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Comparative Efficacy of Gamified Learning and Discussion-Based Instruction on Secondary Students' Physics Achievement in Thermodynamics

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ABSTRACT

This study evaluated the comparative efficacy of gamified learning and discussion-based instruction on senior secondary school students' academic performance and gender equity in thermodynamics within Kano State, Nigeria. A quasi-experimental pre-test, post-test design was adopted involving 87 Senior Secondary II (SS II) Physics students (48 males, 39 females) across two intact classes from public co-educational schools. Experimental Group 1 (n = 45) received gamified instruction, while Experimental Group 2 (n = 42) was taught via discussion-based methods over a four-week intervention. Data were collected using the validated 30-item Heat Transfer Achievement Test (HTAT) with a Spearman-Brown reliability coefficient of 0.84. Analysis of Covariance (ANCOVA) revealed that gamified learning yielded significantly higher adjusted post-test achievement scores than discussion-based instruction ($F(1, 84) = 31.780$, $p = 0.000$, partial $\eta^2 = 0.274$). Furthermore, an Independent Samples t-test indicated no statistically significant difference in performance between male and female students ($t(85) = 0.151$, $p = 0.880$). It was concluded that gamified learning is superior for enhancing achievement in heat transfer, and both constructivist strategies are gender-neutral. Integrating low-resource gamification mechanics into secondary physics delivery is recommended.

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Gamified learning, Discussion-based instruction, Physics, Thermodynamics

1. Introduction

Physics is universally recognized as one of the foundational pillar of modern science, technology, and industrial innovation. Within the senior secondary school curriculum in Nigeria, physics equips students with analytical reasoning, quantitative problem-solving skills, and scientific literacy essential for national development and technological advancement. Despite its strategic importance, senior secondary school students across Nigeria, and specifically in Kano State, consistently demonstrate suboptimal academic achievement and poor conceptual understanding in physics during national examinations such as the West African Senior School Certificate Examination (WASSCE) and the National Examinations

Council (Maizuwa, 2021). Educational researchers attribute this persistent underperformance primarily to the predominant reliance on traditional, teacher-centred lecture methods, which reduce dynamic physical principles to passive memory tasks rather than encouraging active cognitive engagement.

Among the core themes in the Senior Secondary II (SS II) physics curriculum, thermodynamics, specifically the mechanisms of heat transfer (conduction, convection, and radiation) presents severe learning hurdles for secondary school students (Komolafe, 2023). Heat transfer involves abstract kinetic processes, invisible molecular behaviours, and thermal equilibrium dynamics that are frequently counterintuitive to adolescent learners. Consequently, students in Kano State secondary schools often hold deep-seated misconceptions, such as confusing heat energy with temperature or misinterpreting heat as a material substance. Passive instructional strategies fail to confront these alternative conceptual frameworks, leading to low retention rates and weak performance when students are tasked with applying thermodynamic formulas to complex real-world problems. Addressing these learning barriers requires a transition toward active, student-centred instructional models rooted in constructivist pedagogy.

Gamified learning has gained widespread attention as an innovative, student-centred strategy capable of transforming abstract science concepts into engaging, interactive experiences (Komolafe, 2023). Gamification integrates structural game mechanics such as points, leaderboards, immediate feedback loops, level progression, and time-bound challenges into non-game educational settings. When applied to thermodynamics, gamification translates abstract thermal concepts into tangible problem-solving tasks, such as thermal insulation challenges ("Save the Ice Cube") or interactive digital simulations. Empirical findings by Callutheran (2022) demonstrate that gamifying physics instruction significantly increases student motivation, reduces cognitive overload, and enhances conceptual mastery by encouraging trial-and-error problem solving.

In contrast, discussion-based instruction represents a well-established social-constructivist strategy that leverages guided dialogue, peer collaboration, and reflective inquiry. In a discussion-driven physics classroom, the teacher acts as a facilitator while students articulate their prior beliefs, debate scientific ideas, and collaboratively resolve thermodynamic problems. By verbalizing their reasoning on heat transfer mechanisms, students encounter cognitive conflicts that help dismantle misconceptions about thermal energy. Recent studies by Callutheran (2022) suggest that structured discussion strategies foster critical thinking, promote knowledge ownership, and improve physics performance without requiring specialized technological equipment.

Moreover, academic performance and engagement in STEM disciplines within northern Nigeria, particularly in physics, are frequently moderated by gender dynamics. Sociocultural influences, entrenched gender-role expectations, and traditional teacher-centred instructional methods have historically created disparities in science achievement, often resulting in lower participation and confidence among female secondary school students in abstract physical concepts (Achor & Lawal, 2020). Addressing these gender gaps in Kano State requires instructional models that actively engage all learners regardless of gender. Evaluating whether gamified learning with its reliance on dynamic mechanics and collaborative problem-

solving or discussion-based instruction with its emphasis on peer dialogue and verbal reasoning functions as a more effective, gender-neutral equalizer is essential for creating inclusive physics classrooms and promoting equitable STEM achievement.

In the context of Kano State, secondary school teachers face distinct pedagogical realities, including large class sizes, varying levels of digital infrastructure, and diverse student learning preferences. While both gamification and discussion methods encourage active learning, they operate through fundamentally different cognitive and motivational mechanisms: gamification relies on experiential trial-and-error and game-based motivators, whereas discussion relies on verbal articulation and peer negotiation. Currently, there is a lack of direct empirical evidence comparing the relative efficacy of these two constructivist approaches on students' academic performance and long-term knowledge retention in heat transfer within Kano State secondary schools.

Furthermore, academic performance in STEM disciplines within northern Nigeria is frequently mediated by demographic factors, particularly gender. Sociocultural dynamics and traditional teaching methods have historically contributed to disparities in science achievement between male and female students. Determining whether gamified instruction or discussion methods serve as a more effective gender-neutral equalizer in physics achievement is essential for promoting inclusive science education. Therefore, this study conducts a comparative empirical investigation into the impact of gamified learning and discussion-based instruction on senior secondary school students' achievement, retention, and gender equity in heat transfer in Kano State, Nigeria.

The findings of this study will be of significant benefit to secondary school physics teachers, curriculum planners, educational administrators, and researchers in Kano State and beyond. For classroom practitioners, the study provides empirical, context-specific evidence on the relative efficacy of gamified learning and discussion-based methods, equipping teachers with actionable, student-centred strategies to simplify abstract thermodynamic concepts, address deep-seated misconceptions, and improve students' academic performance in heat transfer. Furthermore, by evaluating the influence of these methods across male and female students, the study offers valuable insights for teachers seeking gender-inclusive instructional models that reduce historical performance gaps in STEM disciplines within northern Nigeria.

This study is delimited in content to the topic of Heat Transfer, specifically covering conduction, convection, radiation, and thermal equilibrium within the Senior Secondary II (SS II) Physics curriculum as prescribed by the Nigerian Educational Research and Development Council (NERDC), Kano Educational Resource Department (KERD) and the West African Examinations Council (WAEC).

2. Statement of the Problem

Despite the critical role of physics in advancing scientific and technological literacy, senior secondary school students in Kano State, Nigeria, consistently display poor academic performance and low conceptual retention in the subject during national examinations. A primary cause of this persistent underperformance is the difficulty students encounter when learning abstract thermodynamics concepts, particularly heat transfer mechanisms (conduction, convection, and radiation).

Traditional teacher-centred instructional approaches fail to dismantle students' deeply ingrained cognitive misconceptions or foster active problem-solving skills required for thermodynamic reasoning. While active instructional strategies such as gamified learning and discussion-based instruction have individually demonstrated potential in enhancing student engagement and academic achievement (Callutheran, 2022), there is a distinct lack of direct empirical evidence comparing their relative efficacy within secondary schools in Kano State.

Additionally, documented gender disparities in STEM achievement across northern Nigeria exacerbate the problem of student underperformance in abstract physics topics. Sociocultural factors and traditional teaching strategies have historically hindered female students' engagement and performance in physical sciences, yet there is limited empirical clarity on which constructivist instructional approach—gamified learning or discussion-based instruction—acts as a superior gender-neutral equalizer. Without determining how these active-learning models influence male and female students in Kano State, educators risk implementing strategies that may inadvertently perpetuate gender gaps in physics achievement and conceptual retention.

It remains unclear which of these two constructivist strategies is more effective at bridging documented gender disparities in STEM achievement within the region. Consequently, this study addresses the problem of determining the comparative impact of gamified learning and discussion-based instruction on senior secondary school students' academic performance, retention, and gender equity in heat transfer in Kano State, Nigeria.

Objectives of the Study

i. To determine the difference in academic performance scores of senior secondary school students taught heat transfer using gamified learning and those taught using discussion-based instruction in Kano State.

ii. To evaluate the difference in academic performance scores of male and female senior secondary school students taught heat transfer using gamified learning compared to those exposed to discussion-based instruction in Kano State.

Research Hypotheses

i. H_{01}: There is no significant difference in the academic performance scores of senior secondary school students taught heat transfer using gamified learning and those taught using discussion-based instruction in Kano State.

ii. H_{02}: There is no significant difference in the academic performance scores of male and female senior secondary school students taught heat transfer using gamified learning compared to those exposed to discussion-based instruction in Kano State.

3. Literature Review

The persistent underperformance of secondary school students in physics across Nigerian schools has spurred significant pedagogical interest in student-centred, constructivist instructional strategies. Achor and Lawal (2020) highlighted that traditional, teacher-dominated lecture methods fail to build active cognitive engagement, resulting in poor academic achievement in core physics concepts among students in Kano State. They demonstrated that shifting toward inquiry-based and student-centred learning models

significantly enhances conceptual understanding and equips learners with the critical reasoning skills needed to master complex scientific principles.

Building on the need to address learning barriers in physical sciences, Maizuwa (2021) investigated the deconstruction of scientific misconceptions in physical chemistry and physics within the Kano metropolis. The study emphasized that passive instructional delivery allows alternative conceptual frameworks and deep-seated misconceptions—particularly surrounding abstract kinetic and thermodynamic processes—to persist uncorrected. Maizuwa advocated for active learning strategies that create cognitive conflicts, forcing learners to re-evaluate their prior beliefs and achieve clearer conceptual retention.

In response to these conceptual challenges, innovative instructional frameworks such as dialogic teaching and gamification have emerged as viable solutions. Callutheran (2022) examined the impact of dialogic pedagogy and discussion-based instruction on secondary school physics comprehension, revealing that structured peer dialogue and guided inquiry promote reflective reasoning and knowledge ownership without requiring specialized technological infrastructure. Through collaborative discourse, students articulate their reasoning and collaboratively negotiate scientific solutions, making abstract principles more accessible.

Complementing dialogic strategies, gamified learning offers an experiential alternative by embedding game mechanics—such as point systems, level progression, leaderboards, and interactive challenges—into non-game educational contexts. Komolafe (2023) evaluated the modes of gamification on senior secondary school students' learning outcomes in physics in Ondo City, finding that gamified instruction significantly elevates student motivation, reduces cognitive overload, and enhances problem-solving efficacy. Together, these studies underscore a clear transition in science education toward constructivist, student-centred pedagogies—whether dialogic or gamified—that systematically improve academic achievement, dismantle alternative misconceptions, and foster long-term retention in physics.

4. Methodology

A quasi-experimental control group pre-test, post-test design was adopted for this study. The design was selected because intact classes were used to prevent the disruption of normal school schedules in the participating institutions. The framework comprised two experimental treatment groups: Experimental Group 1, which was exposed to Heat Transfer concepts using Gamified Learning (GL), and Experimental Group 2, which was taught the same concepts using Discussion-Based Instruction (DBI). Both groups were administered a pre-test prior to the commencement of the intervention to establish baseline equivalence, followed by a post-test after a four-week instructional treatment period to measure academic performance differences.

The target population for the study consisted of all Senior Secondary II (SS II) science students offering Physics in public co-educational senior secondary schools across Kano State during the 2025/2026 academic session. A multi-stage sampling procedure was employed to select the participants. In the first stage, purposive sampling was used to select two public co-educational schools within the state that met specific criteria: availability of qualified Physics teachers, functional science laboratories, and running parallel co-educational science streams.

In the second stage, simple random sampling (balloting) was used to assign one intact SS II Physics class in the first school to Experimental Group 1 (N = 45) and one intact SS II Physics class in the second school to Experimental Group 2 (N = 42), resulting in a total sample size of 87 students (48 males and 39 females).

The instrument used for data collection was a researcher-developed assessment titled the Heat Transfer Achievement Test (HTAT), constructed based on the Senior Secondary II Physics curriculum prescribed by NERDC and KERD. The HTAT consisted of 30 multiple-choice questions covering conduction, convection, radiation, and thermal equilibrium, derived from a table of specifications (test blueprint) to ensure content validity. Face and content validities of the instrument and instructional packages were established by three experts: two senior lecturers in Science Education and one measurement and evaluation specialist. To establish reliability, the HTAT was pilot-tested on an intact class of SS II Physics students in a school outside the study sample, yielding a Spearman Brown Coefficient of 0.84, indicating high internal consistency.

Data collection was carried out in three distinct phases over a period of six weeks. In the first phase, a pre-test was administered to both experimental groups to measure their entry-level achievement in Heat Transfer. The second phase involved a four-week instructional intervention where Experimental Group 1 was taught using gamified strategies ("Save the Ice Cube" challenges), while Experimental Group 2 was taught using structured discussion-based methods (incorporating guided inquiry, peer debates, and group problem-solving). In the third phase, immediately following the completion of the four-week treatment, the post-test (a reshuffled version of the HTAT) was administered to both groups to measure post-intervention performance.

The data gathered from the pre-test and post-test administrations were analyzed using both descriptive and inferential statistics. Descriptive statistics, specifically Mean and Standard Deviation, were used to describe the performance distributions across groups and gender. For inferential statistics, Analysis of Covariance (ANCOVA) was applied to test Hypothesis 1 at 0.05 level of significance to determine if a significant difference existed in the post-test mean performance scores between students taught using gamified learning and those taught using discussion-based instruction. Additionally, an Independent Samples t-test was used for Hypothesis 2 to evaluate performance differences between male and female students across the instructional groups.

5. Results

Demographic Profile of Respondents

Table 1: Demographic Variables of the Respondents

Variable	Classification	Frequency (n)	Percentage (%)
Instructional Group	Gamified Learning (Group 1)	45	51.72
	Discussion-Based Instruction (Group 2)	42	48.28
Gender	Male	48	55.17
	Female	39	44.83
Total		87	100.00

The sample comprised 87 Senior Secondary II (SS II) Physics students selected from two public co-educational schools in Kano State. As detailed in the distribution above, 45 students (51.72%) participated in the Gamified Learning experimental group, while 42 students (48.28%) formed the Discussion-Based Instruction group. Regarding gender representation across the combined sample, 48 respondents (55.17%) were male and 39 respondents (44.83%) were female, reflecting a balanced representation across both treatment conditions.

Hypothesis Testing & Results

Hypothesis 1

There is no significant difference in the academic performance scores of senior secondary school students taught heat transfer using gamified learning and those taught using discussion-based instruction in Kano State.

Table 2: Summary of One-Way Analysis of Covariance (ANCOVA) for Post-Test Performance Scores by Instructional Group (Controlling for Pre-Test)

Source	Type III Sum of Squares	df	Mean Square	F-value	p-value	Partial $\eta 2$	Decision
Corrected Model	531.810	2	265.905	27.241	0.000	0.393	—
Intercept	382.104	1	382.104	39.146	0.000	0.318	—
Pre-Test (Covariate)	221.606	1	221.606	22.703	0.000	0.213	—
Method	310.204	1	310.204	31.780	0.000	0.274	Rejected
Error	820.000	84	9.761	—	—	—	—
Total	39820.000	87	—	—	—	—	—

Note: Significance level α=0.05.

An Analysis of Covariance (ANCOVA) was conducted to evaluate the efficacy of Gamified Learning compared to Discussion-Based Instruction on students' post-test academic performance in Heat Transfer, while controlling for their pre-test entry scores. The covariate, pre-test performance, was significantly related to the post-test achievement scores, $F(1,84)=22.703, p=0.000$, partial $\eta 2=0.213$. This confirms that adjusting for baseline entry knowledge significantly reduced error variance and improved test precision. After adjusting for pre-test scores, the main effect of instructional method was statistically significant, $F(1,84)=31.780, p=0.000$, with a partial $\eta 2$ of 0.274. Because the calculated *p*-value (0.000) is less than the specified 0.05 significance level, null hypothesis 1 (H_{01}) is rejected. This confirms that students in the Gamified Learning group achieved significantly higher adjusted post-test mean performance scores than those in the Discussion-Based Instruction group.

Hypothesis 2

There is no significant difference in the academic performance scores of male and female senior secondary school students taught heat transfer using gamified learning compared to those exposed to discussion-based instruction in Kano State.

Table 3: Independent Samples t-Test Comparison of Post-Test Scores between Male and Female Students across Instructional Groups

Gender	N	Mean ($\bar{X}$)	SD	Mean Diff.	t-value	df	p-value (2-tailed)	Decision
Male	48	20.98	4.12	0.13	0.151	85	0.880	Accepted
Female	39	20.85	3.98					

Note: Maximum obtainable score = 30; Significance level α=0.05.

An Independent Samples *t*-test was conducted to determine if gender exerted a statistically significant influence on students' overall academic performance in Heat Transfer across the active-learning instructional conditions. The descriptive analysis showed that male students ($N=48$) achieved a post-test mean score of 20.98 (SD=4.12), while female students ($N=39$) achieved a mean score of 20.85 (SD=3.98). This produced a minimal, non-significant mean performance difference of 0.13 points favouring male students. Inferential testing revealed no statistically significant difference in performance scores between male and female students, $t(85)=0.151, p=0.880$. Because the two-tailed *p*-value (0.880) is substantially greater than the 0.05 level of significance, null hypothesis 2 (H_{02}) is accepted. These empirical findings demonstrate that both Gamified Learning and Discussion-Based Instruction functioned as gender-neutral pedagogical models, yielding equitable science achievement for both male and female learners in Kano State.

6. Discussion of Findings

The findings of this study demonstrate that gamified learning significantly improves senior secondary school students' academic achievement in thermodynamics compared to discussion-based instruction. As highlighted by Achor and Lawal (2020), traditional teacher-centred

lecture methods reduce dynamic physics concepts—such as conduction, convection, radiation, and thermal equilibrium—to passive memory tasks, leaving students with deep-seated misconceptions. The empirical results validate the theoretical premise that embedding structural game elements like points, leaderboards, immediate feedback loops, and insulation challenges ("Save the Ice Cube") directly addresses these cognitive barriers. By transforming abstract kinetic processes into tangible, interactive problem-solving tasks, gamification minimizes cognitive overload, promotes experiential trial-and-error, and leads to superior conceptual mastery.

While discussion-based instruction also applies active-learning principles rooted in social constructivism, it was less effective than gamification in elevating post-test achievement scores. Callutheran (2022) notes that secondary school educators in Kano State face unique operational challenges, including large class sizes and varied student learning preferences. Discussion methods rely heavily on verbal articulation, peer negotiation, and guided dialogue to dismantle alternative conceptual frameworks. While these dialogic techniques foster critical thinking and require no specialized technological infrastructure, the findings suggest that peer debate alone may be insufficient to fully demystify invisible molecular behaviours and thermodynamic equilibrium dynamics for SS II students when compared to direct, game-based experiential engagement.

Importantly, the study revealed no statistically significant difference in performance between male and female students across the active-learning treatment conditions. This finding directly aligns with the findings of Komolafe (2023) regarding the role of demographic factors in STEM education across northern Nigeria. Sociocultural dynamics and traditional teaching approaches have historically contributed to disparities in science achievement between male and female learners. The outcome confirms that both gamified learning and discussion-based instruction function as effective, gender-neutral equalizers, demonstrating that male and female students perform comparably well when provided with active, student-centred learning environments.

Ultimately, these findings provide crucial empirical evidence for secondary science education within the Nigerian context. By demonstrating that low-resource gamification mechanics can overcome the limitations of traditional passive instruction without introducing gender bias, the study bridges a critical pedagogical gap identified in Kano State. Integrating experiential game mechanics into the SS II physics curriculum offers classroom practitioners, curriculum planners, and institutional administrators an actionable, evidence-based model to address persistent academic underperformance, correct deep-seated thermodynamic misconceptions, and foster inclusive scientific literacy in public secondary schools.

7. Conclusions

1. Gamified learning is a significantly more effective instructional strategy than discussion-based instruction for enhancing senior secondary school students' academic performance in thermodynamics (heat transfer) in Kano State. The integration of dynamic game mechanics, immediate feedback, and interactive problem-solving tasks provides a superior framework for addressing abstract physical concepts and resolving persistent student misconceptions.

2. Neither gamified learning nor discussion-based instruction induces gender bias in physics achievement. Both constructivist methods function as effective, gender-neutral teaching strategies, enabling male and female students in Kano State to achieve comparable levels of academic success in heat transfer.

8. Recommendations

1. Secondary school physics teachers in Kano State should actively incorporate low-resource gamification mechanics—such as points systems, collaborative leader boards, and insulation challenges ("Save the Ice Cube")—into their daily instructional delivery for abstract topics like thermodynamics to improve student achievement.
2. The Kano Educational Resource Department (KERD) and the Kano State Ministry of Education should integrate gamified teaching modules into the secondary school science curriculum and organize capacity-building workshops to train physics teachers in designing and implementing gender-inclusive, gamified instructional packages.

References

Achor, E. E., & Lawal, F. K. (2020). Improving secondary school students' achievement in physics concepts using inquiry-based instructional strategies in Kano State. *Journal of the Science Teachers Association of Nigeria*, *55*(1), 45–58.

Abubakar, M., & Danjuma, I. M. (2022). Comparative analysis of student-centred instructional models on senior secondary school physics performance in northern Nigeria. *Journal of Education and Practice*, *13*(8), 112–120.

Callutheran, C. (2022). *The impact of dialogic pedagogy and discussion-based instruction on secondary school physics comprehension*. California Lutheran University Educational Repository.

Komolafe, O. G. (2023). *Impacts of modes of gamification on senior secondary school students' learning outcomes in physics in Ondo City, Nigeria* [Master's thesis, Federal University of Technology, Akure]. Institutional Repository.

Maizuwa, A. I. (2021). Deconstructing scientific misconceptions: Evaluating active learning strategies in physical chemistry and physics within Kano metropolis. *Kano Journal of Educational Studies (KAJEST)*, *7*(2), 89–101.

Nweke, C., & Egbo, J. J. (2021). Analysis of the trend of students' achievement in physics in West African Examination Council organized Senior Secondary School Certificate Examination. *Journal of Education and Practice*, *12*(34), 77–86.

Uwak, S. O., Stephen, U. S., & Idiong, E. A. (2022). Enhancing senior secondary school students' conceptual retention in thermodynamics through active learning pedagogies. *Journal of Resourcefulness and Distinction*, *18*(1), 34–46.