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A New Piece of the Puzzle: Deploying Technologically-Enhanced Jigsaw Method to Solve the Puzzle of Meaningful Learning in Biology

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Abstract This study explores the potency of Technologically Enhanced Jigsaw Method (TEJM) in breaking the barriers to meaningful learning of biology concepts. The explanatory sequential design was employed. A total of 102 secondary school (II) students from two randomly selected schools in Lagos State Education District V participated in the study. The Nervous Coordination Achievement Test (NCAT) which had a reliability coefficient of 0.76 was the instrument used to collect the quantitative data. Treatment lasted Four weeks after the conduct of the pretest, the experimental group was taught using Technologically Enhanced Jigsaw Method and the control group was taught using the conventional lecture method. One-way ANCOVA was employed to analyse the data. The students in the experimental group taught using Technologically Enhanced Jigsaw Method performed significantly better than their control group counterparts. Also, the students had a positive view towards the effectiveness of the Technologically Enhanced Jigsaw Method. Within the limitations of the study, we concluded that Technologically Enhanced Jigsaw Method is capable of promoting meaningful learning in biology. Based on the findings of this study, we recommended that the teachers should employ Technologically Enhanced Jigsaw Method for promoting meaningful learning of biology in contemporary and technology-driven societies. Implications of the study were highlighted.

Keywords: Secondary School/Introductory biology**,** Jigsaw method, Students' achievement, Technology

1. Introduction

Science education serves a greater purpose than simply transmitting knowledge; it is about empowering students to actively pursue knowledge and become independent learners. To do this, students need an immersive learning experience that encourages questioning, critical thinking, and active participation. Science subjects are taught at all educational levels in Nigeria, including primary, secondary, and tertiary institutions. They represent a significant component of the educational system. They equip students with the information and abilities necessary to pursue a career in many different sectors, such as, medicine, engineering, agriculture, and technology. Science subjects help to develop critical thinking, problem-solving, and analytical skills that are necessary for success in a wide range of careers. These skills are essential in fields such as engineering, medicine, and scientific research, as well as in other areas such as business, law, and public policy.

In Africa, the study of science at the senior secondary school level is typically divided into three main subjects: biology, chemistry, and physics. We chose to focus on the biology curriculum for several compelling reasons. Firstly, biology is the subject that most students, whether science-oriented or not, find the most interesting (Nwachukwu & Nwosu, 2007; Onowugbeda et al., 2022). Additionally, biology is a prerequisite for over 90% of post-secondary science professional and academic courses, including medicine, nursing, pharmacy, and zoology. Overall, biology is a crucial science subject in secondary school because it gives students a foundation for

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understanding the natural world, qualifies them for careers in healthcare and biotechnology, fosters an appreciation for the complexity and diversity of life, and helps them develop important life skills.

Despite the importance of biology, recent reports indicate that many students struggle to pass biology exams, with over 50% failing in 2018 and 2019 (Ojekwu & Ogunleye, 2020; WAEC, 2018-2019). This calls for urgent action to improve the teaching of biology and ensure that students have a deeper understanding of the subject. It is no secret that a teacher's approach to teaching has a profound impact on their students' interest and success in the subject. This is especially true at the secondary school level in Nigeria and other parts of Africa, where teachers are the gatekeepers to knowledge, and their teaching style can make or break a student's experience.

Over the years, researchers such as Adesope & Nesbit (2013), Bamidele & Ogunleye (2017), and Adam et al. (2022) have delved into this subject, and their findings have been crystal clear that teacher's approach to teaching is critical determinant of the quantity and quality of learning that students receive. It is no surprise then that for over two decades, the lion's share of research in Africa has been focused on improving students' performance in science and reversing the declining trend of students' interest in the subject. In this quest, the teaching approach that science teachers adopt has been a central point of focus. For Africa to produce the next generation of scientists, inventors, and innovators, it's imperative that science teachers embrace modern teaching approaches that stimulate curiosity, encourage critical thinking, and inspire a lifelong love for science. Only then can we unlock the full potential of our students and usher in a new era of scientific discovery and progress in Africa.

Sadly, in Nigeria, the traditional teaching method for science disciplines is still prevalent. The chalk-and-talk approach is a stale, one-sided process where teachers dominate, and students are relegated to passive observers. As a result, the classroom becomes a breeding ground for rote learning, where students memorize information without actually learning it. While it may be easier for teachers to stick to tradition, it's detrimental to students' academic development and often results in dismal performances during final exams (Yemi et al., 2018). In a world where information is readily available, it's no longer enough to spoon-feed students with facts; they need to develop the skills to think independently and critically (Oladejo et al.,2023). Therefore, it's time to ditch the old ways of teaching and embrace a more interactive and engaging approach that fosters curiosity and self-discovery. Only then can we unlock the full potential of our students and set them up for success in the ever-changing landscape of science and technology. To address this issue, we aim to explore the use of the jigsaw method, a type of cooperative learning strategy, to enhance students' active participation and academic achievement in biology. This approach has been identified as a practical way to assist students in learning better and has been shown to promote learning achievement in various studies (Abed et al., 2019;Yemi et al., 2018; Azmin, 2016; Ojekwu & Ogunleye, 2020).

Cooperative learning is an approach to education that puts students at the center of the learning process. Instead of a traditional teacher-centered approach, students work in small groups to help each other learn and succeed. The goal of cooperative learning is not just to improve academic performance but also to foster team spirit, accountability, and social cohesion (Muñoz-Martínez et al., 2020). There are many different types of cooperative learning strategies, each with its own strengths and weaknesses. These include Students Teams – Achievement Division (STAD), Team-Games-Tournaments (TGT), Jigsaw Method, Team Accelerated Instruction (TAI), Group Investigation (GI), Team Assisted Individualization (TAI), Cooperative Learning and Teaching Scripts (CLTS), Cooperative Integrated Reading and Composition (CIRC), Cooperative Learning Structures, and Complex Instruction (Frerejean, 2019). Out of all these approaches, the Jigsaw method has been shown to be particularly effective in improving academic performance (Yemi et al., 2018; Amedu, 2015; Ojekwu & Ogunleye, 2020), attitude (Azmin, 2016; Olukayode & Salako, 2014), and laboratory skills (Aydin & Biyikli, 2017; Yoruk, 2016). It has no gender effect, making it an inclusive approach that benefits all students (Ibemenji et al., 2019; Yoruk, 2016). In addition to improving academic performance, the Jigsaw method also helps students retain knowledge better (Abed et al., 2019). By emphasizing active participation and teamwork, the Jigsaw method empowers students to take charge of their learning, work together to overcome challenges, and achieve success as a team.

The jigsaw strategy is like a puzzle that brings students of different abilities, ethnic backgrounds, races, and genders together, in a collaborative effort to solve a complex problem. It's like a recipe that mixes all the ingredients to create a delicious dish. In the jigsaw method, students work together in a supportive environment where they can depend on each other to succeed. This method allows students to not only learn the subject matter but also develop valuable skills such as teamwork, communication, and critical thinking (Ojekwu & Ogunleye, 2020). It is like a secret formula that unlocks the potential of each student, allowing them to contribute their unique abilities to the group. Just like how each piece of a puzzle is essential for the final image to be complete, every student in the group is critical for the whole concept to be fully understood. Furthermore, the jigsaw method promotes diversity and reduces racial segregation. In the end, students develop a sense of social cohesion and mutual respect for each other's abilities and differences (Durmus, 2008). According to Francis (2013), the jigsaw teaching method has multiple advantages over traditional teaching methods. One of the key benefits is that teachers find it easy to use since they are not the sole source of knowledge, making it a breeze to implement. Additionally,

jigsaw can be easily combined with other teaching methods (Olukayode & Salako, 2014), making it an all-star player in the teaching world. However, Francis (2013) notes that there are also some potential obstacles associated with the jigsaw technique. One such issue is student dominance, which can be mitigated by assigning a leader for each jigsaw group. Students quickly learn that the group is more effective when everyone is allowed to present their material before questions and comments are made, which reduces issues of dominance. As shown in Figure 1, the jigsaw method is characterized by positive interdependence, face-to-face communication, individual accountability, social skills, and group processing.

Fig. 1: Characteristics of the jigsaw method

On account of the technology flavor of the Jigsaw method, a survey of the findings from several works of the literature suggests that learners have access to YouTube, Wikipedia resources, WhatsApp, Facebook, and other technology-related resources for their online activities regularly (Al-Adwan et al., 2013), suggesting to the study to utilise these technologies to enhance the Jigsaw method. With students already utilizing resources like YouTube, Wikipedia, WhatsApp, and Facebook regularly, incorporating these technologies into the Jigsaw method seems like a natural fit. By using technology to promote meaningful learning, students are able to benefit from their pre-existing interest in contemporary technological devices, as noted by Okebukola (2020). After all, in today's classroom, technology is just as present as the teacher and students themselves, acting as a mediator for the teaching and learning process. TEJM takes advantage of this by requiring students to conduct their own online research on the topic at hand before class. This empowers them with a more comprehensive understanding of the subject matter and prior knowledge to build upon, a concept supported by Ausubel's theory of meaningful learning. With this method, the knowledge gained from online research serves as advanced organizers that can propel students towards their zone of proximal development (ZPD), which is thought to facilitate meaningful learning.

The Jigsaw method has witnessed some studies to test its efficacy in many subject areas. For instance, Nwankwo & Okigbo (2021) investigated the impact of the Jigsaw method on students' performance in chemistry, and found that it led to significant improvement in achievement and knowledge retention. This finding was consistent with previous research by Azmin (2016). Similarly, Olukayode & Salako (2014) reported that the jigsaw technique resulted in better academic performance, as students in the experimental group outperformed those in the control group. These findings suggest that the jigsaw method should be used in combination with other teaching methods to promote unity and peaceful co-existence among students. By supplementing traditional teaching methods with the Jigsaw technique, educators can create a more collaborative and engaging learning environment that benefits all students. A similar trend was found in (Ojekwu & Ogunleye, 2020; Yemi et al. 2018; (Abed et al. 2019). These researchers tested the potency of the Jigsaw method in improving students' performance in perceived difficult science concepts and, in turn, stimulating students' interest in science fields. All these studies attest to the potency of the Jigsaw method in improving students' achievement, knowledge retention, and interest in science.

Despite the increasing body of literature on the efficacy of the Jigsaw method in improving students' academic performance, there is a lack of research on combining the Jigsaw method with other teaching methods, particularly technology-based methods. This lack of research is particularly evident in the area of enhancing the Jigsaw method with technology. This scarcity precludes school teachers from employing potent hybrid teaching methods to break the barrier of difficult concepts and foster meaningful learning of biological concepts. Therefore, the aim of this study is to explore the impact of a TEJM on students' achievement in nervous system, a topic that has consistently been identified as challenging for students to learn over the past decade (Okebukola, 2020; Onowugbeda et al., 2022). By investigating the effects of a TEJM this study seeks to provide valuable insights into how educators can use technology to augment the effectiveness of the Jigsaw method and improve learning outcomes for students. Thus, this study was guided by two research questions and one hypothesis:

a. What impact does Technologically-Enhanced Jigsaw method (TEJM) have on students' achievement in biology?
b. what are the views of students on the effectiveness of the Technologically-Enhanced Jigsaw method (TEJM) method?

Hypothesis
There is no statistically significant difference in the achievement of students taught using TEJM and lecture method.

2. Materials And Methods

This study employed explanatory sequential design. The quantitative approach employed the pre-test, post-test non-equivalent quasi-experimental research design. This approach was used because the researchers could not assign individuals to groups at random at the time of data collection since the school authorities did not consent. While the qualitative approach employed a semi-structured interview schedule to seek the views of students on the effectiveness of the TEJM. The population for the study comprises all biology students in senior secondary schools in Educational District V, Lagos State, Nigeria. The Lagos State Educational District V is part of the six Educational Districts in Lagos State, Nigeria, under the control of the Teaching Service Commission (TESCOM). A total of 102 students participated in this study. This sample was drawn from two randomly sampled public schools located in different education zone with relatively similar characteristics in terms of teacher's (biology) qualification, school facilities, students' population, and location (urbanisation). An intact biology class in one of these schools was used for the experimental group while the other school represents the control group. The experimental group consisted of 56 students (20 boys and 36 girls), while the control group had 46 students (22 boys and 24 girls). The mean age of the students was 15 years. Senior secondary two students (equivalent of grade 11 in the American education system) were considered appropriate for this study on the basis on their exposure to basic principles of biology concepts and learning of some contents, which serves as a prerequisite for this study. Moreover, the students have a fairly stable teaching and learning environment as they are not preparing for the WAEC and NECO examinations. Also, from the structure of the syllabus and general school calendar, they have not been exposed to the concept used in this study (Nervous Coordination) at the time it was conducted (2nd term of SSS 2). Still, they should have gained some requisite knowledge.

The Nervous Coordination Achievement Test (NCAT) was employed to gather the data needed for the study. The instrument had two sections; section A focused on the demographic details of the participants while section B contained 25 discrete items (multiple choice questions) with four options lettered A-D. Each item had three distractors and one key. The Items were constructed using the revised Bloom's taxonomy (Wilson, 2016) of educational objectives for its table of specifications and following the 20-golden rule for multiple-choice questions (Okebukola, 2015). We ensured that the items were almost evenly distributed across the cognitive process dimension and each item carried an equal score weight.

To ensure the validity of the instrument used in this study, face and construct validity was conducted by two experienced biology teachers, a science educator and an English language teacher. Based on their comments and suggestions, six items were restructured and the time allocation was increased from 20 to 25 minutes. These steps were taken to ensure that the instrument accurately measured what it was intended to measure. The careful attention that was given to the validation of the instrument was purposefully tailored toward ensuring sound reliability. The split-half reliability test of the instrument yielded a coefficient of 0.76 which falls between the acceptable range of 0.70 to 0.80 that most instruments used in educational research are benched against (Mohajan, 2017).

2.1 Data Collection

Permission was sought from the authorities of the participating schools and students' consent to voluntarily participate in the study was also cleared with an understanding that they are free to withdraw their interest at any point during the study. The teacher introduced himself and asked the students to do the same. The pretest was first administered to both groups to determine the initial performance of the students. The experimental and the control groups receive the same lesson contents on nervous system for the same lesson periods (45 min × 3 days) per week. However, the experimental group was exposed to the TEJM, while the control group was taught using the conventional lecture method. The intervention lasted for 4 weeks.

The teacher for the experimental class was trained for a week on how to implement the TEJM after which he was subjected to a microteaching session to evaluate his mastery of the approach before the commencement of treatment. The experimental group was taught following the five-step procedure for implementing the TEJM at every lesson:

Step One: The initial phase of implementing the TEJM occurred prior to the class session, whereby the teacher notified the students of the topic (Nervous system) to be studied in advance. Each student was then instructed to utilize their mobile phones or other internet-connected devices to conduct online research, such as watching

relevant YouTube videos and studying online materials, pertaining to Nervous system. This forms the technology flavour of the jigsaw method.

Step two: The lesson commences in the class with the introduction of the topic by the teacher. The material on nervous system was divided into 4 sections with guiding questions. The teacher organized the students into groups based on mixed ability and mixed sex, each with a maximum of five students. This group is called the home group. Within each home group, each student was assigned a specific section of the topic to focus on and read as shown in Table 1.

Table 1: Sections of topics assigned to individual students in the home groups

Group one	Section assigned
Pseudo name- Mary	The brain
Pseudo name- Imran	The Spinal Cord
Pseudo name- Nelson	Neuron
Pseudo name- James	Reflex and voluntary actions
Pseudo name- Amaka	Periphral Nervous System

Step three: After the reading, students who had focused on the same section of the material formed expert groups to discuss and deliberate on their findings. The teacher provided guiding questions to facilitate the discussion within each expert group. During the discussion, each member took notes on the key points discussed so they could later teach their respective home group. Whenever a problem arises, students try to find their own solution before seeking help from the teacher.

Step four: After the expert group discussion, students returned to their respective home groups to share and teach their findings to each other. The purpose of this was to support and help one another to master the material to the best of their ability. Subsequently, the teacher led a brief whole-class discussion to clarify any doubts and to provoke further discussion of the topic based on the interactions that occurred within each home group.

Step five: Then students took individual quizzes, and their scores contribute to the team score using the improvement score system. After completing the quiz, students exchange papers and grade each other's work using an answer sheet provided by the teacher. Each student's score is then recorded in the test score column of the group score sheet. The test scores are then computed as improvement scores by comparing them to each student's base score, which reflects their past performance. The group with the highest average group improvement score is rewarded, and any groups that reach a predetermined improvement score level also receive a reward.

At the end of the week four lesson, a post-test was administered to both groups. The test was conducted with careful attention to ensure no observable differences in the process for the two groups, particularly regarding the allotted time, supervision, and students' willingness to take the test. The classroom atmosphere was designed to be free from distractions and arranged in a manner to minimize boredom and fatigue, ultimately aimed at improving the reliability of the test. A total of 8 students randomly selected from the experimental group (4 males & 4 females) were interviewed on their views on the perceived impact of the methods on their learning of nervous system using the Students' Perception About TEJM Interview Guide. The students' consent to participate in the interview were sought following the permission from the school's authority. They were assured that there are no right or wrong answers to any of the questions and that whatever information they provide will be treated confidentially and used for academic purposes only. The qualitative data were analysed using structured coding (i.e., framework analysis) which afforded us a robust discussion of the results from the quantitative data.

2.2 Ethical considerations

Before the commencement of the study, the consent of relevant authorities of the schools (principals of public schools and, in some cases of private schools, the proprietor) involved in our study was sought for permission to carry out the study in their schools. Also, the research team ensured that all participants consented to participate in the study by signing a consent form on the answer booklet. The study's objectives were fully communicated to the participants while they were assured that their responses were treated as confidential and used only for research purposes. We reassure participants and school authorities of their voluntary participation in the research, which requires them to be free to withdraw from the study at any point and for any reason possible. Apart from the above, respondents were not harmed or abused, physically or psychologically, during the research

3. Results

The analysis followed a step-by-step procedure with the test of the parametric assumptions coming first before we applied the ANCOVA statistic on the data. The Shapiro−Wilk's test of normality showed that the participants for this study were not significantly different from a normal population: experimental group [(N = 56) = 0.18; p >

0.05] and the comparison group [(N = 46) = 0.13; p > 0.05]. The Levene's test (test of homogeneity) also confirmed the two groups were not significantly different from one another (F = 0.10; p > 0.05). Having met these assumptions, we applied the one-way ANCOVA statistic on the achievement scores of the students in the two groups, using the scores generated from the achievement test as the dependent variable, the teaching methods as the fixed factor, and the pretest scores as the covariate.

Research question one

What impact does Technologically-Enhanced Jigsaw Method (TEJM) have on students' achievement in biology? The results in Table 2 expressed the difference in the mean scores of the participants in the experimental groups (M= 19.55, SD=5.35) and control group (M=14.33, SD= 3.73). To determine whether the effect is significant the hypothesis one was tested.

Table 2: Mean and standard deviation of achievement test scores of the two groups

Group	Mean	Std. Deviation	N
Experimental group	19.55	5.35	56
Control group	14.33	3.73	46
Total	17.20	5.35	102

Hypothesis: There is no statistically significant difference in the achievement of students taught using TEJM and lecture method

At 95%confidence level and with the statistical tool having adjusted for any initial difference using the pre-test achievement scores, the result of the one-way ANCOVA in Table 3 revealed that a statistically significant difference exists in achievement of the students in the experimental and the control groups. [F (1, 99) = 31.05; p < 0.05]. This implies that there is strong evidence to suggest that the experimental treatment had a significant impact on the students' achievement, beyond what could be attributed to chance or other factors.

Table 3: Ancova summary table of difference in the achievement of the two groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	901.941[a]	2	450.97	22.389	.000
Intercept	1104.354	1	1104.35	54.826	.000
PRETEST	211.810	1	211.81	10.515	.002
GROUP	625.379	1	625.37	31.047	.000
Error	1994.138	99	20.14		
Total	33058.000	102			
Corrected Total	2896.078	101			

a. R Squared = .311 (Adjusted R Squared = .298)

Research question two

What are the views of students on the effectiveness of the Technologically Enhanced Jigsaw (TEJM) method?

Table 4: Responses from selected students on their views about TEJM.

Students ID	Unedited responses
Pseudo name- Mary (15years old)	I am particularly drawn to the grouping aspect. The way in which students are organized and encouraged to collaborate with one another creates a dynamic learning environment that I find truly fascinating.
Pseudo name- Imran (16years old)	As a group leader, at first, I was afraid to speak in class as I had no prior experience. So, I watched YouTube videos and discussed lessons with my mom to help my group perform well. I wish other teachers would use this method too.
Pseudo name- Nelson (15years old)	I really enjoyed doing group work because it was cool to see how everyone approached the assignments differently. I got to learn a lot from each group and it helped me understand the material better overall.

Pseudo name- James (14 years old)	To be honest, what caught my attention the most was when we were asked to research a specific topic. Doing the research helped me get a better understanding on the subject matter and I learned a lot more about it than I would have just from reading a textbook.
Pseudo name- Amaka (16 years old)	I understand the topic better because my classmates were the ones teaching me, making it easier for me to understand and contribute to the discussion. Additionally, they used simple language, which made it easier for me to ask questions and follow along with the lesson.
Pseudo name- Kaother (18 years old)	Honestly, I think this teaching method is good because It keeps things interesting and I love how we had the group discussions. I've learned so much from my classmates and it's just really fun.
Pseudo name- Bola (17 years old)	I really liked the group work and it made it way more interesting than if we just had to read some boring textbook. Plus, since we were all experts in our own areas, we were able to teach each other and get a better understanding of the topic overall.
Pseudo name- Gbenga (14 years old)	The group work made the classs more interesting. It was also a lot easier to get everything done when we had everyone's help. Since we all had our own specialties, we were able to learn from each other and become experts on the topic overall.

The summary of our findings on the second research question shows that the students consider TEJM a better approach to learning biology and they also confirmed to us that it aided their understanding of the nervous system concepts taught in class (see table 4). Notably, majority of the interviewees considered the YouTube videos, and class group activities as the most impactful aspects of the approach when asked during the interview that "which aspect of the approach did you find most interesting and helpful in your understanding of the topics and why?

4. Discussion

Based on the analysis conducted on research question one, it was found that the students taught with the TEJM performed better than those taught using the conventional lecture method.Flash back on literature shows that the findings corroborated the findings of Namaziandost et al. (2020); Nwankwo & Okigbo, (2021); Yemi et al. (2018); Akkus & Doymuş, (2022), who reported that students taught using Jigsaw method performed significantly better than their counterparts taught using the conventional lecture method. This result also finds semblance with the findings of Onuocha et al. (2021) who revealed that the achievement of students taught social studies using the jigsaw method was significantly better than those taught using the conventional teaching method. Invariably, these findings show the effectiveness of jigsaw teaching strategy as a method for enhancing academic achievement regardless of the subject matter and level of class.

The result obtained in this study is an addition to the body of knowledge that suggests that TEJM can promote students' learning. It can be argued that the improvement in the performance of students taught using the TEJM was a result of the pre-lesson assignments given to the experimental group before each lesson. By completing these assignments, the TEJM students came to class fully prepared and armed with a wealth of knowledge gleaned from the YouTube videos that were related to the subject of the nervous system. The positive impact of engaging with a more knowledgeable source (in this case, the YouTube videos) and the utilization of advanced organizers, as espoused by Vygotsky and Ausubel, appear to have manifested in the students' improved performance. Based on the students' responses to the interview questions, it can be inferred that watching the online videos made a significant contribution to their improved performance.

The group discussions may also have played an important role since students are said to learn easily and without fear from one another (Okebukola et al., 2016). By scaffolding one another during the group discussion, students not only shared knowledge but also fostered a sense of teamwork, enabling average and low-performing students to keep up with their more advanced peers and operate within their zone of proximal development (ZPD), as observed by Adam et al. (2021)&Oladejo et al. (2022). This ZPD concept, as defined by Vygotsky, represents the gap between a student's current level of development and their potential level of development when collaborating with more capable peers or under adult guidance (Bekiryazıcı, 2015). Collaboration, rather than unhealthy competition, was a key factor in facilitating meaningful learning in the TEJM group. This approach stands in stark contrast to the conventional teaching methods used in the control group, where teaching and learning

were confined to the classroom, the teacher dictates what the students learn, and the students were prevented from collaborating and interacting.

The technology component of the TEJM was an active ingredient contributing to learners' success. The assertion by Okebukola (2020) that a typical classroom in any corner of the world today consists of the teacher, the learners, and technology also confirms that technology as a mediator in the teaching and learning process is never silenced. In the TEJM, the students were required to surf the web for relevant knowledge on the topic to be taught. The internet served as a portal for the students to gather advanced organizers, which acted as a beacon, leading them to their zone of proximal development (ZPD). This zone is where the magic happens, where learning is catalyzed and propelled to new heights, as students stretch beyond their limits to grasp new knowledge. The theory of Ausubel backs this positive contribution. Ausubel (1961) demonstrated the importance of prior knowledge in learning new concepts. The TEJM provides a shining example of how technology can be harnessed to supercharge learning, providing students with an immersive and captivating learning experience that stimulates their minds and expands their horizons.

On the other hand, the result of the current study contradicts the submission of Nusrath et al. (2019) who found no statistically significant difference in the achievement of students taught using the jigsaw strategy. This difference may be attributed to factors such as teaching strategy, time and location.

While noting the challenge of generalisability on account of sample size, the findings of this study can contribute significantly to the growing body of empirical evidence that supports hybrid teaching methods such as TEJM as an effective way to overcome obstacles in students' learning of difficult science concepts. Science teachers in Africa and beyond can now wield TEJM as a powerful tool to infuse technology into their pedagogy, ensuring enhanced student performance in traditionally difficult subjects. The study also highlights the potential of TEJM in the post-COVID-19 era, where virtual learning and technology are increasingly prevalent. Policymakers, educators, parents, students, and other stakeholders may find the study valuable in breaking down barriers to student learning. The study emphasizes that utilizing TEJM can be a beneficial way to teach and learn science within a technological environment.

5. Conclusion

The primary assumption of this study was that meaningful learning of nervous system concepts in biology would be promoted when students are exposed to learning with the TEJM. Our findings further validate the potency of TEJM in breaking barriers to meaningful learning of science. These results are consistent with similar studies within and beyond Nigeria and align with Vygotsky's theory of social interaction as a powerful tool for effective learning. Through the lens of our study, we can safely infer that the integration of TEJM can lead to a more successful science education system. Thus, we confidently assert that TEJM is a viable and potent teaching approach for promoting meaningful science learning in contemporary and technology-driven societies.

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