



The Effectiveness of Jigsaw-IV Instructional Strategy on Students' Retention of Wave-Particle Paradox: A Study of Senior Secondary Schools in Katsina State

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ABSTRACT

The study explored the effectiveness of jigsaw-iv instructional strategy on students' retention of wave-particle paradox in physics among senior secondary schools in Katsina State. A quasi-experimental of the pre- and post-tests non-randomized control group was employed, involving 102 students (62 experimental, 40 control) randomly selected from one hundred and sixty-five (165) senior secondary schools offering physics across two senatorial districts in Katsina State with total number of 30,011 students. Data were collected using a 20-item Wave-Particle Paradox Performance Test (WPPPT) with a reliability coefficient of 0.87. Descriptive statistics and ANCOVA were used to analyze the data. Results showed that there is a significant difference in the retention of students taught the wave-particle paradox using the Jigsaw-IV instructional strategy compared to those taught using the traditional method. The study recommends the adoption of Jigsaw instructional strategy in physics education to enhance students' retention of the complex concepts like Wave-Particle Paradox.

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INTRODUCTION

Physics is a fundamental subject that helps us understand the natural world. It provides a foundation for understanding how things work and how the universe behaves. Physics is essential for advancing scientific and technological innovations. It also defined as the discipline that seeks to explain the structure and dynamics of the physical world using mathematical models and experimental observations (Giancoli, 2018). The knowledge gained from physics is used in many different fields. For example, engineering relies heavily on physics to design and build structures, machines, and devices. Medicine also uses physics to develop new treatments and technologies, such as medical imaging and radiation therapy.

The wave-particle paradox is a big idea in physics. It explains how light and matter can behave in two different ways. Sometimes they act like waves, and sometimes they act like tiny particles. This idea is central to quantum

mechanics, a branch of physics that studies the behavior of really small things like atoms and particles. The wave-particle paradox is also important because it challenges our classical way of thinking about the world. In classical physics, objects are either waves or particles, but not both. The wave-particle paradox shows us that, at a small scale, the rules of classical physics do not apply. Understanding this concept is essential for grasping the basics of quantum mechanics and its many applications.

However, this concept is difficult for students to understand because due to its abstract. Research consistently shows that students struggle to understand and apply the wave-particle paradox. This leads to a lack of confidence and motivation in physics. The challenges in understanding physics at the SSCE level stem from factors such as students' limited knowledge of the photoelectric effect, energy levels, photoemission, and difficulty in proving certain expressions (WAEC 2018, 2019, & 2020).

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The difficulty in understanding the wave-particle paradox is often linked to traditional teaching methods in physics classrooms. These methods rely on lectures and rote memorization, which can result in a superficial understanding of complex concepts. Josiah (2020) observed that poor performance in physics at the Senior School Certificate Examinations (SSCE) may be due to the ineffectiveness of the conventional lecture method commonly used in senior secondary schools.

Academic retention is crucial for students' success in physics, as it enables them to build upon previously learned concepts and develop a deeper understanding of complex topics. Retention refers to the ability to retain or remember information, skills, or experiences over time. It involves the process of encoding, storing, and retrieving information, which contributes to the persistence of knowledge and learning outcomes (Anderson & Schunn, 2019). However, students often struggle to retain information in physics, particularly in topics like wave-particle paradox. Research has shown that students' academic retention can be improved through the use of innovative instructional strategies that promote active learning, critical thinking, and collaboration (Ambrose et al., 2010).

One such instructional strategy is Jigsaw-IV, a cooperative learning technique that involves students working in small groups to learn and teach each other about a specific topic. Each group member is responsible for learning a specific portion of the material and teaching it to the other group members. Research has shown that Jigsaw-IV can be an effective instructional strategy for promoting academic achievement and retention, as it encourages active learning, critical thinking, and problem-solving skills (Aronson et al., 2017).

The use of Jigsaw-IV can be particularly beneficial in teaching complex concepts like wave-particle paradox. By working in small groups, students can share their knowledge and understanding of the concept, address any misconceptions, and develop a deeper understanding of the topic. Moreover, Jigsaw-IV can help to promote students' academic retention

by encouraging them to take an active role in their learning and to think critically about the material (Taconis & Kessels, 2017).

Empirical studies on the Jigsaw-IV instructional strategy in science education offer compelling evidence of its effectiveness. For instance, Jamilu, Lawan, and Yusuf (2022) investigated the impact of the Jigsaw-IV strategy on students' performance and retention in geometry, reporting significant improvements compared to traditional teaching methods. Similarly, Samuel (2018) explored the effects of Jigsaw-IV, Group Investigation, and Reversed Jigsaw cooperative instructional strategies on the achievement and retention of Basic Science students, highlighting the positive influence of Jigsaw-IV on academic retention. These findings suggest that the strategy holds promise for addressing similar challenges in physics education, particularly for topics requiring strong conceptual understanding and problem-solving skills. Additionally, Isiaka and Mudasiru (2016) examined the effects of a Computer-Assisted Jigsaw-II Cooperative Strategy on physics achievement and retention, demonstrating that students who engaged with computer-assisted Jigsaw-II significantly outperformed those who received individualized computer instruction in both performance and retention.

Despite the potential benefits of Jigsaw-IV, its effectiveness in promoting students' academic retention in wave-particle paradox has not been extensively explored. Therefore, this study aims to investigate the effect of Jigsaw-IV on students' academic retention 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 retention in wave-particle paradox, a critical concept in quantum mechanics. The findings of this study will provide teachers with valuable insights into the design of innovative instructional strategies that promote deep understanding and academic retention in complex physics concepts.



Objectives of the Study

The objectives of the present study is to:

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

Research Questions

The following research questions were raised;

1. What is the difference in the mean academic retentions cores of students taught wave particle paradox in physics using the Jigsaw-IV instructional strategy and those taught using conventional method in Secondary Schools in Katsina State?
2. What is the comparative mean academic 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.

H₀₁: There is no significant difference in the mean academic retention scores between students taught wave concepts using Jigsaw-IV instructional strategy and those taught using

conventional method in Secondary Schools in Katsina State.

H₀₂: There is no significant difference in the mean academic retention scores between male and female students taught wave particle paradox with Jigsaw-IV instructional strategy in Secondary Schools in Katsina State.

METHODOLOGY

This study employed a quasi-experimental design of the pre-test, post-tests, and post-post-test non-randomized control group. The target population comprised all Senior Secondary School III (SSS III) students in public schools offering physics across two senatorial districts in Katsina State, totaling 165 schools. Cluster sampling was utilized to select two schools, from which 102 students (33 males and 69 females) were chosen through simple random sampling to include intact classes, ensuring gender representation.

The study utilized a single instrument, the Wave Particle Paradox Performance Test (WPPPT), which was pilot-tested and achieved a reliability coefficient of 0.87. Two research questions guided the study, and two hypotheses were tested at a 0.05 significance level. Mean and standard deviation were used to address the research questions, while t-tests were employed for hypothesis testing. Data analysis was conducted using SPSS version 20, ensuring precise computation and interpretation of findings.

RESULTS

RQ1: What is the difference in the mean academic retention 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?

Table 1: Summary of the Mean and Standard deviation of the academic retention of the students taught wave-particle paradox using the Jigsaw-IV strategy and those taught using Traditional method

Variable	N	Post-test		Post post-test		Mean gain
		mean	SD	Mean	SD	
Jigsaw-IV strategy	62	12.44	3.08	11.5	3.46	0.94
Traditional method	40	9.9	1.6	9.43	1.5	-0.47
Mean differences		2.54		2.07		

The table 1 presents the mean and standard deviation results on how well students remembered what they learned after being taught with either the Jigsaw-IV strategy or the traditional method. In the post-test, students in the Jigsaw-IV group scored mean of 12.44 with a standard deviation of 3.08, while students in the traditional group scored 9.90 with a standard deviation of 1.60. Later, in the post post-test, the Jigsaw-IV group had mean score of 11.5 with a standard deviation of 3.46, and the traditional group had 9.43 with a standard deviation of 1.50. The mean gain in scores between the post-test and post post-test was 0.94 for the Jigsaw-IV group and (-0.47) for the traditional group. This means

students taught with the Jigsaw-IV method retained more of wave particle paradox compared to those taught using traditional method. The differences in scores (2.54 in the post-test and 2.07 in the post post-test) show that the Jigsaw-IV strategy helped students perform better and retain knowledge longer

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

Table 2: Summary of the Mean and Standard deviation of the mean academic retention scores between male and female students taught wave particle paradox in physics with Jigsaw-IV strategy

Variable	N	Post-test		Post post-test		Mean gain
		Mean	SD	Mean	SD	
Male	15	11.93	3.35	11.60	3.58	-0.33
Female	47	12.60	3.01	11.47	3.46	-1.13
Mean differences		0.67		0.13		

The table 2 presents the mean and standard deviation results for the post-test and post-post-test scores for male and female students, along with the mean gain. Male students had an average post-test score of 11.93 with a standard deviation of 3.35 and a post-post-test score of 11.60 with a standard deviation of 3.58, resulting in a mean decrease of -0.33. Female students had an average post-test score of 12.60 with a standard deviation of 3.01 and a post-post-test score of 11.47 with a standard deviation of 3.46, showing a mean decrease of -1.13. The mean difference between males and females was

-0.67 at the post-test and 0.13 at the post-post-test, indicating that females scored higher than males at the post-test, but the difference reversed slightly at the post-post-test, where male students scored slightly higher than female students. In conclusion, both males and females experienced a decrease in their retention scores,

H₀₁: There is no significant difference in the mean academic retention scores between students taught wave concepts using Jigsaw-IV instructional strategy and those taught using

traditional method in Secondary Schools in Katsina State.

Table 3: ANCOVA summary of the academic retention 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.
Corrected Model	251.040 ^a	2	125.520	18.466	.000
Intercept	143.541	1	143.541	21.118	.000
Teaching method	15.927	1	15.927	2.343	.129
Posttest	146.354	1	146.354	21.532	.000
Error	672.921	99	6.797		
Total	12572.000	102			
Corrected Total	923.961	101			

a. R Squared = .272 (Adjusted R Squared = .257)

The table 3 presents the ANCOVA results for the academic retention of students taught the wave-particle paradox using the Jigsaw-IV strategy and the Traditional method. The table shows that at 0.05 level of significance, the calculated F (1, 99) is 2.343 with p-value of 0.129, which is greater than 0.05. Therefore, the null hypothesis is rejected. Thus, there is a significant difference in the mean academic retention scores between students taught wave concepts using Jigsaw-IV strategy and those

taught using traditional method in Secondary Schools in Katsina State. However, the post-test scores had a significant effect (F = 21.532, Sig. = 0.000), showing that students' test scores strongly had no impact on the results.

H₀₂: 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.

Table 4. ANCOVA summary of the academic retention 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.
Corrected Model	171.339 ^a	2	85.670	9.023	.000
Intercept	82.460	1	82.460	8.685	.005
Gender	2.746	1	2.746	.289	.593
posttest	171.141	1	171.141	18.026	.000
Error	560.161	59	9.494		
Total	8931.000	62			
Corrected Total	731.500	61			

a. R Squared = .234 (Adjusted R Squared = .208)

The table 4 presents the ANCOVA results for the academic retention scores between male and female students taught wave particle paradox in physics with Jigsaw-IV strategy in Secondary Schools in Katsina State. The table shows that at 0.05 level of significance, the calculated F (1, 59) is 0.289 with p-value of 0.593,

which is greater than 0.05. Therefore, the null hypothesis is accepted. Thus, there is no significant difference in the mean academic retention scores between male and female students taught wave particle paradox with Jigsaw-IV strategy in Secondary Schools in Katsina State, meaning that the gender had no significant effect

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on students' academic retention. However, the post-test scores also had a significant effect on students' academic retention ($F = 18.026$, $\text{Sig.} = 0.000$), showing that students' prior knowledge had an influence on the post-test results.

DISCUSSION OF FINDINGS

The findings of this study highlight the effectiveness of the Jigsaw-IV instructional strategy compared to the traditional teaching method for enhancing academic retention in the wave-particle paradox in physics among secondary school students in Katsina State. For Research Question and Hypothesis 1, the findings reveal that students taught using the Jigsaw-IV strategy achieved significantly higher mean academic retention scores than those taught using the traditional method. This highlights the effectiveness of the Jigsaw-IV strategy in promoting a deeper understanding and retention of complex physics concepts. However, the higher standard deviation observed in the Jigsaw-IV group suggests greater variability in individual retention, indicating differing levels of engagement and understanding among students. The ANCOVA analysis confirmed that the difference in retention scores between the two teaching methods was statistically significant, underscoring the Jigsaw-IV instructional strategy's potential to enhance academic retention more effectively than traditional approaches.

These findings are consistent with prior studies. For instance, John, Agbowuro and Chollom (2023) demonstrated that students taught excretion using the Jigsaw-IV strategy retained more information compared to those taught using the lecture method. Similarly, Jamilu, Iliyasu, Shehu, and Vincent (2022) found a significant difference in the retention of 2-D geometry concepts between studentXD5-Zs taught using the Jigsaw-IV Cooperative Learning Strategy (J4CLS) and those taught with conventional methods, with the J4CLS group achieving higher retention. Furthermore, Samuel and Sambo (2019) reported a significant retention advantage among university science students exposed to Individualized Jigsaw, Jigsaw II, and Jigsaw IV strategies, with Jigsaw IV emerging as the most effective.

For Research Question and Hypothesis 2, the comparison of academic retention scores between male and female students taught using the Jigsaw-IV strategy revealed a negligible mean difference. The results confirmed no significant difference in retention scores between genders. These findings underscore the inclusivity of the Jigsaw-IV strategy, ensuring equitable learning outcomes irrespective of gender. These results align with the findings of Damoeroem and Markus (2021), who demonstrated that the Jigsaw-IV strategy improved students' knowledge retention in physics regardless of gender or performance level. Similarly, John, Racheal, Agbowuro, and Chollom (2023) observed that while female students slightly outperformed male students in retention and performance within the Jigsaw-IV instructional framework, the differences were not statistically significant. Their study further supported the notion of comparable post-test retention outcomes for male and female students in experimental groups using the Jigsaw-IV approach.

CONCLUSIONS

The Jigsaw-iv instructional strategy has demonstrated a significant impact on enhancing students' academic retention of the wave-particle paradox, outperforming traditional teaching methods. This method's effectiveness is evident across genders, as both male and female students achieve comparable retention levels, underscoring its potential to promote equitable learning outcomes in diverse classrooms. Despite its advantages, the higher variability in retention scores among students taught using the Jigsaw-IV strategy suggests that some learners face challenges in fully benefiting from this approach. This variability highlights the diverse levels of engagement and understanding among students, which may stem from differences in prior knowledge, collaborative skills, or adaptability to the method's interactive nature. Therefore, while the Jigsaw-IV strategy is a promising tool for enhancing learning, it requires additional support mechanisms, such as individualized guidance or supplementary resources, to ensure all students can maximize their learning potential and achieve consistent outcomes.

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RECOMMENDATIONS

Schools should adopt the Jigsaw-IV instructional strategy for teaching physics and other STEM subjects to enhance academic retention, supported by teacher training workshops to ensure effective implementation. Additional guidance and resources should be provided to students who may struggle with the collaborative nature of the strategy, ensuring equitable benefits for all learners. Utilizing the Jigsaw-IV approach in mixed-gender classrooms can promote inclusivity and equitable learning opportunities. Furthermore, future research should explore the long-term effects of the Jigsaw-IV strategy on educational outcomes such as critical thinking, problem-solving, and motivation across various subjects and settings.

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