, P. (2012). Whole brain learning in higher education. *Interactive Learning Environments*, 20(2), 111-125.
- De Boer, A. L., Du Toit, P. H., & Bothma, T. (2015). Activating whole brain innovation: A means of nourishing multiple intelligence in higher education. *TD: The Journal for Transdisciplinary Research in Southern Africa*, 11(2), 55-72.
- De Boer, A. L., Steyn, T., & Du Toit, P. H. (2001). A whole brain approach to teaching and learning in higher education. *South African Journal of Higher Education*, 15(3), 185-193.
- Escultura, J. E., & Ricafort, J. D. (2022). Whole Brain teaching strategy in learning waves Philippines. *International Journal of Contemporary Applied Researches*, 9(9), 1-13.
- Etkina, E., Gentile, M., & Van Heuvelen, A. (2013). *College physics*. Pearson Higher Ed.
- Etkina, E., & Planinšič, G. (2015). Defining and developing "critical thinking" through

- devising and testing multiple explanations of the same phenomenon. *The Physics Teacher*, 53(7), 432-437.
- Hassan, N. H. N., & Mohammed, J. M. J. (2024). Effect of problem-based learning method with cooperative learning strategy on academic performance among physics secondary schools students IN Katsina State, Nigeria. *Nigerian Online Journal of Educational Sciences and Technology*, 6(1), 326-337.
- Herrmann, N. (1991). The creative brain. *The Journal of Creative Behavior*, 25(4), 275-295.
- Herrmann, N. (1996). *The whole brain business book*. New York, NY: McGraw-Hill.
- Herrmann, A., & Herrmann-Nehdi, A. (2015). *The whole brain business book: Unlocking the power of whole brain thinking in organizations, teams, and individuals*. New York, NY: McGraw-Hill Education.
- Herrmann-Nehdi, A. (2002). Using the HBDI assessment. In J. Kline (Ed.), *The Handbook of Behavioral and Cognitive Geography*. Edward Elgar Publishing.
- Hughes, M., Hughes, P., & Hodgkinson, I. R. (2016). In pursuit of a 'whole-brain' approach to undergraduate teaching: implications of the Herrmann brain dominance model. *Studies in Higher Education*, 42(12), 2389–2405.
- Isa, S. G., Mammam, M. A., Badar, Y., & Bala, T. (2020). The impact of teaching methods on academic performance of secondary school students in Nigeria. *International Journal of Development Research*, 10(6), 37382-37385.
- Lanzinger, F. (2022). *3D Game Development with Unity*. CRC Press.
- Mbajiorgu, N. (2014). Science and Technology education: instruments for national transformation and global competitiveness. *Journal of Science Teachers Association of Nigeria*, 49(1), 116-135.
- Musa, Y. (2021). Effects of Herrmann's Whole-Brain Model on retention and academic performance among secondary school physics students In Zaria Education Zone, Kaduna, Nigeria (*Masters' dissertation, Ahmadu Bello University, Zaria, Nigeria*).
- Naade, N.B., Alamina, J. I. & Okwelle, P. C. (2018) Effect of 7E's constructivist approach on students' achievement in electromagnetic induction topic in senior secondary schools in Nigeria. *Journal of Education, Society and Behavioural Science*, 24(3), 1-9.
- Okwu & Charles O. (2018). Children's self and Peer-assessment In Harlem, W. (Ed) *ASE Guide to primary science Education*. Hatfield: Association for science Education
- Olatunde-Aiyedun, T. G. (2021). Student teachers' attitude towards teaching practice. *International Journal of Culture and Modernity*, 8, 6-17.
- Parane, F. E. (2023). Challenges and Teaching Methods for Exceptional Learners in Science: Academic Performance and Teacher Perspectives in an Inclusive Junior High School Classroom. *International Journal of Academic and Practical Research*, 2(1), 45-58.

- Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist*, 38(1), 1-4.
- Rubini, B., Septian, B., & Permana, I. (2019, February). Enhancing critical thinking through the science learning on using interactive problem-based module. In *Journal of Physics: Conference Series*, 1157(2), 022001. IOP Publishing.
- Serway, R. A., & Jewett, J. W. (2018). *Physics for scientists and engineers with modern physics (10th ed.)*. Boston, MA: Cengage Learning.
- Siyabola, W., Adeyeye, A., Olaopa, O., & Hassan, O. (2016). Science, technology and innovation indicators in policy-making: the Nigerian experience. *Palgrave Communications*, 2(1), 1-9.
- Smit, T., & du Toit, P. H. (2016). Transforming beginner teacher mentoring interventions for social reform. *South African Journal of Education*, 36(3), 1-12.
- Sontillano, R. D. (2018). Impact of whole brain teaching based instruction on academic performance of grade 8 students in Algebra: Compendium of WBT-based lesson plans. *PUPIL: International Journal of Teaching, Education and Learning*, 2 (2), 98-114.
- Stratton, A. C., & Farmer, A. (2023). The Effects of whole brain teaching on student motivation in reading and writing. *AILACTE Journal*, 20, 31-51.
- Voulvoulis, N., & Burgman, M. A. (2019). The contrasting roles of science and technology in environmental challenges. *Critical Reviews in Environmental Science and Technology*, 49(12), 1079-1106.
- Yusuf, M., Atadoga, M., Falalu, M. K., & Mustapha, S. B. (2019). Effects of Herrmann's Whole- Brain Model on retention among secondary school Physics students in Zaria Education Zone Kaduna State, Nigeria. *International Journal of Research in Education, Science and Technology*, 4(2), 41-50.