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The Effect of Jigsaw-IV Instructional Strategy on Students' Performance in Wave-Particle Paradox among Secondary Schools in Katsina State, Nigeria

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ABSTRACT
The study examined the effectiveness of the Jigsaw-IV instructional strategy on students' performance in the wave-particle paradox among secondary school students in Katsina State, Nigeria. A quasi-experimental design involving pretest and posttest non-randomized control groups was employed, comprising 102 students (62 in the experimental group and 40 in the control group) randomly selected from 165 senior secondary schools offering Physics across two senatorial districts in Katsina State, with a total population of 30,011 students. Data were collected using a 20-item Wave-Particle Paradox Performance Test (WPPPT), which had a reliability coefficient of 0.87. Descriptive statistics and Analysis of Covariance (ANCOVA) were used to analyze the data. The results revealed that students taught using the Jigsaw-IV instructional strategy performed significantly better than those taught using the traditional method. Specifically, students in the Jigsaw-IV group demonstrated a deeper understanding of the wave-particle paradox concept. The study therefore recommends the adoption of the Jigsaw-IV instructional strategy in Physics education to improve students' comprehension of complex concepts such as the wave-particle paradox.

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INTRODUCTION

Physics is a foundational science that underpins many technological advancements and practical applications in the modern world. However, teaching and learning physics often present challenges due to its abstract concepts and mathematical rigor. Despite the significant role that physics plays in scientific and technological innovation, students' performance in this subject has been consistently low, especially in developing countries (Osokoya, 2018).

Wave-particle paradox is a fundamental concept in quantum mechanics that explains how particles, such as electrons, can exhibit both wave-like and particle-like behavior. However, this concept is challenging for students to understand due to its abstract nature. The abstract nature of this concept often leads to difficulties in comprehension, resulting in poor academic performance. Research has consistently shown that students struggle to understand and apply wave-particle paradox, leading to a lack of confidence and motivation in physics. Physics at SSCE may be attributed to a number of factors ranging from students' limited knowledge about photoelectric effect, energy level, photoemission, and inability to systematically prove certain expressions, among others (WAEC 2018, 2019, & 2020).

Teaching wave-particle paradox requires innovative instructional strategies that promote active learning, critical thinking, and collaboration. Traditional teaching methods, which emphasize lecturing and rote memorization, are often ineffective in promoting deep understanding and academic achievement in complex concepts

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like wave-particle paradox. Students may struggle to connect abstract concepts to real-world applications, leading to a lack of engagement and motivation. The persistent underachievement has been attributed to a variety of factors, including ineffective teaching strategies, lack of motivation among students, and the abstract nature of the subject matter. In response to this challenge, researchers and educators have explored innovative instructional strategies to enhance students' understanding and performance. One such strategy is the Jigsaw-IV instructional strategy, which is a cooperative learning approach.

The Jigsaw-IV instructional strategy is an advanced version of the Jigsaw cooperative learning model developed by Aronson in the 1970s. This strategy emphasizes collaborative learning, where students work in small groups to master specific portions of a topic and then share their understanding with peers (Slavin, 2014). Jigsaw-IV integrates structured interactions, group interdependence, and individual accountability, which are key components of effective cooperative learning. Research has shown that cooperative learning strategies like Jigsaw-IV improve students' academic performance, foster critical thinking, and enhance interpersonal skills (Johnson, Johnson, & Smith, 2016). However, while this strategy has been widely studied in subjects like mathematics and biology, its application and efficacy in physics education remain underexplored.

In addition to improving individual performance, the Jigsaw-IV instructional strategy fosters a collaborative classroom culture. In a typical Jigsaw-IV activity, students are divided into "home" groups and "expert" groups. Each member of the home group is assigned a specific subtopic to study and discuss with members of other groups who have the same subtopic. After mastering the subtopic in their expert groups, students return to their home groups to teach what they have learned. This structure not only ensures that every student contributes to the learning process but also promotes the development of communication and teamwork skills (Slavin, 2014).

Empirical studies on the Jigsaw-IV instructional strategy in science education provide promising evidence of its effectiveness. For example, Jamilu, Lawan, and Yusuf (2022) examined the impact of the Jigsaw-IV strategy on students' performance and retention in geometry and found significant improvements compared to traditional teaching methods. Similarly, Josiah and Mankilik (2021) reported positive effects of Jigsaw IV Cooperative Learning Strategy (J4CLS) on secondary school students' achievement in Physics. These findings suggest that the strategy has the potential to address similar challenges in physics education, particularly in topics that require conceptual understanding and problem-solving skills

Despite the potential benefits of Jigsaw-IV instructional strategy, its effectiveness in promoting students' academic performance in wave-particle paradox has not been extensively explored. This study aims to investigate the effect of Jigsaw-IV instructional strategy on students' academic performance in wave-particle paradox, providing valuable insights for educators seeking to improve student understanding and achievement in complex physics concepts.

This study is significant because it explores the effectiveness of Jigsaw-IV instructional strategy in promoting academic achievement in wave-particle paradox, a critical concept in quantum mechanics. The findings of this study will provide educators with valuable insights into the design of innovative instructional strategies that promote deep understanding and academic achievement in complex physics concepts.

STATEMENT OF THE PROBLEM

Physics education plays an important role in developing students' scientific understanding and analytical thinking, enabling them to grasp complex concepts such as the wave-particle paradox. However, students' performance in Nigeria's Senior School Certificate Examination (SSCE) has remained generally poor over the years. Data from the Katsina State Ministry of Education indicate a steady decline in Physics results. In the West African Examinations

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Council (WAEC), performance was notably low in 2017, with only 7.2% of students passing.

Although there was a sharp improvement to 72.7% in 2018, the results subsequently declined, dropping to just 22.6% in 2023. Correspondingly, the WAEC failure rate increased, reaching 77.4% in 2023. The National Examinations Council (NECO) results were comparatively better, recording a high pass rate of 85.5% in 2018. Nevertheless, NECO performance also declined, with the pass rate falling to 48.3% and the failure rate rising to 51.7% in 2023. In summary, both examinations reflected a consistent downward trend in pass rates and an upward trend in failure rates over the years.

Objectives of the Study

The objectives of the present study is to:

1. Determine the effect of Jigsaw-IV instructional strategy on students' academic performance of the wave particle paradox among Secondary Schools in Katsina State.
2. Find the effects of Jigsaw-IV instructional strategy on students' academic performance of male and female students in wave particle paradox in Secondary Schools in Katsina State.

Research Questions

1. What is the difference in the mean academic performance scores of students taught wave particle paradox in physics using the Jigsaw-IV instructional strategy and those taught using traditional method in Secondary Schools in Katsina State?
2. What are the comparative mean retention scores between male and female students taught wave particle paradox in physics with Jigsaw-IV instructional strategy in Secondary Schools in Katsina State?

Research Hypotheses

The following null hypotheses were formulated and tested at $p > 0.05$ levels of significance.

H_{01}: There is no significant difference in the mean academic performance scores between students taught wave concepts using Jigsaw-IV instructional strategy and those taught using traditional method in Secondary Schools in Katsina State.

H_{02}: There is no significant difference in the mean retention scores between male and female students taught wave particle paradox with Jigsaw-IV instructional strategy in Secondary Schools in Katsina State.

METHODOLOGY

A quasi-experimental design involving pre-test and post-test non-randomized control groups was adopted for this study. The target population comprised all Senior Secondary School III (SSS 3) students offering Physics across two senatorial districts in Katsina State, consisting of 165 schools with a total of 30,011 students. Cluster sampling was used to select two schools, from which 102 students (33 males and 69 females) were drawn through simple random sampling of intact classes to ensure gender representation. These students were assigned to experimental and control groups, with 62 and 40 students respectively.

The study employed a single instrument, the Wave Particle Paradox Performance Test (WPPPT), which was pilot-tested using the split-half method and yielded a reliability coefficient of 0.78 based on the Spearman rank correlation. Two research questions were raised, and two hypotheses were tested at a 0.05 level of significance. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was employed to test the hypotheses.

RESULTS

RQ1: What is the difference in the mean academic performance scores of students taught wave particle paradox in physics using the Jigsaw-IV instructional strategy and those taught using traditional method in Secondary Schools in Katsina State?

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Table 1: Mean and Standard Deviation of the Academic Performance of the Students taught Wave-Particle Paradox using the Jigsaw-IV strategy and those taught using Traditional Method

Variable	N	Pre-test		Post-test		
		Mean	SD	Mean	SD	Mean Gain
Jigsaw-IV strategy	62	17.13	1.66	22.44	3.08	5.31
Traditional method	40	16.75	1.48	19.90	1.60	3.15
Mean Difference						

The result in Table 1 shows the mean and standard deviation of the academic performance scores of students taught the wave-particle paradox using the Jigsaw-IV instructional strategy and those taught using the traditional method. Students taught with the Jigsaw-IV strategy had a pretest mean score of 17.13 (SD = 1.66) and a posttest mean score of 22.44 (SD = 3.08), with a mean gain of 5.31, while those taught with the traditional method had a pretest mean score of 16.75 (SD = 1.48) and a posttest mean score of 19.90 (SD = 1.60), with a mean gain of 3.15. Although both groups improved after instruction, students taught using the Jigsaw-IV strategy achieved a higher posttest mean score and a greater mean gain compared to those taught using the traditional method. This indicates that the Jigsaw-IV instructional strategy was more effective in enhancing students' academic performance in the wave-particle paradox concept than the traditional method.

RQ2: What are the comparative mean academic performance scores between male and female students taught wave particle paradox in physics with Jigsaw-IV instructional strategy in Secondary Schools in Katsina State?

Table 2: Mean and Standard Deviation of the Mean Academic Performance Scores between Male and Female Students taught Wave Particle Paradox with Jigsaw-IV strategy

Variable	N	Pre-test		Post-test		
		Mean	SD	Mean	SD	Mean gain
Male	15	17.53	1.85	21.93	3.35	4.4
Female	47	17.00	1.50	22.6	3.01	5.6
Mean differences		0.53		-0.67		1.20

The result in Table 2 shows the mean and standard deviation of the academic performance scores of male and female students taught the wave-particle paradox in physics using the Jigsaw-IV instructional strategy. The male students had a pretest mean score of 17.53 (SD = 1.85) and a posttest mean score of 21.93 (SD = 3.35), giving a mean gain of 4.40. The female students had a pretest mean score of 17.00 (SD = 1.50) and a posttest mean score of 22.60 (SD = 3.01), resulting in a mean gain of 5.60. Although the female students had a slightly lower pretest mean score than their male counterparts, they achieved a higher posttest mean score and a greater mean gain of 1.20. This suggests that both male and female students benefited from the Jigsaw-IV instructional strategy, but female students showed a slightly higher improvement in academic performance in the wave-particle paradox concept.

H_{01}: There is no significant difference in the mean academic performance scores between students taught wave concepts using Jigsaw-IV instructional strategy and those taught using traditional method in Secondary Schools in Katsina State.

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Table 3: ANCOVA of the Academic Performance of Students taught the Wave-Particle Paradox using the Jigsaw-IV strategy and those taught using Traditional Method

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta
Corrected Model	179.918[a]	2	89.959	13.592	.000	0.215
Intercept	410.828	1	410.828	62.073	.000	0.385
teachingmethod1	140.465	1	140.465	21.223	.000	0.177
Pretest	23.613	1	23.613	3.568	.062	0.035
Error	655.229	99	6.618			
Total	14187.000	102				
Corrected Total	835.147	101				

a. R Squared = .215 (Adjusted R Squared = .200)

The result of the Analysis of Covariance (ANCOVA) presented in Table 3 shows that there was a significant main effect of the teaching method on students' academic performance in the wave-particle paradox after controlling for the pretest scores, $F(1,99) = 21.223$, $p < .05$. This indicates that the students taught using the Jigsaw-IV instructional strategy performed significantly better than those taught using the traditional method. The pretest covariate was not significant, $F(1,99) = 3.568$, $p > .05$, suggesting that students' prior knowledge did not significantly influence their posttest performance. The corrected model was significant, $F(2,99) = 13.592$, $p < .05$, explaining 21.5% (Adjusted $R^2 = .200$) of the variance in students' performance. Therefore, the finding implies that the Jigsaw-IV strategy had a positive and significant effect on students' academic performance in the wave-particle paradox compared to the traditional teaching method.

H_{02}: There is no significant difference in the mean academic performance scores between male and female students taught wave particle paradox with Jigsaw-IV instructional strategy in Secondary Schools in Katsina State.

Table 4: ANCOVA of the Academic Performance Scores of Male and Female Students taught Wave Particle Paradox with Jigsaw-IV strategy

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta
Corrected Model	12.185[a]	2	6.093	.634	.534	0.021
Intercept	339.320	1	339.320	35.305	.000	0.374
Gender	6.674	1	6.674	.694	.408	0.012
pretest3	7.196	1	7.196	.749	.390	0.013
Error	567.057	59	9.611			
Total	10167.000	62				
Corrected Total	579.242	61				

a. R Squared = .021 (Adjusted R Squared = -.012)

The Analysis of Covariance (ANCOVA) result in Table 4 shows that there was no significant main effect of gender on the academic performance of students taught the wave-particle paradox using the Jigsaw-IV instructional strategy after controlling for pretest scores, $F(1,59) = 0.694$, $p > .05$. This indicates that male and female students performed comparably when taught with the Jigsaw-IV strategy. Similarly, the pretest covariate was not significant, $F(1,59) = 0.749$, $p > .05$, implying that students' prior knowledge did not significantly influence their posttest performance. The corrected model was not significant, $F(2,59) = 0.634$, $p > .05$, and accounted for only 2.1% (Adjusted $R^2 = -0.012$) of

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the variance in performance, indicating that the model had minimal explanatory power. Therefore, the result suggests that gender had no significant influence on students' academic performance when taught the wave-particle paradox using the Jigsaw-IV instructional strategy.

DISCUSSION OF RESULTS

The study's findings show that the Jigsaw-IV instructional strategy effectively improves students' academic performance in physics. Students taught the wave-particle paradox using this strategy achieved significantly higher mean scores compared to those taught with traditional methods. This suggests that the Jigsaw-IV approach helps students understand complex physics concepts better. The differences in standard deviations between groups show that while traditional methods resulted in more uniform outcomes, the Jigsaw-IV strategy supported diverse individual learning experiences. This diversity reflects the active engagement and peer collaboration promoted by the strategy.

These results align with earlier studies, such as Josiah and Mankilik (2021) which indicated that the students who were taught heat energy measurements using J4CLS received significantly higher grades than those who were taught using the traditional lecture technique; Macmillan (2019) who revealed that students taught using Jigsaw cooperative learning performed significantly higher than those taught using conventional lecture method irrespective of their gender; Amiruddin, Nyoman, and Muhammad (2019) which shows that cooperative learning strategy of jigsaw type has more benefits than direct learning strategy in conceptual understanding on Physics; and Shahri, Matlabi, Esmaeili, and Kianmehr (2017) who showed a significantly better mastery over the subject compared to the group of laboratory sciences students, who taught with lectures method.

This study on gender analysis found no significant difference in the performance of male and female students taught using the Jigsaw-IV strategy. This finding align with studies by Damoeroem, Dakang and Dapar (2022) and Macmillan and Mangut (2021), who noted that both the male and female students exposed to J4CLS achieved high and there was no significant interaction effect of gender on students' achievement in physics after exposure to J4CLS. The slight difference in mean scores between genders suggests that the strategy encourages equal participation and learning opportunities for all students. This finding corroborates the work of Zubairu, Gimba, Ndako, and Mohammed (2019), who reported that there was no statistical difference in the mean achievement scores of both male and female students taught with jigsaw, and also, they found that there is no statistically significant difference between the two groups (male and female students).

CONCLUSIONS:

The study reveals that students taught the wave-particle paradox using the Jigsaw-IV instructional strategy significantly outperformed those taught using traditional methods, as evidenced by a mean score difference of 2.45. Gender-based analysis shows that both male and female students taught using Jigsaw-IV strategy performed equally in their learning outcome. This implies that Jigsaw-IV strategy is gender friendly

RECOMMENDATIONS:

Teachers should adopt the Jigsaw-IV instructional strategy in teaching physics to enhance students' understanding and performance. Teacher training programs should be organized to equip teachers with the skills required for implementing cooperative learning strategies effectively. Additionally, integrating digital tools and simulations with the Jigsaw-IV strategy can further enhance its impact on students' comprehension of abstract physics concepts. Policymakers should support these initiatives by providing necessary resources and fostering a culture of innovative teaching practices in schools.

REFERENCES

Amiruddin Kade, I Nyoman Sudana Degeng, & Muhammad Nur Ali (2019). Effect of Jigsaw Strategy and Learning Style to Conceptual Understanding on Senior

Corresponding author: Abdulkareem Munir
abdulkareemmunir@yahoo.com
Department of Science Education, Umaru Musa Yar'adua University, Nigeria.

High School Students. *International Journal of Emerging Technologies in Learning (IJET),* 14(19): 4-15. https://doi.org/10.3991/ijet.v14i19.11592

Damoeroem Ejilayomi Omokorede, Dakang Paul. D., & Dapar Lot (2022). Effect of Jigsaw Instructional Strategy on Senior School Physics Students' Achievement in Jos, Nigeria. *International Journal of Innovative Research & Development*, *10*(3), 88-94. doi 10.24940/ijird/2021/v10/i3/MAR21044

Macmillan M. Josiah (2019). Effect of Jigsaw cooperative learning in physics: its impact on secondary school students' achievement in Bukuru Metropolis. *GLOJACARF Multidisciplinary, 7*(1): 40-50.

Jamilu, A., Lawan, M., & Yusuf, I. (2022). Impact of Jigsaw-IV strategy on students' performance and retention in geometry. *Journal of Mathematics Education, 13(*2), 45-59.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2016). Cooperative learning: Improving university instruction by basing practice on validated theory. *Journal on Excellence in College Teaching, 25*(4), 85-118.

Josiah M.M. & Mankilik M. (2021), Jigsaw IV Cooperative Learning Strategy: Closing the Gender and School Type Gaps in Physics Achievement of Senior Secondary two Students. *British Journal of Education, Learning and Development Psychology, 4*(2), 18-30.

Osokoya, M. M. (2018). Teaching strategies for improving students' performance in science. *Journal of Science Education, 32*(5), 67-75.

Shahri, M.J., Matlabi, M., Esmaeili, R., & Kianmehr, M. (2017). Effectiveness of teaching: Jigsaw technique vs. lecture for medical students' Physics course. *Bali Medical Journal* 6(3): 529-533. DOI:10.15562/bmj.v6i3.400

Slavin, R. E. (2014). Cooperative learning and academic achievement: Why does group work? Anales de Psicología, 30(3), 785-791.

West African Examinations Council. (2018). Chief examiner's report: May/June 2018 WASSCE.

West African Examinations Council. (2019). Chief examiner's report: May/June 2019WASSCE.

West African Examinations Council. (2020). Chief examiner's report: May/June 2020 WASSCE.

Zubairu, D. M., Gimba, R. W., Ndako, U. Z., & Mohammed, N. J. (2019). Effects of Computer Simulation Instruction and Jigsaw 1 Method on Achievement in Physics among Secondary School Students' in Katcha Local Government Niger State. *Journal of Science, Technology, Mathematics and Education (JOSTMED), 15*(4), 118-127.

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