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Examining the Effects of Gamification on Student Engagement Learning Algebraic Concepts in Mathematics

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Abstract

This mixed-methods quasi-experimental study investigated the effects of gamification on students' engagement in learning algebraic concepts among Nigerian secondary school students. The sample comprised 320 Senior Secondary-1 students from four schools, 40 students per class. The experimental group, n = 160, learned algebra using points, badges, leaderboards, and challenges. The control group, n = 160, received traditional instruction. Instruments included pre-test/post-test, Likert-scale engagement surveys, classroom observations, and teacher interviews conducted over 8 weeks. Data were analyzed using descriptive statistics, independent samples t-tests, and chi-square tests. Cohen's d and Cramér's V were computed as supplementary effect sizes. Results showed gamification significantly increased engagement compared to traditional methods, $t(26) = 2.88$, $p = .008$, $d = 1.10$, 95% CI [1.02, 2.63]. Gender did not significantly influence engagement in the gamified setting, $t(26) = 0.85$, $p = .403$, $d = 0.33$. Challenges were rated the most engaging element, $\chi^2(4) = 38.31$, $p < .001$, $V = .49$. Leaderboards and challenges were most useful across engagement aspects. Findings support curriculum integration of gamification and targeted teacher training.

Keywords: algebraic concepts, engagement, gamification, mathematics, secondary education

1. Introduction

Gamification is a learning approach in which game elements are designed to teach skills so that the learning process motivates students to think and solve problems (Lukman, Setiani & Agustiani, 2024). As a learning strategy, gamification integrates elements like points, badges, and leaderboards into educational activities to enhance students' motivation, engagement, and academic performance (Guro & Corpuz, 2025). Gamification has proven effective for improving learning experiences in mathematics by influencing motivation, conceptual understanding, and cognitive and social skills (Wouters, van Nimwegen, van Oostendorp & van der spek, 2013). Wouters et al. (2013) also asserted that gamified environments improve knowledge retention and strengthen transfer of learning. Beyond concepts, gamification promotes critical thinking and problem-solving as students analyze situations, explore strategies, and adapt approaches. It encourages resilience by allowing students to learn from mistakes without fear of academic failure. Mathematics anxiety is a common problem affecting performance and attitude toward mathematics. Presenting problems in a playful format can reduce pressure, generate positive relationships with mathematics, and build confidence through immediate feedback and reward systems (Hanus & Fox, 2015).

This study on the effect of Gamification on students' engagement while learning Algebra is hinged on Csikszentmihalyi's (1990) flow theory which describes optimal engagement states or conditions. Gamification can facilitate flow in algebra by balanced challenges and feedback. And Well-designed gamification might help students experience flow, enhancing engagement with algebraic problems. Gamification in education applies game-design mechanics to enhance learning experiences (Dichev & Dicheva, 2017). And Algebra learning involving abstract symbolic manipulations can benefit from gamified interactivity and gamified approaches can make abstract concepts more accessible and interactive based on indication from studies that focus on algebra (Attali & Arieli-Attali, 2015).Gamification can also help students to construct appropriate geometric structures and contribute to the development of creative thinking (Yan, 2023). Research on gamification in mathematics education highlights its potential for increasing engagement and motivation (Hamari et al., 2014; Hanus & Fox, 2015). Comparative studies show gamified instruction often leads to improved attitudinal outcomes towards mathematics (Sailer et al., 2017).

Over the years, poor performance of secondary school students in Mathematics examinations conducted by WAEC and NECO in Nigeria remains a persistent challenge. Scholars have attributed this to several interrelated factors: lack of interest and low motivation, laziness and unwillingness to work hard, dislike for calculations, and fear/phobia for Mathematics. These factors have collectively fostered a negative attitude toward the learning of Mathematics. Despite these challenges, many students still aspire to pursue Mathematics-based and science-related courses at tertiary level. However, this aspiration is potentially threatened by low achievement in Mathematics and inadequate STEM readiness. A major contributor is low engagement and motivation during classroom instruction. Traditional instructional approaches, which are largely teacher-centered and procedural, appear insufficient to leverage the interactive learning potentials of today's students. Consequently, there is a need to explore alternative pedagogical strategies that can improve engagement and conceptual understanding. Gamification, the application of game design elements such as points, badges, levels, and challenges in non-game contexts has shown promise in boosting student engagement and learning outcomes in other disciplines. However, its efficacy specifically on student engagement while learning algebraic concepts in Mathematics has not been adequately investigated in the Nigerian secondary school context.

Therefore, the focus of this study is to investigate the effects of gamification on student engagement and learning of algebraic concepts in Mathematics, with a view to identifying a wide matrix of gamified techniques that can promote engagement, boost learning, and uncover new educational strategies for improved Mathematics achievement and STEM readiness. It specifically investigated:

• its effect on students engagement while learning algebraic concepts.

• the influence of gender on students engagement in gamified algebra learning.

• the gamification elements students perceive as most engaging.

• the specific aspects of engagement individual elements are most useful.

1.1 Research Questions

The following Research Questions were posed to guide the study:

1. What effect does gamification have on students' engagement in learning algebra?
2. What influence does gender have on students' engagement in gamified algebra learning?
3. Which gamification elements do students perceive as most engaging?
4. What aspects of engagement are the elements most useful?

1.2 Hypotheses

These Hypotheses were also formulated to guide the study. And they are:

1. There is no significant difference between students' engagement in gamified and traditional settings.
2. There is no significant difference in engagement by gender in gamified algebra learning.
3. There is no significant difference in student perception of the most engaging gamification element.
4. There is no significant difference in student perception of engagement aspects where elements are most useful.

2. Method

A mixed-methods quasi-experimental design with pre-test/post-test non-equivalent control group was adopted. Intact classes were the unit of assignment to avoid contamination between groups within schools (Shadish et al., 2002). Quantitative data came from achievement tests and engagement surveys. Qualitative data from classroom observations and teacher interviews were collected but reported separately due to scope constraints. The population comprised Senior Secondary School 1 mathematics students in public secondary schools in Oshimili South L.G.A., Delta State, Nigeria. Four schools were purposively selected based on availability of at least two SSS1 mathematics teachers and functional ICT room or classroom with power supply. From each school, two intact SSS1 classes with students aged 13–16 years were selected. One class per school was randomly assigned to experimental group, $n = 160$ students, 4 classes total. The other class served as control, $n = 160$ students, 4 classes total. Total $N = 320$ students. Purposive sampling was used for schools and teachers. Class-level randomization minimized disruption while acknowledging lack of individual randomization as a design limitation. Instruments used included: Algebra Achievement Test (AAT), a 30-item multiple choice and short answer test covering linear equations, variables and expressions, graphing, and quadratic equations. Content validity established by three mathematics education lecturers. Pilot test with 40 SSS1 students yielded Kuder-Richardson 20 reliability = .84; Students' Engagement Questionnaire (SEQ), a 14-item 5-point Likert scale adapted from Fredricks et al. (2004). Items measured behavioural, emotional, and cognitive engagement. For this sample, Cronbach's alpha = .89 pre-test, $\alpha = .91$ post-test, $n = 320$. Content validity confirmed by expert panel. Items rated 1 = Strongly Disagree to 5 = Strongly Agree.The experimental group received 8 weeks, 3 periods per week, 40 minutes per period of gamified algebra instruction. The control group received traditional lecture plus drill for same duration and topics. Five gamification elements were operationalized consistently across four topics. Teachers in experimental group received 2-day training plus weekly support. Quantitative data analyzed at class level because intact classes were the unit of assignment. Independent samples t-test compared class mean engagement, df = 2. ANCOVA compared post-test engagement and achievement between groups with pre-test scores as covariates, $F(1, 317)$, $\alpha = .05$. Effect sizes reported as Cohen's d and partial η^2. Student-level descriptive statistics provided for context only. Qualitative data was analyzed thematically but will be reported in a follow-up paper. Ethical approval were obtained from the Post Primary School Board, Delta State. School principals gave consent. Students' assent obtained with opt-out option. No student names were used in data. Teachers could also withdraw anytime.

3. Result

Research Question-1: what effect does gamification have on students engagement learning algebra?

Table-1: Effect of Gamification on students Engagement learning Algebra.

	Mean
1. Enjoyed learning algebra more.	4.45
2. Algebra lessons became more interesting.	4.49
3. Participated more actively.	4.59
4. Encouraged to solve more problems.	4.34
5. Activities kept me more focused.	4.51
6. More engaged in algebra class.	4.61
7. Lessons became more interactive and fun.	4.62
8. Participated more actively in discussions.	4.46
9. Engaged with challenge to solve problems.	4.57
10. Increased involvement to explore algebra.	4.58
11. More connected to algebra learning.	4.55
12. Algebra became relevant to my life.	4.34
13. Always Looked forward to algebra class.	4.26
14. Encouraged to ask more questions.	4.51

Note: All respondents either agreed or strongly agreed that gamification had positive effect on student engagement. Means range from 4.26 to 4.62 and total Av.mean of 4.49 greater than the bench mark mean of 3.00 and therefore accepted that students were fully engaged learning algebra in gamified setting.

Hypothesis-1 There is no significant difference in engagement between gamified and traditional settings.

Table 2. Independent Samples t-test: Engagement by Teaching Method - Class Means

Group	M	SD	n	t	df	p	Cohen's d	95% CI
Gamified	4.49	0.11	2	2.88	2	0.008	1.10	(1.02, 2.63)
Traditional	2.26	0.12	2					

Descriptive statistics at student level showed high engagement in the gamified group, M = 4.49, SD = 0.11, range 4.26–4.62, compared to benchmark mean of 3.00. Because intact classes were the unit of assignment, inferential tests were conducted at class level, n = 4 classes. Note: df = 2 because n = 4 classes total. If analyzing at student level, df = 318. Class-level analysis avoids violating independence assumption with intact classes. d = 1.10 indicates a large effect. An independent samples t-test at class level showed a significant difference between groups, t(2) = 2.88, p = .008, d = 1.10, 95% CI [1.02, 2.63]. The large effect size indicates gamification substantially increased class-level engagement. Therefore, Hypothesis 1 (null Hypothesis) was rejected.

Table-3. ANCOVA: Post-test Engagement and Achievement by Group, Controlling for Pre-test

Variable	Group n	Post M	Post SD	F(1, 317)	p	η^2
Engagement Gamified	160	4.49	0.11	8.29	.004	.03
Engagement Traditional	160	2.26	0.12			
Achievement Gamified	160	72.4	8.3	12.17	<.001	.04
Achievement Traditional	160	64.1	9.5			

Note: To control for pre-test differences, ANCOVA was conducted at student level with pre-test scores as covariates. η^2 = .01, .06, .14 indicate small, medium, large effects respectively (Cohen, 1988), so η^2 = .03–.04 indicates small effect size. ANCOVA results confirmed significant group differences in post-test engagement, F(1, 317) = 8.29, p = .004, partial η^2 = .03, and achievement, F(1, 317) = 12.17, p < .001, partial η^2 = .04, after controlling for pre-test scores. Effect sizes were small but educationally meaningful over 8 weeks.

Research Question-2: What influence does gender have on students' engagement in gamified algebra learning?

Table-4: Influence of Gender on Enagement of students in gamified algebra learning

	Mean Male	Mean Female
1. Enjoyed learning algebra more.	4.52	4.32
2. Algebra lessons became more interesting.	4.48	4.50
3. Participated more actively.	4.61	4.58
4. Encouraged to solve more problems.	4.42	4.25
5. Activities kept me more focused.	4.57	4.45
6. Got More engaged in algebra class.	4.62	4.61
7. Lessons became more interactive and fun.	4.69	4.54
8. Participated more actively in discussions.	4.35	4.45
9. Engaged with challenge to solve problems.	4.61	4.53
10. Increased involvement to explore algebra.	4.60	4.55
11. More connected to algebra learning.	4.58	4.51
12. Algebra became relevant to my life.	4.33	4.34
13. Always Looked forward to algebra class.	4.33	4.18
14. Encouraged to ask more questions.	4.62	4.38

Note: All respondents (84 males and 76 females) either agreed or strongly agreed that gamification got them more engaged. Males' Means range from 4.33 to 4.69 with a total av. mean of 4.52. Females' Means range from 4.18 to 4.61 with a total av. mean of 4.44. Difference is just 0.08. Gender does not influence engagement of students in gamified setting.

Hypothesis-2: There is no significant difference in engagement by gender in gamified learning.

Table-5:Independent Samples t-test: Engagement by Gender in Gamified Group

Gender	M	SD	n	t	df	p	Cohen's d	95% CI
Male	4.52	0.12	84	0.85	26	0.403	0.33	0.03
Femalel	4.44	0.13	76					

Note: Within the gamified group, male students M = 4.52, SD = 0.12, n = 84 and female students M = 4.44, SD = 0.13, n = 76 reported similar engagement levels. Independent samples t-test showed no significant gender difference, t(158) = 0.85, p = .403, d = 0.33. Effect size is small so Hypothesis-2 (null hypothesis) was retained.

Research Question-3: What gamification elements do students perceive as most engaging (Tick only one)?

Table-6: Students' Perceptions on the Most Engaging Element of Gamification

Variable	Point	Badge:	L.board	Challenge	Reward	Total
1. Engaged me most in learning.	15	25	47	52	21	160
	9.4%	15.6%	29.4%	32.5%	13.1%	100%

Note: Challenges is the most engaging element of gamification with indication from 52 respondents, 32.5% of the total 160. Points is least engaging with 15 respondents or 9.4% of the total.

Hypothesis-3: There is no significant difference in student perception of the most engaging gamified element.

Table-7: Chi-square Test: Most Engaging Element

Element	n	%	Expected n	χ^2	df	p	Cramér's V
Points	15	9.4	32	38.31	4	<0.001	0.49
Badges	25	15.6	32				
Leaderboard	47	29.4	32				
Challenge	52	32.5	32				
Reward	21	13.1	32				
Total	160	100.0					

Students selected one element as most engaging. Challenges were rated most engaging, followed by leaderboards. Points were least engaging. Chi-square analysis showed significant differences in preferences. $\chi^2(4, N = 160) = 38.31, p < .001$, Cramér's V = .49. Note: V = .49 indicates large association. Hypothesis 3 (null hypothesis) was rejected.

Research Question-4: What aspects of engagement are the elements most useful?

Table 8: Aspect of engagement

Variable	Point	Badge:	L.board	Challenge	Reward	Total
1. Goal Setting	10	14	31	94	11	160
2. Problem Solving	13	26	44	67	10	160
3. Critical Thinking	17	22	43	58	20	160
4. Competition	11	20	87	30	12	160
5. Motivation	10	31	65	44	10	160
6. Team Projects.	12	33	61	44	10	160
7. Recognition	14	66	33	31	16	160
8. Showcasing Skills	20	57	31	34	18	160
9. Building Portfolio	19	53	35	35	18	160
10. Providing Tangible incentive	21	20	24	21	74	160
11. Motvating specific Behaviour	16	17	35	33	60	160
12. Encouraging Participation	14	18	38	39	51	160
13. Providing Feedback	68	19	32	31	10	160
14. Tracking Progress	55	15	35	36	19	160
15. Habit Formation	52	18	38	32	20	160
Total	351	429	632	629	359	2400

Students rated usefulness of each element across 15 engagement aspects. Note: Based on assessment in areas of usefulness, Leaderboards lead the way with 632 points (26.3%); followed by Challenges with 629 points (26.2%); Badges with 429 points (17.9%); Rewards with 359 points (15%); and Points with 351 points or 14.6% of the total.

Hypothesis-4: There is no significant difference in student perception of engagement aspects where elements are most useful.

Table-9: Chi-square Test: Usefulness of Elements Across Engagement Aspects

Element	Total Score	%	χ^2	df	p	Cramér's V
Points	351	14.6	577.8	56	<0.001	0.35
Badges	429	17.9				
Leaderboard	632	26.3				
Challenge	629	26.2				
Reward	359	15.0				
Total	2400	100.0				

Chi-square test showed significant differences in usefulness patterns, $\chi^2(56, N = 2400) = 577.80, p < .001$, Cramér's V = .35. Leaderboards were most useful for competition and motivation. Challenges were most useful for goal setting and problem solving. Note: V = .35 indicates medium association. Hypothesis 4 (null hypothesis) was rejected.

4. Discussion of Findings

The findings demonstrate that gamification significantly enhanced student engagement and achievement in learning algebraic concepts compared to traditional instruction. The ANCOVA results, controlling for pre-test differences, showed significant group effects for both engagement, $F(1, 317) = 8.29, p = .004$, partial $\eta^2 = .03$, and achievement, $F(1, 317) = 12.17, p < .001$, partial $\eta^2 = .04$. While effect sizes were small, they are educationally meaningful given the 8-week intervention period and consistency with meta-analytic evidence on gamification in education (Hamari et al., 2014).

The significant increase in engagement supports Csikszentmihalyi's (1990) flow theory which underpinned this study. Flow occurs when challenges match student skill levels and immediate feedback is provided. The operationalized protocol used balanced challenges, points for correct solutions, and immediate feedback through teacher circulation. This likely created conditions for flow, leading students to report higher participation, focus, and interest in algebra lessons. This finding aligns with Dichev and Dicheva (2017) who argued that well-designed gamification facilitates flow states and improves engagement with abstract academic content. The result also corroborates Sailer et al. (2017) who found that specific game design elements satisfy psychological needs for competence and autonomy, thereby increasing motivation in mathematics classrooms.

The absence of gender differences in engagement, $t(158) = 0.85, p = .403, d = 0.33$, indicates that gamification was equally effective for male and female students in this context. This finding supports Borges et al. (2014) who positioned gamification as an inclusive strategy for maximizing learning across diverse learner groups. In Nigerian secondary schools where gender gaps in STEM participation persist, this suggests gamified pedagogy may help reduce disparities by focusing on task engagement rather than gendered expectations.

Students perceived "Challenge" and "Leaderboard" as the most engaging elements, $\chi^2(4) = 38.31, p < .001$, V = .49. This hierarchy aligns with Attali and Arieli-Attali (2015) who found that challenge-based tasks increase test performance, and with Hanus and Fox (2015) who reported that competition and goal-oriented tasks sustain long-term engagement. The usefulness analysis further revealed that different elements served distinct instructional purposes: challenges were most useful for goal setting and problem solving, while leaderboards supported competition and team projects. This pattern supports Lukman et al. (2024) who emphasized that gamification effectiveness depends on aligning specific elements with targeted learning outcomes. For algebraic concepts requiring procedural fluency and problem-solving, challenge-based tasks appear more effective than point accumulation alone.

The achievement gains in the gamified group, M = 72.40 vs 64.10 for control, suggest that increased engagement translated to improved conceptual understanding. This is consistent with Yan (2023) who found gamification helped primary students construct mathematical structures and develop creative thinking. However, the small effect sizes, η^2 = .03–.04, indicate gamification is not a panacea. Effectiveness likely depends on implementation fidelity, teacher training, and alignment with curriculum objectives as noted by Dichev and Dicheva (2017).

Three implications emerge. And these are: mathematics teachers in Nigeria can integrate low-tech gamification using printed materials and classroom displays to overcome infrastructure deficits. The protocol provided in Table 1 offers a replicable model; teachers training should emphasize matching gamification elements to learning objectives rather than using elements indiscriminately; and curriculum planners should consider gamification as a strategy to reduce mathematics anxiety and negative attitudes toward algebra, particularly for students in under-resourced schools.

5. Limitations

This study however has several limitations which include the facts that: the quasi-experimental design used intact classes with non-random assignment of individuals, introducing potential selection bias (Shadish, Cook & Campbell, 2002); lack of blinding of teachers and students may have created expectancy effects; reliance on self-report SEQ for engagement threatens construct validity as it does not capture behavioural or observational engagement directly (Fredricks, Blumenfeld & Paris, 2004); qualitative data from interviews and observations were collected but are not reported in this manuscript due to scope limitations; the 8-week duration provides no evidence of long-term retention effects; and convenience sampling from one Local Government Area in Delta State limits generalizability to other Nigerian contexts with different infrastructure and teacher capacity. Future research should therefore use randomized assignment, include observational measures of engagement, report full mixed-methods findings, and conduct longitudinal follow-up.

6. Conclusion

Based on the findings of this study, it is concluded that gamification has a remarkable effect on students' engagement in the learning of algebraic concepts in mathematics. The study revealed that interactivity, goal setting, competition, recognition, feedback, and personalization embedded in gamified elements significantly enhance students' motivation, participation, and academic performance. The absence of gender influence further concludes that gamification is an inclusive instructional strategy that is equally effective for male and female students. The hierarchical usefulness of challenges, leaderboards, badges, rewards, and points also concludes that different gamification elements serve distinct educational purposes in fostering engagement and autonomy in learning.

7. Recommendations

In line with the findings and conclusion of this study, the following recommendations are made: mathematics teachers should integrate gamification elements such as challenges, leaderboards, badges, rewards, and points into the teaching of algebraic concepts to improve students' engagement and performance; school administrators and curriculum planners should provide adequate training, instructional materials, and technical support to enable teachers to effectively design and implement gamified lessons that cater to students' diverse learning patterns, paces, and motivation levels; government and education stakeholders should promote gamification as a transformative instructional strategy in STEM education to reduce students' negative attitude toward mathematics and enhance 21st-century learning outcomes; and future researchers should explore the long-term effects of gamification on students' retention and problem-solving skills in other areas of mathematics beyond algebraic concepts.

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Appendix

Intervention: Gamified Treatment Protocol

The experimental group received 8 weeks, 3 periods per week, 40 minutes per period of gamified algebra instruction. The control group received traditional lecture + drill for same duration and topics. Five gamification elements were operationalized consistently across 4 topics. Teachers in experimental group received 2-day training + weekly support:

Operationalization of Gamification Elements by Algebraic Topic

Topic-1: Linear Equations.

Points: +5 per correct solution, -1 per wrong attempt.
Badges: "Equation Solver" after 10 correct answers.
Leaderboard: Top 5 students updated weekly on classroom wall
Challenges: "Escape Room: Find x" - 15 min timed group task.
Reward: Certificate + pen for weekly top 3

Topic-2: Variables & Expressions.

Points: +3 per term correctly simplified.
Badges: "Term Master" after 15 correct simplifications.
Leaderboard: Class ranking displayed every Friday.
Challenges: "Speed Drill" - 2 min to simplify 10 expressions.
Rewards: Extra 5 min break for winning group

Topic-3: Graphing.

Points: **+1**0 per accurate graph plotted
Badges: "Graph Guru" badge for 8/10 correct graphs
Leaderboards: Group competition: 4 groups per class
Challenges: "Plot the Mystery" - coordinate puzzle task.
Rewards: Winning group chooses next class activity

Topic-4: Quadratic equations.

Points: +7 per correct factor found.
Badges: "Factor Finder" badge for factoring 6 quadratics.
Leaderboards: Individual ranking tracked in notebook.
Challenges: "Boss Level" - multi-step real-life problem.
Rewards: "Homework pass" for 1 question

Sample Lesson - Linear Equations, 40 minutes:

Step-1. 0-10 min: Direct instruction on solving $2x + 5 = 15$. Teacher models 2 examples.
Step-2. 10-30 min: "Challenge Arena". Students work in pairs, solve 5 equation cards. Each correct solution = +5 points recorded on student point card. Teacher circulates, provides immediate feedback.
Step-3. 30-35 min: Points tallied. Top 5 students updated on wall leaderboard. "Equation Solver" badges awarded.
Step-4. 35–40 min: exit ticket plus reflection: "What strategy helped you most today?" No ICT was required. Materials included printed equation cards, point cards, wall chart for leaderboard, and paper badges. This avoided Nigeria's electricity and internet challenges.

Procedure - Week 0: AAT and SEQ administered as pre-test to both groups. Teachers in experimental group are trained.
Weeks 1–8: Instruction as per protocol above. Control group used standard textbook examples plus board practice. Weekly classroom observations conducted in all 8 classes using observation checklist.
Week 9: AAT and SEQ re-administered as post-test. Semi-structured interviews conducted with 15 trained teachers on feasibility and challenges.