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Enhancing Conceptual Understanding of Electric Circuit Analysis through the Jigsaw Method: A Quasi-Experimental Study in Senior High Schools

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ABSTRACT

Purpose of the study: This study examines the effectiveness of the Jigsaw cooperative learning method in improving Form 1 students' understanding of electric circuit analysis, problem-solving skills, and its impact compared to traditional teaching.

Methodology: A quasi-experimental pre-test and post-test design was employed, involving 87 students from Obiri Yeboah SHS and Dadieso SHS. Over a one-week intervention, the Jigsaw method was integrated into regular physics lessons. Data were collected through tests and questionnaires administered before and after the intervention to assess the students' knowledge and learning experiences. SPSS was used for statistical analysis, evaluating the effectiveness of the Jigsaw method in improving conceptual understanding.

Main Findings: The results demonstrated a significant increase in students' comprehension of electric circuits. At Obiri Yeboah SHS, the average score rose from 50.19 (pre-test) to 83.69 (post-test), and at Dadieso SHS, from 46.50 to 86.57. The Jigsaw method not only improved students' understanding of the subject but also enhanced their problem-solving abilities, communication skills, and motivation to learn. Statistical analyses, including t-tests and Cohen's d, indicated a strong, significant effect size, reinforcing the method's effectiveness.

Novelty/Originality of this study: This study provides compelling evidence of the Jigsaw method's ability to enhance student performance and deepen conceptual understanding in science education, particularly in electric circuit analysis. The findings underscore the importance of cooperative learning techniques in promoting active participation, peer teaching, and higher levels of student engagement, suggesting that such strategies are critical for fostering more interactive and impactful classroom experiences.

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1. INTRODUCTION

Physics classes should be designed to foster engagement and ensure active student participation through the use of innovative and captivating activities that maintain attention throughout the lecture [1], [2]. To improve physics teaching, it is important to supervise students' achievement, characteristics, and feelings [3], [4]. In recent decades, across various areas of the educational landscape, a broad consensus has emerged on the importance of fostering greater student engagement and commitment to their own learning. This shift underscores the effectiveness of implementing active educational strategies, such as cooperative learning [5], [6]. To simplify the understanding of concepts and spark interest in learning physics, teachers should adopt methods that support students by serving as facilitators, guiding them toward achieving learning objectives.

Therefore, it is essential for teachers to be familiar with motivational techniques that can inspire students' interest in physics [7]. Employing student-centered instructional methods and techniques to "teach students how to learn" in modern educational systems can promote long-lasting knowledge, enabling students to apply this understanding in their daily lives [8]. Teacher-centered instructional approaches appear inadequate in cultivating the critical thinking and problem-solving abilities that are essential for improved student performance [9]. The Jigsaw method is one such strategy that has drawn notice for how well it improves students understanding originally created by Elliot Aronson in the 1970s [10].

This cooperative learning approach places a strong emphasis on peer teaching and cooperative group work to help students develop a more comprehensive knowledge of difficult ideas [11]. One of the fundamentally new practices in the realm of education is cooperative learning [12]. Working in "teams" or "cooperative groups" allows students to develop interpersonal skills that will be valuable in their future careers. " [13]. In contrast to individual instruction or competitive learning, this method pushes pupils to learn how to float together actions aimed at enhancing students' understanding [14]. In this case, students are in charge of both their own and other people's education [15].

The six characteristics of cooperative learning groups include appropriate grouping, positive interdependence, individual accountability, face-to-face verbal engagement, social skills, and group processing [16]. For a number of years, cooperative learning has been utilized to raise student achievement. This approach involves evaluating each student on an individual basis and holding them accountable for sharing and understanding the material [17]. It is an approach that uses a range of instructional techniques to increase students' understanding [18]. The application of the Jigsaw technique to electric circuit analysis is examined in this article. Electric circuit analysis is a vital yet difficult topic to most students. Teachers hope that by employing this approach, students will have a stronger conceptual understanding of electric circuits, which is necessary in order to study more difficult physics and engineering concepts.

This research will look at how the Jigsaw technique can be used strategically to increase student interest in, understanding of, and retention of electric circuit concepts. It will also evaluate how well it works to change students' attitudes toward learning in the classroom. In the context of Form 1 science education, students often struggle with grasping complex concepts related to electric circuit analysis. Traditional teaching methods may not adequately address the conceptual challenges faced by these students, leading to gaps in their understanding and application of fundamental principles [19]. Previous research has shown that tratditional teaching metthods, especially in physics education, often fail to engage students or deepen their understanding of complex concepts [20]. The jigsaw method, a cooperative learning strategy, has been suggested as a potential solution to enhance students' conceptual understanding by promoting active engagement and collaborative problem-solving [21]. However, there is limited empirical evidence on the effectiveness of the jigsaw method specifically for teaching electric circuit analysis.

The purpose of this study is to investigate the effectiveness of the jigsaw method in enhancing the conceptual understanding of electric circuit analysis among first year science students. By implementing and evaluating the jigsaw method in the classroom, this study aims to determine whether this cooperative learning approach can improve students' grasp of electric circuit concepts, foster better retention of information, and enhance their overall learning experience. The study sought to determine how the jigsaw method affect Form 1 science students' conceptual understanding of electric circuit analysis compared to traditional teaching methods. How the differences in learning outcomes related to electric circuit analysis when using the jigsaw method versus conventional teaching approaches and how Form 1 science students perceive their learning experience and engagement when taught electric circuit analysis using the jigsaw method.

Elliot Aronson invented the jigsaw style of teaching in 1971, and Robert Slavin improved upon it in 1986 with regard to assessment procedures [22]. This approach was created by Aronson to help kids in Austin, Texas's recently desegregated schools close their achievement gaps [23]. Teachers have been using this strategy and its components to foster collaboration in classroom settings from early grades to post-secondary education for the past years [24]. The Jigsaw method, initially developed by Professor Elliot Aronson in 1971, was created to address inter-group tensions in newly desegregated schools. The method fosters collaboration by requiring students to work together and rely on one another, which helps defuse hostility and improve learning [17].

Research, such as Costouros [25] and Baken, et al. [26] , has demonstrated its positive impact on student grades, learning experiences, and retention, particularly in subjects like biology and across different educational settings. Additionally, Yuliza [27] found that the Jigsaw method consistently improves student motivation, achievement, and overall learning. Theoretically, this method is supported by Social Interdependence Theory, which emphasizes the importance of collaboration, and Constructivist Learning Theory, which encourages active engagement and knowledge integration [28]. It also aligns with Deci and Ryan’s Self-Determination Theory, as students' intrinsic motivation is increased when they are responsible for their peers' learning [29].

The effectiveness of this technique can be evaluated through cognitive assessments, conceptual understanding tests, and student engagement surveys, making it a valuable tool in educational practice [30]. Despite extensive research on cooperative learning strategies in physics education, there remains a gap in understanding the specific impact of the Jigsaw method on students' conceptual grasp of electric circuit analysis. Traditional lecture-based approaches often fail to actively engage students or address their individual learning needs, leading to persistent misconceptions and challenges in problem-solving [31].

While prior studies have explored the effectiveness of cooperative learning in broad scientific contexts, limited empirical evidence exists regarding its application in foundational physics topics such as electric circuits. This study seeks to bridge this gap by evaluating the effectiveness of the Jigsaw method in enhancing Form 1 science students' comprehension, engagement, and retention of electric circuit concepts, thereby providing valuable insights into its potential as an instructional strategy in secondary physics education.

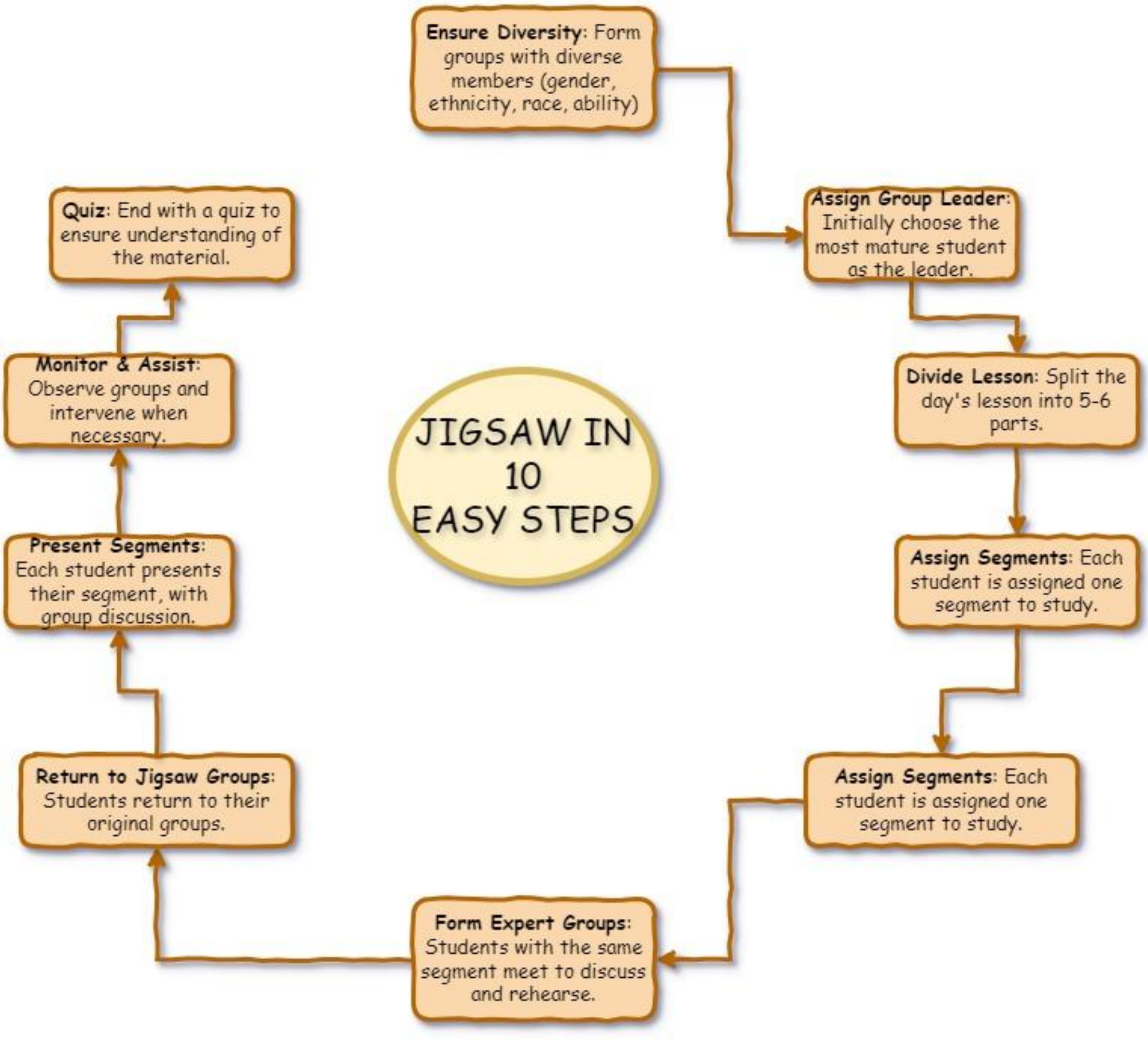

Figure 1. Jigsaw in 10 easy steps

2. RESEARCH METHOD

This study utilized a quasi-experimental design to evaluate the effectiveness of traditional lecture-based instruction and the Jigsaw cooperative learning approach in teaching electric circuit analysis to senior high school students. This approach was selected because it allows for comparing the impact of different instructional strategies within a real-world classroom setting, where random assignment of participants is often impractical. The quasi-experimental method enabled the researchers to maintain the natural integrity of the classroom environment while systematically investigating the effectiveness of the intervention.

The study adopted a pre-test-intervention-post-test model to assess the impact of these instructional strategies on student learning outcomes. Conducted as an Action Research initiative, the study sought to enhance students' conceptual understanding of electric circuits by integrating the Jigsaw method alongside the traditional teaching practices commonly used in science classrooms.

2.1 Population and Sample

Participants were drawn from Form 1 students at Obiri Yeboah Senior High School and Dadieso Senior High School. The study followed a quantitative approach, comparing test results from the traditional teaching method with those from the intervention that incorporated the Jigsaw method into the regular physics curriculum. Over a one-week period, students engaged in cooperative learning through the Jigsaw method, which involved small group discussions, peer teaching, and cooperative problem-solving to break down and comprehend complex concepts related to electric circuits.

2.2 Research Instrument

To evaluate the intervention's efficacy, pre- and post-tests were administered to measure students' knowledge of electric circuits before and after the Jigsaw-enhanced instruction. A structured questionnaire was also administered to collect qualitative data on students' experiences with the Jigsaw method. The questionnaire included both closed-ended and open-ended items to capture multiple dimensions of the students' experiences, including their levels of engagement, perceptions of cooporation, and the perceived impact on their conceptual understanding of electric circuits. The questionnaire was designed based on existing frameworks for evaluating cooperative learning strategies and underwent a rigorous review process to ensure relevance and clarity. A pilot test was conducted with a small sample to refine the questionnaire, resulting in modifications that improved its reliability and appropriateness for the study.

2.3 Data Analysis Techniques

Data were analyzed using SPSS (version 27.0) to determine whether the intervention significantly improved students' understanding of electric circuits. Descriptive and inferential statistical techniques, including paired t-tests and effect size calculations, were employed to evaluate learning gains and measure the intervention's impact.

2.4 Reliability and Validity of Instrument

The reliability and validity of data collection instruments were carefully ensured. Content validity was achieved by designing test items that comprehensively covered key aspects of electric circuit analysis addressed in the Jigsaw method. Construct validity was enhanced by including questions that accurately measured the underlying concepts and skills related to electric circuits. Criterion-related validity was established by comparing students' post-intervention performance with their prior achievements. Additionally, the test instruments were reviewed by experienced physics educators, whose feedback informed final refinements. This study's robust methodological design, combining quantitative and qualitative approaches, ensured a comprehensive understanding of how the Jigsaw cooperative learning method impacts student engagement, cooperation, and conceptual understanding in the context of physics education.

3. RESULTS AND DISCUSSION

The study focused exclusively on selected schools, with a total student population of 87 participants. Out of these, 31 were female and 56 were male.

Table 1. Paired Sample Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Obiri Yeboah SHS	Pre-test	50.19	59	12.352	1.608
	Post-test	83.69	59	7.491	.975
Dadieso SHS	Pre-test	46.50	28	12.557	2.373
	Post-test	86.57	28	7.198	1.360

Table 1 provides statistics on the pre-test and post-test statistics for students at Dadieso SHS and Obiri Yeboah SHS. The mean pre-test score for Obiri Yeboah SHS (50.19) is slightly higher than that of Dadieso SHS (46.50). This suggests that students at Obiri Yeboah SHS had a marginally better initial understanding of electric circuit analysis before the intervention. After the intervention (using the Jigsaw method), the post-test scores for both schools increased significantly. The mean post-test score for Obiri Yeboah SHS is 83.69, while for Dadieso SHS it is 86.57. This shows a notable improvement in conceptual understanding for both groups. The mean score for Obiri Yeboah SHS increased from 50.19 (pre-test) to 83.69 (post-test), which is a gain of 33.50 points. The mean score for Dadieso SHS increased from 46.50 (pre-test) to 86.57 (post-test), a gain of 40.07 points. The improvement for Dadieso SHS is slightly higher, suggesting that the students there might have benefited more from the Jigsaw method or had a greater relative gain in understanding. The SD values for both schools decrease in the post-test compared to the pre-test. This indicates a reduction in score variability after the intervention, suggesting that the students' performance became more consistent. The SEM, which indicates the precision of the mean scores, also decreased for both schools in the post-test. This further confirms a more consistent performance across the student groups after the intervention. The substantial increase in mean scores from pre-test to post-test at both schools indicates that the Jigsaw method was effective in enhancing the students' understanding of electric circuit analysis. The reduction in standard deviation and standard error suggests that not only did the overall performance improve, but the range of scores also became narrower, pointing to a more uniformly distributed improvement among the students.

Table 2. Paired Sample Statistics

	t	df	Sig. (2-tailed)
Obiri Yeboah SHS	-25.419	58	.000
Dadieso SHS	-19.014	27	.000

Additionally as indicated in table 2, the t-value and p-value were, respectively, -19.014 and 0.00 for Dadieso SHS and 25.419 and 0.00 for Obiri Yeboah SHS. The t-value is a number that measures the size of the difference between your sample data and what you expect under a hypothesis, relative to the variation in your data [32]. A very large negative t-value (in absolute terms) shows a strong effect size and indicates that the change in scores is both large and statistically significant. The p-value (.000) again shows that this improvement is statistically significant, indicating that the Jigsaw method effectively enhanced students' understanding reinforcing the effectiveness of the Jigsaw method [33].

Table 3. Paired Samples Effect Sizes

					95% Confidence Interval	
			Standardizer[a]	Point Estimate	Lower	Upper
Obiri Yeboah SHS	Pre-test - Post-test	Cohen's *d*	10.126	-3.309	-3.959	-2.654
		Hedges' correction	10.192	-3.288	-3.933	-2.637
Dadieso SHS	Pre-test - Post-test	Cohen's *d*	11.152	-3.593	-4.610	-2.566
		Hedges' correction	11.310	-3.543	-4.546	-2.530

Cohen's d and Hedges' g are commonly used to measure the effect size, which indicates the magnitude of the difference between the pre-test and post-test scores. The negative values indicate a positive learning gain (post-test scores are higher than pre-test). From table 3 both schools showed extremely high effect sizes (in absolute terms), indicating that the Jigsaw method had an exceptionally strong effect on students' understanding of electric circuit analysis. The confidence intervals for both schools are relatively narrow, reflecting a high level of precision in the estimated effect sizes. The absence of zero within these intervals suggests that the improvements are statistically significant. The Jigsaw method has proven to be highly effective in improving the conceptual understanding of electric circuit analysis among Form 1 science students at both Obiri Yeboah SHS and Dadieso SHS. The large effect sizes and narrow confidence intervals indicate not only a strong impact of the intervention but also confidence in the reliability of these results. This suggests that the Jigsaw method can be a powerful tool for enhancing student learning outcomes in science education.

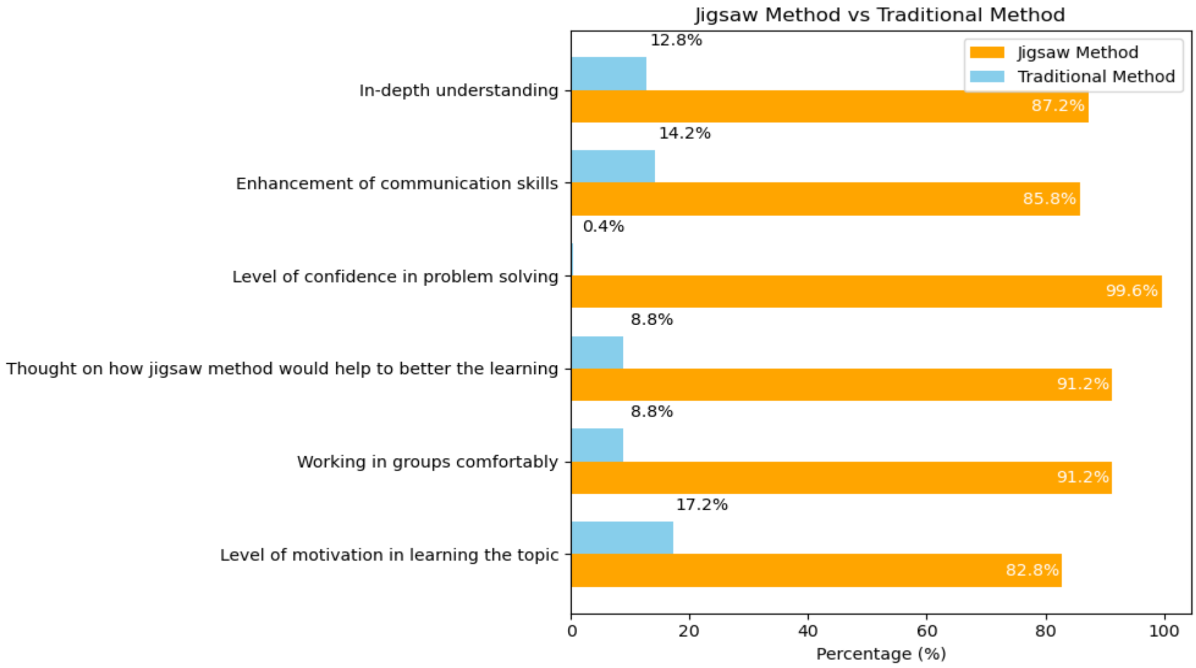

Figure 2. Response from questionnaire at Obiri Yeboah SHS

From figure 2, the jigsaw method significantly improves students' in-depth understanding of the topic compared to the traditional method. It received a much higher percentage and rating, indicating it is much more effective for this aspect. The jigsaw method is also much better at enhancing communication skills than the traditional method. The higher percentage and rating suggest that students engage more effectively in communication when using the jigsaw method. The jigsaw method greatly boosts confidence in problem-solving abilities, showing an almost complete reliance on this method for improving confidence compared to the traditional approach. There is a strong positive perception of how the jigsaw method could enhance the understanding of the topic, far surpassing the traditional method's effectiveness. The jigsaw method significantly improves comfortability in group work compared to the traditional method, as reflected by both the higher percentage and rating. The jigsaw method is more effective at increasing motivation for learning the topic, as indicated by the higher percentage and rating compared to the traditional method. Overall, the jigsaw method demonstrates superior effectiveness in all measured aspects compared to the traditional method. It enhances in-depth understanding, communication skills, confidence in problem-solving, perception of how to better the topic, comfortability in group work, and motivation to learn.

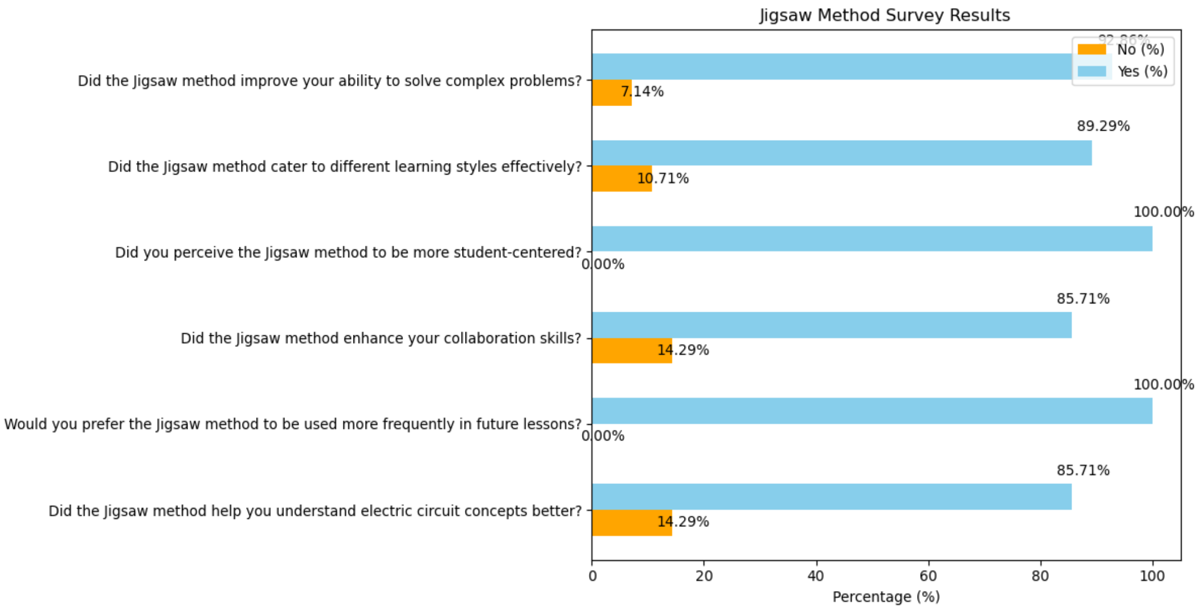

Figure 3. Response from questionnaire at Dadieso SHS

From figure 3, the majority of respondents felt that the Jigsaw method significantly improved their ability to solve complex problems. This suggests that the cooperative nature of the Jigsaw method might contribute to better problem-solving skills. A high percentage of respondents believe that the Jigsaw method effectively addresses various learning styles, indicating that it accommodates diverse learning preferences better than the traditional method. Every respondent felt that the Jigsaw method is more student-centred. This suggests that the method is perceived as giving students more control over their learning process compared to traditional approaches. A significant majority of respondents feel that the Jigsaw method enhances cooperation skills. This reflects the method's focus on group work and shared learning, which likely fosters teamwork and communication among students. All respondents expressed a preference for more frequent use of the Jigsaw method. This strong preference indicates high satisfaction with the method and a desire for its continued or increased application in future lessons. Most respondents felt that the Jigsaw method improved their understanding of electric circuit concepts, suggesting that the method is effective in enhancing comprehension in specific subject areas. The data overwhelmingly supports the effectiveness of the Jigsaw method compared to traditional teaching methods. Respondents found it beneficial in solving complex problems, accommodating different learning styles, fostering student-centred learning, improving cooperation skills, and understanding specific concepts better. Additionally, there is a strong preference for using the Jigsaw method more frequently, indicating high satisfaction and perceived value in its application.

The Jigsaw method, which involves students working in groups where each member becomes an 'expert' on a part of the topic and then teaches it to their peers [34], appears to be highly effective in improving the conceptual understanding of electric circuit analysis in Form 1 science students. Both schools show a significant improvement in test scores from pre-test to post-test, reflecting that the Jigsaw method had a positive effect. While both schools demonstrated substantial gains, the improvement was slightly higher at Obiri Yeboah SHS. This could be attributed to various factors such as differences in implementation, classroom dynamics, or student engagement levels. The p-values for both schools are well below the conventional alpha level of 0.05, confirming that the observed improvements are not due to random chance but likely due to the intervention.

The jigsaw method, a cooperative learning strategy, promotes active participation among students by dividing the lesson into segments and assigning each segment to different groups. This approach fosters a deeper understanding of the material, as students must teach their segment to their peers. The data from Obiri Yeboah SHS and Dadieso SHS sheds light on the effectiveness of this method in enhancing students' conceptual understanding of electric circuit analysis. The data shows significant improvements in student performance from pre-test to post-test when using the jigsaw method. For instance, students at Obiri Yeboah SHS had a mean score increase from 50.19 in the pre-test to 83.69 in the post-test, indicating an enhancement of 33.5 points. Similarly, Dadieso SHS students showed an increase from 46.50 to 86.57, a 40.07-point increase. The t-tests reveal statistically significant differences ($p < 0.001$) in both schools, suggesting that the jigsaw method positively impacts students' conceptual understanding of electric circuit analysis compared to traditional methods. The effect size measurements, particularly Cohen's d and Hedges' correction, provide a quantitative assessment of learning outcomes. For Obiri Yeboah SHS, Cohen's d is approximately 10.126, and for Dadieso SHS, it is about 11.152. Both figures indicate a very large effect size, suggesting that students using the jigsaw method had significantly better learning outcomes than those taught using conventional methods. These results imply that the jigsaw method not only enhances understanding but does so in a way that is markedly more effective than traditional teaching methods. The cooperative nature of the jigsaw method likely leads to increased engagement. Students typically report higher satisfaction and a better learning experience when they are active participants in the learning process. The necessity to teach their peers can boost confidence and comprehension, fostering a sense of community and accountability among learners. Observationally, students often exhibit greater enthusiasm and motivation in jigsaw settings compared to traditional, lecture-based environments. The findings from Obiri Yeboah SHS and Dadieso SHS demonstrate that the jigsaw method significantly enhances the conceptual understanding of electric circuit analysis for Form 1 science students. The substantial gains in test scores, along with the very large effect sizes, underscore the method's effectiveness over traditional

The findings from previous studies support the effectiveness of the Jigsaw technique in improving students' understanding of physics. For instance, Blajvaz, et al. [3] demonstrated that the introduction of the Jigsaw method in lower secondary physics education led to significant improvements in students' academic performance, motivation to learn physics, and metacognitive awareness. Their research found that implementing the Jigsaw technique in seventh-grade physics classes enhanced students' achievement and engagement. Similarly Jafariyan, et al. [35] compared the Jigsaw method to traditional lectures in a physics course for medical students and found that students who participated in the Jigsaw approach performed better than those who received only lecture-based instruction. This suggests that cooperative learning strategies, like the Jigsaw method, effectively address conceptual understanding challenges.

In this study, the Jigsaw method significantly enhanced students' conceptual understanding of electric circuits, as evidenced by the improved post-test scores. The intervention combined cooperative learning with hands-on exercises and theoretical instruction, fostering deeper engagement and comprehension. The cooperative nature of the Jigsaw approach facilitated active knowledge construction, allowing students to develop meaning through teamwork. Statistical analysis confirmed that the method led to a notable improvement in students' performance, with a marked increase in post-test scores and a reduction in score variability. These results indicate that the Jigsaw technique fosters a more consistent and thorough understanding of complex physics concepts, such as electric circuits.

Moreover, the study's findings highlight the importance of integrating cooperative learning strategies like the Jigsaw method into physics education. By shifting away from traditional teaching methods, the Jigsaw approach encourages active participation, teamwork, and hands-on learning, which significantly enhances students' ability to grasp challenging material. Future research could further investigate which aspects of the Jigsaw technique contribute most to these learning gains and how they can be refined for even greater effectiveness in the classroom.

4. CONCLUSION

This study set out to assess the effectiveness of the Jigsaw method in enhancing the conceptual understanding of electric circuit analysis among Form 1 science students. The findings demonstrate that the Jigsaw method significantly improves students' comprehension of electric circuits by fostering active engagement, cooperation, and participation in the learning process. Innovative and interactive teaching techniques, such as the Jigsaw method, capture students' attention and sustain their interest throughout lessons, making physics more enjoyable and ensuring active involvement. The study concludes that incorporating the Jigsaw technique into classroom instruction is instrumental in improving student performance, not only in electric circuits but also in science education as a whole. Practical applications of these findings include integrating cooperative learning strategies like the Jigsaw method into the national science curriculum, particularly in topics that students traditionally find challenging. Teachers could receive training on effective implementation of the Jigsaw method, ensuring that they can adapt this approach to suit diverse classroom environments and subjects. To build upon this study, further research could explore the long-term impact of the Jigsaw method on students' retention of knowledge and their performance in other areas of physics or science education. Additionally, future studies could examine how the Jigsaw method compares with other cooperative learning techniques, such as peer-assisted learning or group investigations, in fostering conceptual understanding. Research into the application of the Jigsaw method in different educational levels or subject areas, such as biology or chemistry, would also provide valuable insights into its broader effectiveness. Investigating the potential of digital tools to enhance the Jigsaw method could further improve its scalability and adaptability in modern classrooms. By leveraging cooperative learning approaches like the Jigsaw method, educators can create a more engaging and effective learning environment, ultimately fostering better academic outcomes and a deeper understanding of scientific concepts.

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