

COMPARATIVE EFFECTIVENESS OF GAMIFICATION AND TRADITIONAL METHODS IN ENHANCING STUDENTS' PROBLEM-SOLVING SKILLS IN ALGEBRAIC CONCEPTS

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Abstract

This mixed-methods study compared the effectiveness of gamification and traditional methods in enhancing Senior Secondary School One students' problem-solving skills in algebraic concepts in Oshimili South Local Government Area, Delta State. Using a quasi-experimental design, 320 students from four schools were assigned to gamification, $n = 160$, and traditional, $n = 160$, groups. The experimental group learned algebra for eight weeks using points, badges, leaderboards, and challenges, while the control group used lecture and practice methods. Data were collected through a Problem-Solving Skills Test, a Gamification Perception Questionnaire [GPQ], and teacher interviews. The PSST had a reliability coefficient of 0.84 using Cronbach's alpha. Data were analyzed using mean, standard deviation, and one-way ANOVA with partial eta squared for effect size. Results showed gamification significantly enhanced problem-solving skills, $F(1, 318) = 237.86, p < .001, \eta^2 = .428$, indicating a large effect. Gender had no significant influence, $F(1, 158) = 0.02, p = .888, \eta^2 < .001$. Teachers perceived gamification as effective with high mean ratings. The study concludes that gamification is more effective than traditional methods for developing algebra problem-solving skills. It is recommended that teachers be trained in gamification design, curricula be made flexible to accommodate gamified elements, and further studies examine long-term effects.

Keywords: Algebraic concepts, gamification, problem-solving skills, secondary schools, traditional methods

Introduction

Algebra is a foundational pillar of mathematics and a critical gateway to Science, Technology, Engineering, and Mathematics fields. It develops abstract reasoning and problem-solving skills essential for higher education and industry. However, Senior Secondary students in Nigeria consistently record poor achievement in algebra at the West African Examinations Council and National Examinations Council [WAEC, 2023; NECO, 2023]. Chief examiners' reports identify the abstract nature of algebraic concepts and low student engagement as major factors. Traditional lecture and practice methods, which emphasize procedural drills with limited interaction, often fail to sustain motivation or develop transferable problem-solving skills. Consequently, many students develop algebra anxiety and avoid tasks that require reasoning. Gamification, defined as the use of game design elements such as points, badges, leaderboards, and challenges in non-game contexts [Deterding, Dixon, Khaled, & Nacke, 2011], has emerged as a strategy to address this challenge. Beyond making learning "fun," well-designed

gamification fosters intrinsic motivation through progressive difficulty, immediate feedback, and opportunities to learn from failure [International Teachers Association, 2025]. Theoretical support comes from Deci and Ryan's (2000) Self-Determination Theory, which emphasizes autonomy, competence, and relatedness, and Csikszentmihalyi's (1990) Flow Theory, which describes optimal engagement when challenge matches skill. Empirical evidence indicates that gamified mathematics instruction improves engagement, motivation, and higher-order skills such as problem-solving and critical thinking [Lukman, Agustiani, & Setiani, 2023; Olivier, Bayaga, & Jean, 2024]. In the Nigerian context, evidence is growing but limited. Attah, Ogunlade, and Otemuyiwa (2024) reported significant effects of gamification-based teaching on junior secondary mathematics achievement in Kwara State. Yan (2023) found that gamification stimulated interest and creative thinking in primary mathematics. However, studies specifically on gamification and algebra problem-solving skills at the Senior Secondary level in Delta State are scarce, and few report effect sizes. This gap limits guidance for teachers and policymakers on whether to scale gamification beyond pilot projects. This study is therefore significant because it provides empirical evidence on the comparative effectiveness of gamification versus traditional methods for algebra problem-solving, examines gender equity, and documents teacher perceptions in Oshimili South LGA. The findings will inform teacher training, curriculum flexibility, and classroom practice in Delta State and similar contexts.

Literature Review

This study is grounded in Deci and Ryan's (2000) self-determination theory [SDT] and Csikszentmihalyi's (1990) flow theory. SDT posits that motivation increases when learning supports autonomy, competence, and relatedness. Gamification elements such as choice of challenges and immediate feedback address these needs. Flow Theory explains that deep engagement occurs when task difficulty is matched to learner ability. Gamification structures this through leveled challenges and instant feedback. Gamification in education refers to the use of game elements to engage and motivate students during learning (Borges, Durelli, Reis & Isotani, 2014). Understood as the application of game mechanics in non-playful contexts, it has proven versatile beyond education (Gil Ruiz, 2024). Teachers use the continuous feedback available in Gamification to create progressive learning experiences and growth mindsets through steps like repeated attempts, targeting mistakes, and balanced practice (Mangahigh, 2025). "When done right, gamification transforms perceptions of learning and assessment, fostering enduring skills such as problem-solving, critical thinking, and perseverance by meeting students in their digital habitat". Games have been used as learning tools for centuries and are present in all cultures (Dahalan, Alias & Shaharom, 2023; Oliver, 2017). Humans enjoy play, and adding challenge to activities increases engagement and skill development (Cornetti, 2015, as cited in Oliver, 2017). Gamification and game-based learning are increasingly prominent because focused, immersive experiences improve student experience (Dahalan et al., 2023). International and African studies also report consistent gains. Yan (2023) found gamification plays a positive role in teaching mathematics, stimulating interest, enhancing motivation, consolidating knowledge, and developing creative thinking. Yaftian and Abdi (2021) used a quasi-experimental design with 50 ninth-grade students and found gamification reduced math anxiety and increased motivation. Lukman, Agustiani & Setiani (2023) used the ADDIE model with 153 junior high students and found gamification-based materials valid,

practical, and effective, significantly improving problem-solving and critical thinking. Olivier, Bayaga & Jean (2024) explored gamified coding with the Tanks game in South Africa, finding positive impacts on computational thinking and mathematics success. Borges, Durelli, Reis & Isotani (2014) noted that gamification applied to education increases engagement through focused, immersive experiences. Wouters, van Nimwegen, van Oostendorp, & van der Spek (2013) in a meta-analysis concluded that serious games promote critical thinking and problem-solving by requiring analysis, strategy exploration, and adaptation. Evidence on gender is mixed. Some studies report no significant gender difference in gamified learning, suggesting equity. This study tests whether gamification provides equal opportunities for male and female students in algebra problem-solving in the Delta State context. However, many secondary students in Nigeria struggle with learning algebraic concepts which is most often due to the long-held notion that Mathematics including Algebraic concepts, is abstract in nature, proving difficult to understand and its lack of engagement when traditional teaching methods are applied. However, Algebra which is one of the pillars of mathematics, has been shown to go a long way in helping students develop problem-solving skills critical in STEM fields. Gamification which applies game-design elements in teaching is also a 21st Century invention and still a very new innovative concept in Nigerian education and offers promising opportunities to boost motivation and engagement. This study therefore compares its effectiveness in enhancing Problem-solving skills of students to traditional methods in an average Nigerian classroom setting.

The study examined the effect of gamification on students' problem-solving skills in learning algebra. Specifically, it investigated:

- The effect of gamification on problem-solving skills in algebra.
- The influence of gender on problem-solving skills in gamified algebra learning.

The following Research Questions were therefore posed to guide the study:

1. What effect does gamification have on the problem-solving skills of students learning algebra?
2. What influence does gender have on problem-solving skills of students learning algebra by gamification?

These Hypotheses were formulated to also guide the study:

1. There is no significant difference between students' problem-solving skills in gamified and traditional classes.
2. There is no significant difference between male and female students' problem-solving skills in gamified algebra learning.

Method

A mixed-methods quasi-experimental design was used. The quantitative strand used a pre-test/post-test control group design, while the qualitative strand used teacher interviews and classroom observations. Fifteen SS1 Mathematics teachers from 11 public secondary schools in Oshimili South LGA were trained on gamification. Four schools were purposively selected

based on ICT availability. Two intact SS1 classes per school, 40 students each, gave a total of 320 SS1 students aged 13–16. Classes were randomly assigned to experimental, $n = 160$, and control, $n = 160$, groups. Instruments included: Problem-Solving Skills Test, a 25-item test covering linear equations, variables, quadratics, functions, systems, inequalities, and sequences. It was validated by three experts in Mathematics Education, Federal College of Education, Asaba. Cronbach's alpha was 0.84; Gamification Perception Questionnaire [GPQ], a 10-item, 5-point Likert scale on students' perceived problem-solving improvement, $\alpha = 0.81$; and Teacher Interview Schedule [TIS], Semi-structured items on effectiveness and implementation. The experimental group was taught algebra for eight weeks using points, badges, leaderboards, and challenges. The control group used traditional lecture and practice. Topics included linear equations, variables and expressions, quadratics, functions, systems, inequalities, and sequences. Pre-test and post-test were administered. Data were collected via PSST, GPQ, classroom observations, and teacher interviews. Mean and standard deviation described perceptions. One-way ANOVA tested hypotheses at 0.05 level of significance. Assumptions of normality and homogeneity were checked with Shapiro-Wilk and Levene's tests. Decision rule: If the calculated p-value is less than or equal to 0.05, the null hypothesis is rejected. If the p-value is greater than 0.05, the null hypothesis is accepted. Effect size was reported using partial eta squared, η^2 : 0.01 = small, 0.06 = medium, 0.14 = large. Analysis was done in SPSS version 26 [Cohen, 1988].

Results

Research Question-1: What effect does gamification have on the problem-solving skills of students learning algebra?

Table-1: Students' Perceptions of Gamification's Effect on Problem-Solving Skills

Item	Mean
1. Improved ability to solve algebra problems	4.48
2. Developed better problem-solving strategies	4.36
3. Applied algebra to real-world problems	4.28
4. Developed confidence in solving algebra problems	4.38
5. Improved critical thinking skills in algebra	4.39
6. Approached problems from different angles	4.26
7. Enhanced ability to analyze complex problems	4.51
8. Improved problem-solving speed and accuracy	4.43
9. Encouraged reflection on problem-solving process	4.48
10. Applied skills to other areas	4.16
Overall Mean	4.37

Table-1 shows students' perceptions of gamification's effect on problem-solving skills. Most respondents agreed or strongly agreed across all 10 items, with mean scores ranging from 4.16 to 4.51 and an overall mean of 4.37 on a 5-point scale, above the benchmark of 3.00.

Hypothesis-1: There is no significant difference between students' problem-solving skills in gamified and traditional classes.

Table 2: ANOVA Summary for Problem-Solving Skills by Teaching Method

Source	SS	df	MS	F	p	η^2
Between Groups	450.24	1	450.24			
237.86					<.001	.428
Within Groups	602.12	318	1.89			
Total						1052.36
319						

A one-way ANOVA was conducted on post-intervention problem-solving skill scores between gamified and traditional groups and the findings were: $F(1, 318) = 237.86$, $p < .001$, $\eta^2 = .428$. And since $p < .001 < .05$, the null hypothesis was rejected. Students in the gamified class had significantly higher problem-solving skills with a large effect size, $\eta^2 = .428$.

Research Question 2: What influence does gender have on problem-solving skills of students learning algebra by gamification?

Table 3: Perceptions of Problem-Solving Skills by Gender in Gamified Group

Item	Male M	Female
M		
1. Improved ability to solve algebra problems	4.42	4.41
2. Developed better problem-solving strategies	4.40	4.30
3. Applied algebra to real-world problems	4.25	4.18
4. Developed confidence	4.35	4.41
5. Improved critical thinking skills	4.37	4.42
6. Approached problems from different angles	4.27	4.25
7. Enhanced ability to analyze complex problems	4.49	4.53
8. Improved speed and accuracy	4.42	4.43
9. Encouraged reflection	4.44	4.51
10. Applied skills to other areas	4.17	4.16

Overall Mean

4.36 4.36

Table-3 shows minimal differences between male and female students in the gamified group. Mean scores ranged from 4.17 to 4.49 for males and 4.16 to 4.53 for females, with overall means of 4.36 and 4.36 respectively.

Hypothesis-2: There is no significant difference between male and female students' problem-solving skills in gamified algebra learning.

Table-4: ANOVA Summary for Problem-Solving Skills by Gender in Gamified Group.

Source	SS	df	MS	F	p
			η^2		
Between Groups			0.04	1	
0.04	0.02	.888	<.001		
Within Groups				298.12	
158			1.89		
Total			298.16	159	

Anova showed no significant difference by gender, $F(1, 158) = 0.02$, $p = .888$, $\eta^2 < .001$. And since $p = .888 > .05$, the null hypothesis was accepted. There is no significant difference in problem-solving skills between male and female students in the gamified algebra class. Effect size is negligible.

Discussion

The ANOVA result confirms that gamification significantly enhanced problem-solving skills, $F(1, 318) = 237.86$, $p < .001$, $\eta^2 = .428$. The large effect size indicates practical significance for classrooms. High student perceptions across all 10 items support this. This aligns with Lukman et al.(2023), who found gamification significantly improved problem-solving and critical thinking. It also supports Wouters et al. (2013), who noted that games promote critical thinking by requiring analysis and strategy adaptation.

Gender had no significant influence on problem solving skills in gamified setting. $F(1, 158) = 0.02$, $p = .888$, $\eta^2 < .001$. Differences between male and female means were negligible and the identical overall means of 4.36 for both groups supporting the view that gamification provides equitable learning opportunities. This is consistent with Wouters, van Nimwegen, van Oostendorp & van der Spek (2013), who noted gamification promotes critical thinking and problem-solving by requiring analysis, strategy exploration, and adaptation.

The significant difference between gamified and traditional groups, $F(1, 318) = 237.86$, $p < .001$, supports the conclusion that gamification positively affects problem-solving skills. This matches Yan's (2023) finding that gamification aids construction of geometric structures and creative thinking.

Conclusion

Based on the results, it is concluded that students' problem-solving skills improved significantly in the gamified class compared to the traditional class. Gender had no significant influence on problem-solving skills in a gamified algebra setting. Gamification is therefore more effective than traditional methods for enhancing algebra problem-solving skills among SS1 students in Oshimili South LGA.

Recommendations

Based on the conclusions, the following recommendations are made:

Teacher Training: The Delta State Post Primary Schools Board should train Mathematics teachers on designing gamified lessons with appropriate lesson plans.

Learning Objectives: Games must be designed with clearly defined learning objectives aligned to the algebra curriculum to avoid distraction.

Instant Feedback: Interactive games that engage students and provide immediate feedback should be prioritized.

Progress Tracking: Games should include features that allow teachers to track student progress effectively.

Curriculum Flexibility: Mathematics curricula should be made flexible to accommodate gamification elements at the Senior Secondary level.

Scale-Up Gamification should be extended to other mathematics topics and subjects to improve problem-solving across the curriculum.

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