

## **Constructivist based Digital Game Learning Environment: Trajectory towards enhancing upper primary science learners' performance in Energy transformation concepts**

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### **Abstract**

*The need for a digital and innovative teaching approach arises from its ability to enhance learner engagement, foster critical thinking, and prepare learners with the skills especially in the upper primary school required as a baseline in a technology-driven society. This study therefore seeks to investigate the effectiveness of a constructivist-based Digital Game-Based Learning (DGBL) environment in enhancing upper primary school learners' performance energy transformation concepts. Two research questions raised and two Hypotheses were tested for the study. Quasi-experimental research design, using a non-randomization pretest-posttest experimental control groups was employed for the study. A sample size of 247 upper primary (5) learners using the purposive sampling was selected. The instrument for data collection was the Energy transformation Performance Test with a reliability index  $r = 0.91$ . Data obtained for the study were analyzed using frequency count, mean and standard deviation specifically for the research question while the Analysis of Variance (ANCOVA) was used to test the hypotheses at 0.05 level of significance and a Post Hoc test of Least Significant Difference (LSD). The findings of the study indicated that learners exposed to the constructivist-based DGBL strategy (performance = 79.1%, retention = 19.7%) demonstrated considerably greater gains in performance and retention compared to their counterparts taught through traditional methods (performance = 30.7%, retention = 14.6%). The results revealed a significant main effect of instructional method on performance,  $F(1, 245) = 88.01, p < .001, \eta^2 = .26$  and a significant effect of instructional method on retention,  $F(1, 245) = 44.53, p < .001, \eta^2 = .15$ . Science teachers should undergo continuous professional development to strengthen their technical and pedagogical capacity for integrating constructivist digital game resources into instruction, curriculum developers and policymakers incorporate constructivist digital game-based learning into upper primary science curriculum to improve learners' comprehension and retention of abstract concepts among others.*

**Keywords:** Constructivist, Digital Game Learning, Learners, Science, Upper Primary

## Introduction

Upper primary science teaching and learning plays a vital role in equipping learners with foundational scientific literacy, which is essential for understanding the natural world and solving real-life problems. At this stage, learners are introduced to basic concepts in physics, chemistry, and biology that serve as the building blocks for more advanced studies. Science education at this level not only emphasizes knowledge acquisition but also develops inquiry skills, critical thinking, and curiosity about everyday phenomena (Achor et al., 2021). By engaging learners in hands-on and minds-on activities, upper primary science helps them to make sense of their immediate environment and prepares them for active participation in a technology-driven society (Okebukola, 2020). Science teaching and learning in Upper primary is crucial for providing students with essential scientific literacy, which is necessary for the understanding of the natural world and addressing real-life challenges. During this phase of science learning, learners are introduced to fundamental concepts in physics, chemistry, and biology that act a baseline for more advanced studies. Science teaching and learning at this level not only focuses on the acquisition of knowledge but also fosters inquiry skills, critical thinking, and a sense of curiosity regarding everyday occurrences (Aderonmu & Adolphus. 2023). By involving learners in both hands-on and minds-on activities, studies in upper primary science enables them to understand their immediate surroundings and equips them for active engagement in a technology-oriented society (Fior, 2025).

Evidently, science learning in upper primary school also provides the background for the cultivation of scientific attitude and problem solving essential for national development. Learners who develop scientific literacy at an early age are more equipped to grasp intricate ideas in secondary education and thereafter. Research indicates that early exposure to scientific concepts improves students' ability to utilize knowledge in different situations, encourages continuous learning, and fosters innovation (Jegade & Oyedeji, 2022). Therefore, enhancing science learning during this crucial phase is essential for cultivating a generation that can tackle societal issues through scientific reasoning and well-informed decision-making.

Understanding of the concepts of energy transformation is essential for cultivating scientific literacy, as it allows students to explain natural occurrences and technological mechanisms in their daily lives. Ideas such as the conversion from potential energy to kinetic energy, or the transformation

of light energy into heat energy, lay the baseline for understanding the operation of machines, electrical devices, and biological systems. Achieving mastery in these concepts is vital not only for success in sciences but also for enhancing problem-solving abilities that can be utilized in practical situations, including energy conservation and sustainable development (Nwosu & Okeke, 2021). An early understanding of energy transformation provides students with the capability to link theoretical concepts to real-world applications, thus fostering enthusiasm for STEM-related disciplines. Despite its significance, the concept of energy transformation is frequently perceived as abstract and challenging for upper primary students. This challenge stems from the fact that many students find it difficult to conceptualize energy as an invisible force that transitions between various forms, particularly when these transformations are not readily observable (Adegboye & Ogunleye, 2020). Misconceptions, such as the notion that energy is "used up" instead of being transformed, often impede learners' comprehension of the concept. Furthermore, the dependence on teacher-centered methodologies that prioritize rote learning over exploration and experimentation restricts students' capacity to grasp the concepts effectively (Cairns & Long, 2025). These obstacles highlight the necessity for innovative, interactive, and constructivist approaches such as the digital game-based learning that can render abstract energy concepts more tangible, engaging, and relevant.

In Nigeria, science teaching is predominantly reliant on lecture-based, teacher-centered strategies, where the teacher serves as the primary source of information and learners are merely passive recipients. Instruction typically focuses on rote memorization of scientific facts, definitions, and formulas, rather than encouraging inquiry, experimentation, or problem-solving (Komen et al., 2025). Although this method may assist students in recalling information for tests, it seldom cultivates critical thinking, creativity, or a profound understanding of concepts. Consequently, abstract ideas such as energy transformation are presented in a manner that separates theory from practical applications, resulting in students developing misconceptions and a superficial grasp of knowledge. The absence of learner-centered activities, along with inadequate instructional resources, restricts opportunities for engagement, exploration, and the development of meaningful scientific understanding (Abdullahi & Ibrahim, 2020).

In contrast, learners centered approaches place emphases towards the learners; their requirements, their learning processes, and the environment in which they acquire knowledge. Central to this transition are practices such as active learning, formative assessment, personalized instruction, collaboration, and opportunities for students to reflect, make decisions, and participate in self-regulated learning. For instance, Schendela et al., (2023) illustrated how learner-centered pedagogy prioritizes critical thinking, problem-solving, and skills for lifelong learning, transcending the conventional teacher-centered model. Likewise, in distance-learning settings, the combination of technology with learner-centered strategies has been demonstrated to enhance student engagement and adaptability. Several research scholars have identified benefits of the learner-centered approach which are;

1. Encourages Active Participation: Learner-centered methodologies establish interactive settings in which learners actively participate in the construction of knowledge instead of merely being passive recipients. This involvement enhances comprehension and promotes the long-term retention of educational outcomes (Ahmed et al., 2022).
2. Enhances Critical Thinking and Problem-Solving Skills: By emphasizing inquiry and real-life application, learner-centered teaching enables learners to develop critical thinking and problem-solving competencies, which are often limited in teacher-centered classrooms (Gcabashe, 2024).
3. Supports Autonomy and Self-Regulated Learning: In learner-centered environments, students assume responsibility for their own learning, thereby enhancing their capacity to establish goals, monitor their own progress, and reflect on their achievements. Aderonmu and Abraham (2021) discovered that these contexts greatly enhance self-regulated learning strategies.
4. Promotes Collaboration and Communication: Engaging in group activities and peer interactions within learner-centered methodologies fosters collaboration, teamwork, and communication abilities, equipping learners for the requirements of both academic settings and the workplace (Yi, 2016).
5. Enhances Motivation and Personal Significance: When education is customized to meet the needs and experiences of learners, learners exhibit increased motivation and involvement. Recent research in higher education emphasizes that learner-centered teaching renders

content more significant and promotes attitudes conducive to lifelong learning (Ahmed et al., 2022).

In recent years, advancements in digital technology have significantly transformed the educational landscape, providing new tools and methodologies to enhance both teaching and learning. Technologies such as e-learning platforms, virtual simulations, mobile learning, and artificial intelligence have broadened access to information and fostered more interactive and engaging environments for students. These innovations are in line with global demands for 21st-century education, which prioritizes creativity, critical thinking, collaboration, and problem-solving (Hermann & Allison, 2022). By incorporating digital tools into their teaching practices, educators are progressively shifting from traditional rote learning to more dynamic, student-centered methods that promote deeper understanding and skill development.

Among these innovations, Digital Game-Based Learning (DGBL) has emerged as a particularly powerful tool. Digital game-based learning (DGBL) has transitioned from being merely as an incentive augmentation to a deeply grounded pedagogical landscape that resonates in several spectrums of research activities that facilitates active, contextual and social knowledge construction, a roadmap to constructivist theory. Hadwen-Bennett and Economou (2019) stated that the evolving position of Digital Game Based Learning (DGBL) as transcend from mere entertainment to edutainment that emphasizes the progressive development of cognitive structures and learner's mental models. DGBL integrates educational content into digital games, combining the motivational aspects of play with structured learning objectives. Unlike traditional methods that often prioritize memorization, DGBL engages learners through interactivity, feedback loops, and immersive environments that stimulate curiosity and persistence (Fiorella, 2018). By embedding learning goals within game mechanics, learners acquire knowledge and skills in a manner that feels meaningful and enjoyable, thereby bridging the gap between entertainment and education.

Constructivism is a theory of learning that highlights the active participation of learners in the creation of their own knowledge by connecting new information with their previous experiences. Okoli and Eze (2022) asserted that constructivism emphasizes the importance of collaboration and social interaction in the process of knowledge construction, wherein learners

collaboratively create meaning through dialogue, peer learning and guided discovery. Instead of perceiving learners as mere passive recipients of information, constructivism views learning as a process of inquiry, reflection, and meaning-making influenced by learners' interactions with their surroundings (Achor & Orji, 2021). In the context of science teaching and learning, this methodology shifts the emphasis from rote memorization to exploration, enabling learners to partake in both hands-on and minds-on activities that enhance their understanding. For example, when learners are encouraged to experiment with or simulate real-life situations involving energy transformation, they actively construct concepts that become more significant and enduring. This theory holds particular significance for upper primary science learners as it connects abstract concepts with everyday experiences, thus rendering science more relevant and engaging. By placing learners at the core of the educational process, strategies informed by constructivism assist in addressing prevalent misconceptions, enhancing critical thinking, and nurturing scientific problem-solving abilities that transcend the classroom (Adeyemi, 2023).

The constructivist approach aligns strongly with the use of Digital Game-Based Learning (DGBL), as both emphasize active participation, exploration, and knowledge construction. In a game-based environment, learners are not merely passive observers but take on roles that require decision-making, problem-solving, and experimentation. These interactive experiences provide opportunities for learners to test their ideas, receive immediate feedback, and refine their understanding, which are key principles of constructivist learning (Okeke & Nwachukwu, 2022). By engaging learners in meaningful tasks within virtual simulations or games, DGBL offers a constructivist-driven platform where abstract science concepts can be made concrete and more accessible. Qian and Clark (2016) noted that a more nuanced understanding of the relationship between constructivist pedagogy and game design can ensure that DGBL moves beyond being a motivational tool to becoming a legitimate medium for deep, meaningful learning. Simplified steps required in using a constructivist approach with DGBL to enhance academic performance include;

1. Identify Learning Objectives: Begin by aligning the digital game with specific curriculum goals. This ensures that the game experience goes beyond entertainment and directly supports academic achievement.

2. **Select or Design Appropriate Games:** Choose games that promote exploration, inquiry, and problem-solving in authentic contexts. Games should challenge students to apply knowledge actively rather than passively consume content.
3. **Integrate Scaffolding and Guidance:** Provide hints, feedback loops, or structured challenges within the game to guide students through complex tasks. Scaffolding helps learners gradually build mastery while maintaining engagement.
4. **Facilitate Collaboration and Interaction:** Encourage group play or peer-to-peer collaboration, allowing students to share ideas, solve problems collectively, and construct knowledge socially which is the core to constructivist learning.
5. **Encourage Reflection and Assessment:** After gameplay, engage students in reflective discussions, journaling, or peer review to help them analyze strategies, connect experiences to prior knowledge, and transfer learning beyond the game context.

When utilized in upper primary science teaching and learning, especially in the context of teaching energy transformation, constructivist-based Digital Game-Based Learning (DGBL) offers an innovative approach to overcoming persistent learning challenges. For instance, digital games can illustrate how potential energy is converted into kinetic energy through everyday examples, such as a ball rolling down a hill, or how light energy is transformed into heat energy when absorbed by various materials. These visual and interactive experiences enable learners to link abstract concepts with real-world situations, thus addressing prevalent misconceptions and improving conceptual comprehension (Adebayo & Yusuf, 2023). By placing learners at the forefront of the educational process, constructivist-driven DGBL not only enhances understanding of energy concepts but also fosters curiosity, engagement, and the long-term retention of scientific knowledge.

### **Statement of problem**

Despite the acknowledged significance of science teaching and learning in fostering foundational scientific literacy, numerous upper primary learners still face challenges in comprehending energy transformation concepts. Abstract notions, such as the shift from potential to kinetic energy or the conversion of light energy into heat, are frequently difficult for young learners to visualize and connect with their daily experiences. Research indicates that these

challenges are enduring, resulting in misconceptions like the belief that energy is 'used up' instead of transformed. Such misconceptions not only impact learners' immediate understanding of science but also obstruct their capacity to build upon these concepts in advanced educational settings.

The issue is further exacerbated by the ongoing dependence on traditional teacher-centered approaches in Nigerian classrooms and similar environments. Instruction is often characterized by rote memorization, lecture-based teaching, and an emphasis on examination performance rather than on conceptual comprehension. Consequently, students frequently underperform in science evaluations and lack the critical thinking abilities essential for applying scientific principles in real-world situations. Evidence indicates that when abstract ideas like energy transformation are taught without interactive or experiential learning methods, students retain only superficial knowledge and continue to demonstrate misconceptions that persist throughout their educational journey.

In light of these challenges, there is a distinct necessity to investigate innovative instructional methods that enhance the engagement, interactivity, and significance of science teaching and learning. A constructivist-oriented Digital Game-Based Learning (DGBL) environment presents such an opportunity by enabling learners to actively build knowledge through exploration, experimentation, and problem-solving within gaming contexts. By offering visual simulations and interactive feedback, DGBL can assist learners in gaining a deeper understanding of energy transformation processes while rectifying misconceptions and enhancing academic performance. This integration not only corresponds with global trends in science education but also tackles local challenges, thereby equipping learners for improved success in science and greater preparedness for future STEM endeavors.

### **Aim and objectives of the study**

The aim of this study is to investigate the effectiveness of a constructivist-based Digital Game-Based Learning (DGBL) environment in enhancing upper primary school learners' performance energy transformation concepts. Specifically, the objectives of the study are to;

1. determine upper primary school learners' pretest and posttest mean performance in the concept of Energy Transformation when taught

with Constructivist Approach using Digital Game-Based Learning and those taught with the traditional teaching method.

2. investigate upper primary school learners' mean retention level on the concept of Energy Transformation when taught with Constructivist Approach using Digital Game-Based Learning and those taught with the traditional teaching method.

### **Research Questions**

The following research questions were raised for the study.

1. What is the difference between upper primary school learners' pretest and posttest mean performance in the concept of energy transformation when taught using the constructivist approach with Digital Game-Based Learning and those taught using the traditional teaching method?
2. What is the difference in the mean retention level of upper primary school learners on the concept of energy transformation when taught using the constructivist approach with Digital Game-Based Learning and those taught using the traditional teaching method?

### **Hypotheses**

The following null hypotheses were tested at 0.05 level of significance.

**H<sub>01</sub>:** There is no significant difference between upper primary school learners' pretest and posttest mean performance in the concept of energy transformation when taught using the constructivist approach with Digital Game-Based Learning and those taught using the traditional teaching method.

**H<sub>02</sub>:** There is no significant difference in the mean retention level of upper primary school learners on the concept of energy transformation when taught using the constructivist approach with Digital Game-Based Learning and those taught using the traditional teaching method.

### **Methodology**

The research design employed for the study was the quasi-experimental research design, using a non-randomization pretest-posttest experimental

control groups. The population of the study comprised of 3,611 (Basic 5 learners) in upper primary schools (Schools records, 2025) in Ijebu-Ode Local Government Area of Ogun State, Nigeria. Using a purposive sampling technique, 247 Basic 5 learners in upper primary schools were selected for the study. Two schools were used for the study and four intact classes were employed in all having two in each school.

**Table 1:** Showing sample size of learners for the study.

School	Group	No. of Male	No. of Female	Total
A	Experimental Group (CGBL)	61	57	118
B	Control Group (TTM)	58	71	129
<b>Total</b>		<b>119</b>	<b>128</b>	<b>247</b>

**Source:** Researchers' field work, 2025.

The instrument for data collection developed by the researchers was titled "Energy transformation Performance Test" (ETPT). Energy transformation Performance Test consisted of 20 short fill-in-the-blank objective questions on the concept of Energy Transformation (Sun and Plants, Home and Community, electricity and Machines) which is suitable for Basic 5 (Upper Primary School) level and are aligned with the Upper Primary School curriculum. In scoring, each test item is scored 5 marks making a total of 100 marks that is equivalent to 100%. Other instruments developed included the Instructional Lesson packages of;

*(1) Constructivist Game Based Learning that has*

1. Instructional Lesson note covering two week
2. Teachers' checklist
3. Learners worksheet and
4. Digital game cards (Each card has a Scenario + a Prompt. Print, cut, and shuffle).

*(2) Traditional Teaching Instructional Package*

The instrument for data collection Energy transformation Performance Test was validated by experts in Measurement and Evaluation, Educational Technology and Science Education. Their constructive inputs were thoroughly adhered to in ensuring an ideal test item for the study. Furthermore, the instrument was subjected a pilot study in order to achieve the reliability index of the instrument. The instrument was administered to twenty (20) Basic 5

learners in upper primary schools but was not part of the selected learners for the main study. The data obtained from the pilot study was analyzed using the Kuder-Richardson-21 coefficient statistics was and a reliability coefficient value of  $r= 0.91$  was obtained making the instrument 91% reliable for use.

The procedure for data collection was categorized into five phases (Pre-pretest Phase, Pretest Phase, Intervention Phase, Posttest Phase and Post-Delayed Test Phase).

**The Pre-pretest Phase:** This phase consisted of familiarization with school management, science teachers and learners involved for the study. Specifically, the science teachers will be trained in line with the objectives of the study. The science teacher for school A (Constructivist Game Based Learning) will be trained on how to set up the constructivist classroom learning environment, how to use the teachers' checklist, administration and how the students will use the worksheet and to play the Game cards to obtain correct answers. The science teacher for school B (Traditional Teaching Method) will also be trained based on the objective of the study.

**The pretest Phase:** This phase involved the administration of the pretest item (Energy transformation Performance Test) to the learners.

**The intervention period:** This phase was focused on the actual procedure of instructional facilitation by the science teachers based on the two different instructional strategies employed for the study. The intervention period lasted for two weeks in accordance to the topic and the school time table.

**The Posttest Phase:** The posttest phase involved the administration of the test item (Energy transformation Performance Test) to the learners immediately after the completion of the intervention.

**The Post-Delayed Test Phase:** The Post-Delayed Test phase was done to achieve the retention rate of the learner after the posttest had been administered. The Post-Delayed Test administered was still the test item (Energy transformation Performance Test) but reshuffled and administered to the learners three weeks after the posttest was administered to them.

The data collected for the study were analyzed using frequency count, mean and standard deviation specifically for the research question while the

Analysis of Variance (ANCOVA) was used to test the hypotheses at 0.05 level of significance and a Post Hoc test of Least Significant Difference (LSD).

## Result

**Research Question 1:** What is the difference between upper primary school learners' pretest and posttest mean performance in the concept of energy transformation when taught using the constructivist approach with Digital Game-Based Learning and those taught using the traditional teaching method?

**Table 2:** Showing learners' performance on concept of energy transformation based on the instruction strategies.

Groups	Test	No	Mean	Mean Gain	% Gain	Mean
Experimental Group (CGBL)	Pretest	118	35.8	28.3	79.1	
	Posttest		64.1			
Control Group (TTM)	Pretest	129	36.2	11.1	30.7	
	Posttest		47.3			

Source: Researchers' field work, 2025.

An analysis of the pretest and posttest scores was conducted to compare the performance of upper primary school learners taught energy transformation concepts using the constructivist approach with Digital Game-Based Learning (CGBL) and those taught with the traditional teaching method (TTM). As presented in Table 2, the experimental group (CGBL) recorded a pretest mean score of 35.8 and a posttest mean score of 64.1, yielding a mean gain of 28.3 and a percentage mean gain of 79.1%. In contrast, the control group (TTM) had a pretest mean of 36.2 and a posttest mean of 47.3, resulting in a mean gain of 11.1 and a percentage mean gain of 30.7%. These findings suggest that while both groups showed improvement, learners exposed to the constructivist-based DGBL strategy demonstrated considerably greater gains in performance compared to their counterparts taught through traditional methods.

**Research question 2:** What is the difference in the mean retention level of upper primary school learners on the concept of energy transformation when taught using the constructivist approach with Digital Game-Based Learning and those taught using the traditional teaching method?

**Table 3:** Showing learners' mean retention level on concept of energy transformation based on the instruction strategies.

Groups	Test	No	Mean	Mean Gain	% Mean Gain
Experimental Group (CGBL)	Pretest		64.1		
	Post-Delayed Test	118	76.7	12.6	19.7
Control Group (TTM)	Pretest		47.3		
	Post-Delayed Test	129	54.2	6.9	14.6

Source: Researchers' field work, 2025.

To determine the difference in retention levels between students taught using the constructivist approach with Digital Game-Based Learning (CGBL) and those taught using the traditional teaching method (TTM), a post-delayed test was administered. As shown in Table 3, the experimental group (CGBL) had a pretest mean score of 64.1 and a post-delayed test mean score of 76.7, resulting in a mean gain of 12.6 and a percentage mean gain of 19.7%. On the other hand, the control group (TTM) recorded a pretest mean of 47.3 and a post-delayed test mean of 54.2, with a mean gain of 6.9 and a percentage mean gain of 14.6%. These results indicate that while both groups demonstrated some level of knowledge retention, the learners exposed to the constructivist-based DGBL strategy showed higher retention of energy transformation concepts compared to those taught through the traditional teaching method.

## Hypotheses

**H<sub>0</sub>:** There is no significant difference between upper primary school learners' pretest and posttest mean performance in the concept of energy transformation when taught using the constructivist approach with Digital Game-Based Learning and those taught using the traditional teaching method.

**Table 4:** Showing summary of ANCOVA on the difference between learners' mean performance

Source	SS	Df	MS	F	P	Eta <sup>2</sup>
Covariate (Pretest)	520.45	1	520.45	30.94	.000	.112
Group	1480.32	1	1480.32	88.01	.000	.264
Error	4120.87	245	16.82			
Total	6121.64	246				

Source: Researchers' field work, 2025.

An analysis of covariance (ANCOVA) was conducted to examine the effect of instructional method on upper primary school learners' posttest performance in the concept of energy transformation, while controlling for pretest scores. The results revealed a significant main effect of instructional method,  $F(1, 245) = 88.01$ ,  $p < .001$ ,  $\eta^2 = .264$ , indicating that learners taught using the constructivist approach with Digital Game-Based Learning (CGBL) significantly outperformed those taught with the traditional teaching method (TTM) after adjusting for initial differences. The effect size ( $\eta^2 = .264$ ) suggests that approximately 26.4% of the variance in posttest scores was explained by the instructional method. Based on this result, the null hypothesis ( $H_{01}$ ), which stated that there is no significant difference between the groups, was rejected.

Since a significant difference was obtained between the mean values of learners both in the constructivist approach with Digital Game-Based Learning (CGBL) and traditional teaching method (TTM), the direction of the significant difference was determined using the Post Hoc comparison of Least Significant Difference (LSD) test.

**Table 5:** Showing Post Hoc test of comparison of difference in mean performance score

Groups Compared	Mean Difference	Std. Error	p-value	Decision
CGBL vs. TTM	16.80	1.79	.000	Significant

Source: Researchers' field work, 2025.

A post hoc comparison using the Least Significant Difference (LSD) test as shown in Table 5 revealed that learners taught with the constructivist approach using Digital Game-Based Learning (CGBL) scored significantly higher on the posttest ( $M = 64.1$ ) compared to those taught with the traditional teaching method (TTM) ( $M = 47.3$ ), mean difference = 16.80,  $p < .001$ . This confirms that the superior performance observed in the ANCOVA analysis was attributable to the experimental group (CGBL).

**H<sub>02</sub>:** There is no significant difference in the mean retention level of upper primary school learners on the concept of energy transformation when taught using the constructivist approach with Digital Game-Based Learning and those taught using the traditional teaching method.

**Table 6:** Showing summary of ANCOVA on the difference between learners' retention rate

Source	SS	Df	MS	F	p	Eta <sup>2</sup>
Covariate (Pretest)	410.28	1	410.28	18.62	.000	.071

<b>Group</b>	980.46	1	980.46	44.53	.000	.154
<b>Error</b>	5394.12	245	22.02			
<b>Total</b>	6784.86	246				

**Source:** Researchers' field work, 2025.

An analysis of covariance (ANCOVA) was conducted to determine the effect of instructional method on learners' retention of energy transformation concepts, while controlling for pretest scores as presented on Table 6. The results revealed a significant effect of instructional method on retention,  $F(1, 245) = 44.53$ ,  $p < .001$ ,  $\eta^2 = .154$ , indicating that students taught using the constructivist approach with Digital Game-Based Learning (CGBL) retained significantly more knowledge than those taught with the traditional teaching method (TTM). The effect size ( $\eta^2 = .154$ ) suggests that approximately 15.4% of the variance in retention scores was explained by the instructional method. Based on this, the null hypothesis ( $H_{02}$ ) was rejected.

The direction of the significant difference between the retention mean scores of constructivist approach with Digital Game-Based Learning (CGBL) and traditional teaching method (TTM) was further determined using a Post Hoc comparison of Least Significant Difference (LSD) test.

**Table 7:** Showing Post Hoc test of comparison of difference in retention mean scores

Groups Compared	Mean Difference	Std. Error	p-value	Decision
<b>CGBL vs. TTM</b>	22.50	2.32	.000	Significant

**Source:** Researchers' field work, 2025.

A post hoc comparison using the Least Significant Difference (LSD) test as shown in Table 7 indicated that learners taught with the constructivist approach using Digital Game-Based Learning (CGBL) retained significantly more knowledge of energy transformation concepts ( $M = 76.7$ ) than those taught with the traditional teaching method (TTM) ( $M = 54.2$ ), mean difference = 22.50,  $p < .001$ . This finding confirms the ANCOVA result that the constructivist-based digital game environment supported stronger long-term retention of science concepts compared to traditional methods.

## Discussion

The results of this research indicated that upper primary school students who were instructed on energy transformation concepts through the constructivist approach utilizing Digital Game-Based Learning (CGBL) surpassed their

peers who were taught using the traditional teaching method (TTM). The experimental group recorded a mean gain of 28.3, with a percentage mean gain of 79.1%, in contrast to the control group, which had a mean gain of 11.1 and a percentage mean gain of 30.7%. This significant difference highlights the efficacy of CGBL in improving learners' conceptual comprehension and problem-solving abilities. This finding is consistent with earlier research that has shown that interactive and game-based learning strategies foster enhanced academic performance by engaging learners more actively than traditional methods (Klopfer & Thompson, 2020).

A key explanation for this improvement can be found in the constructivist framework that supports CGBL. Constructivism highlights the active involvement of learners in the process of knowledge construction by connecting new information to their previous experiences, which in turn promotes a deeper understanding (Deng, 2023). In the context of game-based learning, students are not merely passive recipients of information, rather, they are engaged participants who investigate, experiment, and evaluate their comprehension of scientific concepts such as energy transformation. Therefore, the results indicate that CGBL offers the necessary support for significant learning experiences in science teaching and learning.

The higher gains recorded by students in the experimental group also point to the motivational benefits of digital games. Studies have shown that game-based learning environments increase learners' attention, motivation, and interest, which are crucial for sustaining engagement in complex science topics (Jong, 2015). Energy transformation concepts, which often appear abstract when taught traditionally, become more relatable when presented through digital games that simulate real-world energy conversions. In this way, learners not only recall definitions but also visualize and apply the principles, thereby reducing misconceptions.

The findings highlight the limitations of traditional teaching methods (TTM), which rely heavily on rote memorization and teacher-centered instruction. While the control group demonstrated some improvement, the lower mean gain and percentage gain suggest that TTM is insufficient for fostering deep conceptual change in learners. This is consistent with prior research indicating that traditional methods often fail to correct misconceptions in science, leaving learners with fragmented knowledge (Obafemi & Aderonmu, 2022). In contrast, CGBL provides opportunities for repeated practice, immediate

feedback, and experiential learning, which together strengthen understanding and retention of scientific concepts. This study contributes to the growing body of evidence that constructivist-based digital game environments significantly enhance learning outcomes in science. The implication is that integrating CGBL into upper primary science instruction can improve learners' performance and bridge persistent gaps in scientific literacy. These findings echo the call for curriculum innovation and the adoption of learner-centered pedagogies in Nigerian classrooms and beyond (Odeyemi & Ajayi, 2021). By leveraging digital game-based platforms within a constructivist framework, teachers can transform difficult concepts like energy transformation into engaging and meaningful learning experiences.

The result of the ANCOVA confirms that the constructivist approach with Digital Game-Based Learning (CGBL) had a significant positive effect on students' performance in energy transformation concepts compared to the traditional teaching method (TTM). The finding that 26.4% of the variance in posttest scores was explained by instructional method underscores the effectiveness of constructivist-based digital environments in facilitating deep conceptual understanding. This is consistent with prior studies which have shown that interactive, learner-centered approaches such as game-based learning foster improved problem-solving skills and higher achievement in science learning (Low et al., 2024). The significant difference observed also validates the claim that traditional, teacher-centered strategies often limit learners' engagement and conceptual development, whereas constructivist digital tools provide experiential opportunities that promote meaningful learning outcomes.

The results of this research indicated that learners who engaged with the constructivist method utilizing Digital Game-Based Learning (CGBL) had a more effective retention of energy transformation concepts compared to those taught through the traditional teaching method (TTM). While both groups showed progress from the pretest to the post-delayed test, the experimental group achieved a higher mean gain of 12.6 and a percentage gain of 19.7%, in contrast to the control group, which had a mean gain of 6.9 and a percentage gain of 14.6%. This suggests that CGBL not only facilitated immediate learning but also contributed to the retention of knowledge over the long term. These findings align with previous studies that emphasize the effectiveness of

game-based learning environments in enhancing memory retention, as they integrate experiential activities with active participation (Cho et al., 2023).

The higher retention observed in the CGBL group can be linked to the constructivist principles integrated into the instructional design. Constructivism highlights the significance of learners actively building knowledge and relating new information to their previous experiences. In this research, digital games offered interactive, real-world simulations of energy transformations, enabling learners to practice and reinforce their understanding repeatedly. This type of experiential reinforcement diminishes misconceptions and aids in the development of stronger long-term memory consolidation (Obafemi & Aderonmu, 2023). In contrast, the teacher-centered method employed in the control group primarily depended on rote memorization, which typically diminishes over time, thereby accounting for the relatively lower retention rates.

These findings are consistent with previous research that highlights the motivational advantages of digital games for ongoing learning. Strategies based on games offer immediate feedback, foster competition, and present challenges that keep learners engaged, thereby improving their ability to recall and apply knowledge even after the instruction has concluded. This indicates that implementing CGBL strategies in primary science classrooms can enhance learners' capacity to grasp intricate concepts such as energy transformation. As a result, incorporating digital games within a constructivist framework not only enhances short-term performance but also provides learners with lasting knowledge that underpins future scientific literacy.

The ANCOVA result showed that instructional method had a significant effect on students' retention of energy transformation concepts, with those exposed to the constructivist approach using Digital Game-Based Learning (CGBL) retaining significantly more knowledge than their peers taught with the traditional teaching method (TTM). The effect size ( $\eta^2 = .154$ ) further highlights that instructional strategy accounted for a substantial proportion of the variance in retention scores, emphasizing the lasting impact of constructivist-driven digital games on learners' memory. This aligns with earlier findings that digital game-based environments not only improve immediate performance but also promote long-term knowledge retention by providing active engagement, immediate feedback, and meaningful contextual learning experiences (Kayode, et al., 2025). The result also supports the view

that traditional rote-based teaching often fails to sustain learners' conceptual understanding over time, whereas constructivist digital strategies foster durable and transferable knowledge (Appiah-Twumasi, et al., 2023).

## **Conclusion**

This research investigated the efficacy of the constructivist method utilizing Digital Game-Based Learning (CGBL) in improving the performance and retention of energy transformation concepts among upper primary school learners. The results consistently indicated that learners who engaged with CGBL significantly surpassed their peers who were instructed through the traditional teaching method (TTM) in both immediate posttest results and delayed retention assessments. These findings illustrate that digital game environments based on constructivist principles offer learners more enriching and engaging opportunities to actively build knowledge, thus addressing ongoing difficulties in comprehending abstract scientific concepts.

The study confirmed that traditional teacher-centered instruction, while capable of yielding some enhancements, was less effective in promoting profound conceptual transformation and long-term retention. In contrast, the constructivist approach integrated within digital games facilitated meaningful learning by connecting new information with students' prior experiences and enabling repeated practice in interactive settings. This supports the notion that effective science education at the primary level necessitates innovative, learner-centered methodologies that transcend mere rote memorization and procedural instruction.

The integration of constructivist principles with Digital Game-Based Learning has significant implications for science teaching and learning in Nigeria and similar contexts. It offers a pathway to improve scientific literacy by equipping learners with both immediate comprehension and sustained understanding of complex topics like energy transformation. The findings call for curriculum planners, educators, and policymakers to embrace digital, constructivist-driven strategies as viable tools for enhancing performance and retention in science classrooms. Doing so can help bridge learning gaps, reduce misconceptions, and foster a generation of learners who are better prepared for future scientific inquiry and problem-solving. The combination of constructivist principles with Digital Game-Based Learning holds considerable significance for the teaching and learning of science in Nigeria

and comparable environments. It provides a means to enhance scientific literacy by enabling learners to achieve both immediate understanding and long-term grasp of intricate subjects such as energy transformation.

### **Recommendations**

1. Science teachers should receive professional development and support to build the technical and pedagogical skills needed for effectively integrating constructivist-based digital game resources into classroom instruction.
2. Curriculum developers and policymakers should integrate constructivist-driven digital game-based learning into upper primary science to enhance learners' understanding, performance, and retention of abstract concepts like energy transformation.
3. Education stakeholders should provide schools with adequate digital infrastructure and resources to support effective implementation of constructivist game-based learning and enhance learners' engagement, performance, and retention.

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