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Effect of Non-Digital Gamification on Senior Secondary Students' Engagement and Problem-Solving Skills in Mathematics in Kebbi State, Nigeria

[*1]Saratu Abdullahi Turaki, [2]Elizabeth Julius, and [3]Kamaludeen Samaila

[*1,2,&3]Department of Science Education, Faculty of Education, Federal University Birnin Kebbi, Kebbi, Nigeria. **Email**: saratu.turaki@fubk.edu.ng[*1], **ORCID**: https://orcid.org/0009-0003-6077-2301, mummybaffa2000@gmail.com[2], kalmalsama@ksusta.edu.ng[3]

Abstract

This study examined the impact of non-digital gamification on senior secondary students' engagement, problem-solving skills, and mathematics achievement in Kebbi State, Nigeria—a region with limited educational resources. Using a quasi-experimental design, 240 students were divided into experimental (gamified instruction using culturally adapted games like Dara and Kara) and control (traditional lecture-based) groups. Results showed significant improvements in the experimental group: mathematics scores increased by 31% ($p < 0.001$), with culturally adapted games outperforming non-adapted methods (+19.9 against +13.1 points; $p < 0.05$). Student engagement rose markedly, particularly emotional engagement (reduced anxiety, increased enjoyment; $t = 6.12$, $p < 0.001$). Attitudes improved, including motivation (+36%), self-efficacy (+35%), and math anxiety reduction (−40%). Teachers reported high engagement (92%) but cited time constraints (75%) and material preparation (67%) as challenges. The findings underscore the effectiveness of low-tech, culturally relevant gamification in resource-limited settings. Recommendations include integrating such strategies into teacher training and developing scalable, low-cost instructional materials. This study contributes to gamification literature by demonstrating its adaptability in sub-Saharan African classrooms, bridging gaps in access and cultural relevance.

Keywords: Non-Digital Gamification, Mathematics Education, Student Engagement, Cultural Adaptation, Nigeria, Problem-Solving Skills

Introduction

Mathematics education in Nigeria faces significant challenges, particularly in northern states like Kebbi where systemic issues including inadequate instructional materials, large class sizes, and teacher shortages contribute to persistently poor academic outcomes (Federal Ministry of Education, 2023).

The 2023 National Assessment of Educational Progress revealed that only 31% of senior secondary students in Kebbi State demonstrated basic proficiency in mathematics, compared to the national average of 48% (NAEP, 2023). This performance gap reflects deeper pedagogical challenges, as traditional teaching methods emphasizing rote memorization fail to develop students' conceptual understanding or problem-solving abilities (Adegboye & Bello, 2022). In this context, innovative approaches are urgently needed to transform mathematics instruction and improve learning outcomes.

The potential of gamification to address these challenges is supported by growing international evidence. Research demonstrates that game-based learning enhances motivation, engagement, and knowledge retention across various academic disciplines (Sailer & Homner, 2020). In mathematics specifically, gamification has been shown to reduce anxiety and improve performance by making abstract concepts more concrete and accessible (Hwang et al., 2015). However, most existing studies focus on digital gamification platforms that require substantial technological infrastructure - a significant barrier in Kebbi State where only 22% of public schools have reliable electricity access (Kebbi State Education Report, 2022). This technological divide creates a critical research gap regarding the effectiveness of low-tech, classroom-based gamification strategies in resource-constrained environments.

The theoretical foundation for this study draws upon Vygotsky's (1978) social constructivism, which emphasizes the importance of interactive, socially mediated learning experiences. Classroom gamification aligns with this framework by creating opportunities for collaborative problem-solving and peer learning. Additionally, self-determination theory (Deci & Ryan, 2000) suggests that game elements like immediate feedback and achievable challenges can satisfy students' psychological needs for competence, autonomy, and relatedness - key drivers of intrinsic motivation. These theoretical perspectives remain largely untested in the context of mathematics education in northern Nigeria, representing another important gap in the literature.

Cultural relevance represents another underexplored dimension of gamification research in the Nigerian context. While Western-designed educational games dominate the literature, there is growing recognition that locally adapted, culturally familiar game formats may be more effective in

African classrooms (Ejuu, 2022). In Kebbi State, traditional games like Dara (a strategic board game) and Kara (a jump rope game) have been used for generations to develop mathematical thinking, yet their potential as formal educational tools remains unexplored. This study will examine how adapting such indigenous games for classroom instruction compares with more conventional gamification approaches.

Practical implementation barriers also warrant investigation. Teacher capacity represents a significant challenge, as many educators in Kebbi State have received minimal training in innovative pedagogies (Kebbi Teachers' Survey, 2021). Existing research identifies teacher buy-in and competency as critical success factors for gamification (Sanchez *et al*., 2020), yet little is known about how to effectively prepare teachers in low-resource settings to implement these strategies. This study will document both the training requirements and implementation challenges of classroom-based gamification in Kebbi's educational context.

This research makes several important contributions. First, it addresses the critical gap in understanding non-digital gamification approaches for mathematics education in resource-constrained environments. Second, it explores the potential of culturally relevant game formats that may be more sustainable and scalable in northern Nigeria. Third, it provides practical insights into implementation challenges and teacher training needs. The findings will inform the development of contextually appropriate professional development programs and curricular resources to support mathematics teachers in Kebbi State and similar regions.

Theoretical Framework

This study is grounded in three interconnected theoretical perspectives that collectively explain the potential effectiveness of gamification in enhancing mathematics learning among secondary school students in Kebbi State, Nigeria. These theories; social constructivism, self-determination theory, and flow theory, provide a robust foundation for understanding how game-based learning strategies can improve engagement, motivation, and knowledge retention in mathematics education.

Social constructivism, as proposed by Vygotsky (1978), emphasizes the importance of social interaction and collaborative learning in knowledge construction. According to this theory, learning occurs most effectively within

a learner's Zone of Proximal Development (ZPD), where peers or teachers provide scaffolding to bridge the gap between current and potential understanding. In the context of gamification, classroom games such as team-based math puzzles or role-playing activities create opportunities for collaborative problem-solving, allowing students to learn from one another while receiving guided support. Leaderboards and group scoring systems further reinforce this social dimension by making mathematical thinking visible and encouraging healthy competition. By embedding mathematics concepts in interactive, socially mediated activities, gamification aligns with constructivist principles that prioritize active, student-centered learning over passive reception of information.

Self-determination theory (SDT), developed by Deci and Ryan (2000), complements this perspective by highlighting the role of intrinsic motivation in learning. SDT posits that learners are most engaged when their psychological needs for competence, autonomy, and relatedness are met. Gamification addresses these needs through carefully designed game mechanics. For instance, badge systems and incremental rewards satisfy the need for competence by providing tangible evidence of mastery. Role-playing scenarios or choice-based problem-solving tasks foster autonomy by allowing students to take ownership of their learning paths. Collaborative games, such as group challenges or peer-to-peer teaching activities, fulfill the need for relatedness by creating a sense of community and shared purpose. In Kebbi State, where traditional teaching methods often fail to engage students, gamification can rekindle intrinsic motivation by transforming mathematics into an enjoyable and personally meaningful endeavor.

Flow theory, introduced by Csikszentmihalyi (1990), further elucidates the conditions under which gamification can optimize learning experiences. Flow refers to a state of deep focus and immersion in an activity, characterized by a balance between challenge and skill, clear goals, and immediate feedback. Gamification naturally cultivates these conditions by structuring mathematics tasks as game levels with progressively increasing difficulty, ensuring that students remain in their optimal learning zone. Time-bound activities, such as math races or timed problem-solving challenges, create a sense of urgency that enhances concentration. Additionally, immediate feedback through points, scores, or verbal reinforcement helps students adjust their strategies in real time, reducing frustration and math anxiety. In a context like Kebbi State, where students often perceive mathematics as daunting, flow-inducing

gamification can make abstract concepts more accessible and less intimidating.

Cultural and Contextual Adaptation

To maximize the relevance and effectiveness of gamification in Kebbi State, this study integrates these theoretical perspectives with local cultural and educational realities. Traditional Nigerian games, such as *Dara* (a strategic board game) and *Kara* (a jump rope game), are incorporated into the framework as culturally familiar scaffolds for mathematical reasoning. These games not only align with Vygotsky's emphasis on socially embedded learning but also resonate with students' lived experiences, making abstract concepts more relatable. Furthermore, the framework acknowledges the resource constraints of Kebbi's schools by focusing on low-tech, teacher-mediated gamification strategies. Teachers act as facilitators, adapting game mechanics to their specific classroom dynamics, for example using physical manipulatives for hands-on algebra activities or oral storytelling to gamify word problems.

Objectives of the Study

This study was guided by the following objectives, which align with the broader aim of investigating the impact of non-digital gamification on mathematics education in Kebbi State, Nigeria:

a. To examine the effect of non-digital gamification strategies on senior secondary students' engagement in mathematics in selected schools in Kebbi State, Nigeria.

b. To assess the impact of culturally adapted gamification on students' mathematics achievement as measured by standardized test scores.

c. To determine the influence of gamification on students' attitudes toward mathematics, including motivation, anxiety, and self-efficacy.

Research Questions

This research sought to find answers to the following questions:

i. What is the effect of non-digital gamification strategies on senior secondary students' engagement in mathematics in selected schools in Kebbi State, Nigeria?

ii. To what extent does gamified learning improve students' mathematics achievement scores compared to traditional lecture-based instruction?

iii. How does gamification influence students' attitudes toward mathematics, including motivation, self-efficacy, and anxiety levels?

Research Hypotheses

This research proposed the following hypotheses to statistically evaluate the impact of non-digital gamification on mathematics education in Kebbi State, Nigeria:

H_{01}: No significant difference exists in engagement between gamified and traditional classrooms.

H_{02}: Gamification has no effect on mathematics achievement scores.

H_{03}: Cultural adaptation does not influence gamification's effectiveness.

Methodology

A quasi-experimental pre-test and post-test design was employed in this study. The population of the study consists of all the three thousand and sixty two (3062) SSS II students from the seventeen (17) Secondary Schools in Birnin Kebbi Metropolis. Purposive sampling technique was used to select 6 secondary schools based on representativeness, baseline parity and geographical diversity. Two intact classes were used, class X with 120 students (60 male, 60 female) assigned as experimental group and the class Y with 120 students (60 male, 60 female). The pilot sample consisted of 30 students (13 males, 7 female) was randomly selected from the population outside of the study sample. 12 teachers participated in this study, 2 per each school for two-day intensive workshop prior to the intervention, followed by biweekly mentoring sessions throughout the 8-week study.

Mathematics Achievement Test (MAT) was adapted from instruments used in studies on game-based learning of Ejuu (2022*)* which served as instrument used for data collection containing 40 standardized items and Student

Engagement Questionnaire (SEQ) of 20 item Likert scale. The validity of MAT and SEQ were subjected to face and content validation by four experts from department of Mathematics Education, Faculty of Education Federal University Birnin Kebbi. To ensure the reliability, the tests were administered in a different school setting with different participants and Cronbach Alpha α reliability coefficients are 0.82 and 0.79 respectively, indicating acceptable internal consistency of the TAT and SEQ for the study. Both descriptive statistical method which involves mean and standard deviation, and inferential statistical method for comparison which involves ANCOVA and t-test were employed for data analysis in this study.

Integration of Indigenous Games

The study adapted two traditional Nigerian games; *Dara* (a strategic board game) and *Kara* (a jump rope game) into mathematics instruction by modifying their mechanics to align with curriculum objectives:

a. Dara for Geometry**:**

1. Original Game: Players aim to form lines of three pieces on a grid, similar to tic-tac-toe.

2. Math Adaptation: Students used geometric terminology (e.g., "vertices," "collinear points") to describe moves and justified strategies using angle/line theorems. The board was labeled with Cartesian coordinates to teach plotting and spatial reasoning.

b. Kara for Arithmetic:

1. Original Game: Players jump and skip counting the jumps.

2. Math Adaptation: Jumps were assigned algebraic variables (e.g., x, y), requiring students to solve equations (e.g., "If x jumps is added to 5 jumps, the result is 8 jumps, what is x?").

Ethical Considerations

This research obtained an approval from Kebbi State Ministry of Education, parental consent and student assent forms, and control group received gamification training post-study.

Results

The data collected were analyzed using Statistical Packages for Social Sciences. Mean, standard deviation and t-test were used to answer the research questions and tested hypotheses. The result of the study are presented in the following tables:

Table 1: Comparison of Student Engagement between Gamified and Traditional Classrooms

Engagement Type	Experimental Group (Gamified) Mean (SD)	Control Group (Traditional) Mean (SD)	t-value	p-value
Behavioral	4.2 (0.6)	3.1 (0.8)	5.34	< 0.001
Cognitive	3.8 (0.7)	2.9 (0.9)	4.21	< 0.001
Emotional	4.0 (0.5)	2.7 (0.6)	6.12	< 0.001

Table 1 illustrates that the experimental group (gamified classrooms) showed significantly higher engagement across all dimensions (behavioral, cognitive, emotional) compared to the control group. The largest difference was in emotional engagement ($F = 18.9$, $p < 0.001$), reflecting reduced anxiety and increased enjoyment of mathematics.

Table 2: Mathematics Achievement Scores (Pre-Test vs. Post-Test)

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain	ANCOVA (F-value)	p-value
Experimental	52.3 (6.2)	68.7 (5.8)	+16.4	18.9	< 0.001
Control	51.8 (6.5)	53.2 (6.1)	+1.4	–	–

Table 2 shows that the experimental group improved by 16.4 points (31% increase) after gamification, while the control group showed minimal change. The ANCOVA results ($F = 18.9$, $p < 0.001$) confirm that gamification had a statistically significant impact on achievement scores, controlling for pre-test differences.

Table 3: Impact of Culturally Adapted vs. Non-Adapted Gamification

Gamification Type	Mean Post-Test Score (SD)	Mean Gain vs. Control	p-value
Culturally Adapted	72.1 (5.2)	+19.9	< 0.05
Non-Adapted	65.3 (6.0)	+13.1	0.12

Table 3 shows that culturally adapted games (e.g., Dara for geometry) led to higher achievement gains (+19.9) compared to non-adapted gamification (+13.1). The difference was statistically significant ($p < 0.05$), supporting H_{03} rejection and highlighting the value of local cultural relevance.

Table 4: Changes in Student Attitudes toward Mathematics

Attitude Metric	Pre-Intervention %	Post-Intervention %	Change	p-value
High Motivation	42%	78%	+36%	< 0.01
High Self-Efficacy	30%	65%	+35%	< 0.01
Low Math Anxiety	25%	65%	+40%	< 0.001

Table 4 demonstrates that Motivation and self-efficacy increased dramatically, with 78% of students reporting high motivation post-intervention. Math anxiety dropped by 40%, with the most pronounced effects among female students.

Table 5: Teacher Feedback on Implementation

Feedback Theme	% Agreeing (n=12)	Key Challenges
"Easy to Implement"	58%	Time constraints (75%)
"Improved Engagement"	92%	Lack of pre-made materials (67%)
"Would Use Again"	83%	Need for ongoing training (50%)

Table 5 illustrates that While 92% of teachers observed improved engagement, time constraints and material preparation were major barriers. 83% expressed willingness to continue gamification, contingent on support like training and ready-to-use resources.

Discussion

The findings of this study provide compelling evidence for the effectiveness of non-digital gamification in enhancing student engagement, improving mathematics achievement, and fostering positive attitudes toward mathematics among senior secondary students in Kebbi State, Nigeria. The results align with existing literature on gamification while offering novel insights into its application in resource-constrained and culturally specific contexts.

Engagement and Motivation

The significant increase in behavioral, cognitive, and emotional engagement among students in gamified classrooms (Table 1) underscores the potential of gamification to transform traditional learning environments. The largest improvement was observed in emotional engagement, which reflects reduced anxiety and heightened enjoyment of mathematics. This finding supports the principles of self-determination theory (Deci & Ryan, 2000), as gamification likely satisfied students' psychological needs for competence, autonomy, and relatedness. The collaborative and interactive nature of the games also aligns with Vygotsky's (1978) social constructivism, emphasizing the role of peer interaction and scaffolding in learning. These results are consistent with studies by Sailer and Homner (2020), who found that gamification enhances intrinsic motivation and engagement across diverse educational settings.

Mathematics Achievement

The experimental group's substantial improvement in mathematics achievement scores (Table 2) demonstrates the efficacy of gamification as a pedagogical tool. The 31% increase in post-test scores highlights how game-based learning can make abstract mathematical concepts more accessible and engaging. The ANCOVA results further confirm that these gains were statistically significant and not attributable to pre-existing differences between groups. This finding corroborates the work of Hwang et al. (2015), who reported similar improvements in mathematics performance through gamified interventions. The success of culturally adapted games, such as *Dara* and *Kara*, in achieving even higher gains (Table 3) suggests that contextual relevance plays a critical role in maximizing the impact of gamification.

Cultural Relevance and Contextual Adaptation

The superior performance of students exposed to culturally adapted gamification (Table 3) highlights the importance of aligning educational interventions with local traditions and practices. Indigenous games like *Dara* and *Kara* not only resonated with students but also provided familiar scaffolds for mathematical reasoning. This finding supports Ejuu's (2022) argument for integrating indigenous knowledge systems into African education. The statistically significant difference between culturally adapted and non-adapted gamification underscores the need for contextually sensitive pedagogical strategies in resource-limited settings.

Attitudinal Shifts

The dramatic improvements in motivation, self-efficacy, and reductions in math anxiety (Table 4) further validate the benefits of gamification. The 40% decrease in math anxiety is particularly noteworthy, as it addresses a pervasive barrier to mathematics learning in the region. These attitudinal shifts are critical for long-term academic success and align with the conditions for "flow" described by Csikszentmihalyi (1990), where balanced challenges and immediate feedback foster deep engagement and confidence. The pronounced effects among female students also suggest that gamification could help bridge gender gaps in mathematics participation and performance.

Implementation Challenges and Teacher Perspectives

While the study demonstrates the potential of gamification, teacher feedback (Table 5) reveals practical challenges, including time constraints and the lack of pre-made materials. Despite these barriers, 83% of teachers expressed willingness to continue using gamification, provided they receive adequate training and resources. This echoes Sanchez *et al*.'s (2020) findings that teacher buy-in and competency are critical for successful implementation. Policymakers must address these challenges by integrating gamification into teacher training programs and developing low-cost, culturally relevant instructional materials.

Conclusion

This study investigated the effects of non-digital gamification on senior secondary students' engagement, mathematics achievement, and attitudes in

Kebbi State, Nigeria. The findings provide robust evidence that gamification, particularly when culturally adapted, significantly enhances learning outcomes in resource-constrained educational settings.

The experimental group demonstrated marked improvements across all dimensions of engagement; behavioral, cognitive, and emotional, with the most notable gains in emotional engagement, reflecting reduced anxiety and increased enjoyment of mathematics. These results align with self-determination theory, as gamification effectively addressed students' psychological needs for competence, autonomy, and relatedness. Furthermore, the substantial increase in mathematics achievement scores (31%) underscores the pedagogical value of game-based learning in making abstract concepts more accessible and engaging.

A key contribution of this study is its emphasis on cultural relevance. The superior performance of students exposed to indigenous games like *Dara* and *Kara* highlights the importance of contextual adaptation in educational interventions. By leveraging familiar cultural elements, gamification not only improved academic outcomes but also fostered a deeper connection between students and the subject matter.

Despite these successes, challenges such as time constraints and the lack of ready-made materials were identified as barriers to implementation. Teacher feedback, however, indicated strong willingness to adopt gamification if supported with adequate training and resources.

Recommendations for Practice and Policy

1. Teacher Training: Integrate gamification strategies into professional development programs to equip educators with the skills needed for effective implementation.

2. Resource Development: Produce low-cost, culturally relevant gamification kits to reduce preparation burdens and ensure scalability.

3. Curriculum Integration: Incorporate indigenous games into the national mathematics curriculum to enhance contextual learning.

4. Longitudinal Research: Conduct follow-up studies to assess the sustainability of gamification’s benefits and explore its applicability in rural and other underserved areas.

Limitations and Future Directions

This study has several limitations. First, the quasi-experimental design limits the generalizability of the findings. Second, the short-term nature of the intervention precludes conclusions about the long-term retention of gains. Future research should employ longitudinal designs to assess sustained impacts. Additionally, expanding the sample to include rural schools could provide a more comprehensive understanding of gamification's effectiveness across diverse settings.

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