Kogi Journal of Education and Pedagogy (KOJEP), Vol. 4, No. 1, JUNE, 2025

ISSN 2736-0091
E-ISSN 2737-0107

AI-ENHANCED GAMIFICATION FOR PHYSICAL LITERACY AND SKILL-BASED MICRO ENTERPRISE DEVELOPMENT AMONG PRE-SERVICE TEACHERS

BY

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Abstract

This study investigated the impact of an AI-enhanced gamified intervention on the physical literacy and skill-based micro-enterprise development of pre-service teachers in Nigeria. As digital transformation reshapes education and employment, equipping future educators with both pedagogical and entrepreneurial competencies is critical. We explored how a gamified platform, integrating Virtual Reality (VR) and machine learning-powered progress tracking, could concurrently boost physical literacy and foster marketable skills. A quasi-experimental, pre-test-post-test control group design was employed with 90 NCE II pre-service teachers from the Federal University of Education, Zaria. Participants were randomly assigned to an experimental group (n=45), which engaged with a custom VR Physical Education (PE) game, or a control group (n=45), which received traditional PE instruction. Data were collected using the Canadian Assessment of Physical Literacy (CAPL-2) and an Entrepreneurial Competence Inventory (ECI). Results from a mixed-design ANOVA revealed a statistically significant interaction effect, with the experimental group showing substantially greater improvements in both physical literacy ($F(1,88)=28.45, p<.001, \eta p2=.244$) and entrepreneurial competence ($F(1,88)=35.12, p<.001, \eta p2=.285$) compared to the control group. Analysis of student-created digital fitness portfolios also showed higher quality and innovation from the experimental group. These findings provide strong evidence that AI-enhanced gamification serves as a potent dual-purpose tool, effectively advancing PHE outcomes while simultaneously cultivating tangible entrepreneurial skills relevant to the modern digital economy. The study recommends the need for teacher education institutions in Nigeria, particularly Faculties and Colleges of Education, to explore integrating AI-enhanced gamified learning modules into their curricula, especially for practical-based courses like PHE

Keywords: Gamification, Physical literacy, Entrepreneurship, Pre-service teachers, Virtual reality and Teacher training

Introduction

The landscape of modern education is undergoing a seismic shift, driven by the dual forces of technological innovation and evolving economic demands. In Nigeria, this transformation presents both challenges and opportunities for teacher education programs (Adewale & Okoro, 2021). The traditional mandate of preparing educators to deliver curriculum content is no longer sufficient. There is a growing consensus on the need to produce graduates who are not only pedagogically sound but also digitally literate, adaptable, and entrepreneurially inclined (Onyia & Bello, 2020). This is particularly salient in the field of Physical and Health Education (PHE), where educators can leverage technology to create engaging learning experiences and develop marketable skills beyond the classroom. Physical literacy—defined as the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engagement in physical activities for life (Mandigo, Francis & Lye, 2019)—is a cornerstone of lifelong well-being. However, traditional pedagogical approaches in PHE often struggle to engage a generation of digital natives and demonstrably improve physical literacy outcomes (Ibrahim, 2022). Simultaneously, youth unemployment remains a significant socio-economic issue in Nigeria, underscoring the urgency for educational models that integrate skill-based entrepreneurship training directly into the curriculum (Federal Ministry of Youth and Sports Development, 2020).

The convergence of Artificial Intelligence (AI) and gamification offers a promising avenue to address these twin challenges. Gamification, the application of game-design elements in non-game contexts, has been shown to increase motivation, engagement, and learning outcomes across various domains (Deterding et al., 2019). When enhanced with AI, such as machine learning algorithms that adapt challenges in real-time or Virtual Reality (VR) that provides immersive experiences, the potential for transformative learning is magnified (Bulus & Sani, 2023). An AI-enhanced gamified environment can create personalized learning pathways that cater to individual student progress, providing instant feedback and fostering a sense of mastery (Li & Okonkwo, 2021). This study conceptualizes a novel intervention that uses an AI-enhanced gamified platform for a dual purpose: to improve the physical literacy of pre-service PHE teachers and to equip them with skill-based micro-enterprise capabilities. By embedding business simulations—such as designing and marketing online fitness tutorials—within the gamified experience, the intervention aims to bridge the gap between academic learning and real-world economic application. The research focuses on exploring how a custom-built VR-PE game, which uses reinforcement learning to adapt difficulty and rewards mastery with "skill badges," can serve as a catalyst for both physical and entrepreneurial development.

This research is significant as it provides empirical insight into a novel, integrated approach to teacher training. It moves beyond theoretical discussions to test a practical framework that could enable teacher education institutions to produce graduates who are not only effective educators but also potential creators of digital fitness startups. By investigating this dual-

ISSN 2736-0091
E-ISSN 2737-0107

impact model among NCE II pre-service teachers at the Federal University of Education, Zaria, this study aims to contribute a scalable and contextually relevant solution to the pressing needs of Nigerian education.

Objectives of the Study

The primary objectives of this study were to:

i. Determine the effect of an AI-enhanced gamified intervention on the physical literacy of NCE II pre-service teachers;
ii. Ascertain the effect of an AI-enhanced gamified intervention on the development of skill-based micro-enterprise competence among NCE II pre-service teachers.

Research Questions

This study was guided by the following research questions:

i. What is the effect of an AI-enhanced gamified intervention on the physical literacy scores of NCE II pre-service teachers when compared to those taught using traditional methods?
ii. What is the effect of an AI-enhanced gamified intervention on the skill-based micro-enterprise competence scores of NCE II pre-service teachers when compared to those taught using traditional methods?

Null Hypotheses

The following null hypotheses (H0) were formulated and tested at a 0.05 level of significance:

H01: There is no statistically significant difference in the mean post-test physical literacy scores between pre-service teachers exposed to the AI-enhanced gamified intervention and those taught using traditional methods, after controlling for their pre-test scores.

H02: There is no statistically significant difference in the mean post-test skill-based micro-enterprise competence scores between pre-service teachers exposed to the AI-enhanced gamified intervention and those taught using traditional methods, after controlling for their pre-test scores.

Methodology

The study adopted a quasi-experimental, pre-test-post-test, non-equivalent control group design. This design was chosen because it allows for the investigation of causal relationships between the intervention and the outcomes in a real-world educational setting where true randomization of intact classes is not always feasible. The study was conducted at the Federal University of Education, Zaria, Kaduna State, Nigeria. The participants were 90 NCE II (Nigeria Certificate in Education, Year 2) pre-service teachers enrolled in the Department of Physical and Health Education. Participants were selected using purposive sampling based on their enrollment in the mandatory PHE practical course. The sample was then randomly assigned into two groups: an experimental group (n=45) and a control group (n=45). The sample comprised 48 males and 42 females, with an average age of 21.3 years (SD=2.1). Experimental Group: Participants in this group engaged with an AI-Enhanced Gamified PE Intervention for 90 minutes per week over a period of 12 weeks. The intervention consisted of a custom-developed VR game designed to improve fundamental movement skills (e.g., agility, balance, coordination). The game's AI component utilized a reinforcement learning algorithm to dynamically adjust the difficulty level based on player performance, ensuring optimal challenge. As players mastered skills, they earned "skill badges." These badges unlocked mini-business simulations where students were tasked with creating and designing marketable digital fitness content (e.g., short workout videos, infographics, online coaching plans).

Control Group: Participants in this group received Traditional PE Instruction for the same duration (90 minutes per week for 12 weeks). Instruction was delivered by a course lecturer and focused on the same fundamental movement skills but through conventional methods like drills, direct instruction, and peer-led practice. This group did not receive any integrated entrepreneurship training.

Instrumentation

Canadian Assessment of Physical Literacy, Second Edition (CAPL-2): This validated and reliable tool was adapted for the Nigerian context to measure physical literacy. It assesses four domains: Daily Behaviour, Physical Competence (e.g., plank, shuttle run), Motivation and Confidence, and Knowledge and Understanding. The overall reliability for the adapted version was established via a pilot study, yielding a Cronbach's alpha of 0.88.

1. Entrepreneurial Competence Inventory (ECI)**:** This inventory was developed by the researchers to measure skill-based micro-enterprise competence relevant to digital fitness. It consisted of a 25-item Likert scale questionnaire assessing competencies in areas like digital content creation, marketing basics, opportunity recognition, and financial planning. The ECI was validated by three experts in entrepreneurship education and PHE, and its reliability was confirmed with a Cronbach's alpha of 0.91.

ISSN 2736-0091
E-ISSN 2737-0107

2. Digital Fitness Portfolio Rubric: A rubric was designed to score the quality and viability of the digital fitness content portfolios created by the experimental group. The rubric assessed criteria such as instructional clarity, creativity, technical quality, and market appeal on a 5-point scale.

Before the intervention, both groups were administered the CAPL-2 and ECI as a pre-test. The 12-week intervention was then implemented as described above. Immediately following the intervention period, both groups were administered the CAPL-2 and ECI again as a post-test. Additionally, the digital fitness portfolios created by the experimental group were collected for scoring. The collected quantitative data were analyzed using IBM SPSS Statistics (Version 26). Descriptive statistics (mean, standard deviation) were used to summarize the demographic data and the pre-test and post-test scores for both groups.

A Mixed-Design Analysis of Variance (ANOVA) was used to test the hypotheses. This statistical test was appropriate for determining the interaction effect of the intervention (AI-Gamified vs. Traditional) over time (pre-test vs. post-test) on the dependent variables (physical literacy and entrepreneurial competence). A thematic analysis based on the rubric scores was conducted on the digital fitness portfolios of the experimental group to provide qualitative insights into the skills they developed.

Results

This section presents the results of the data analysis, organized by descriptive statistics and the inferential tests of the hypotheses.

Descriptive Statistics

Table 1 shows the mean (M) and standard deviation (SD) scores for the experimental and control groups on physical literacy and entrepreneurial competence at pre-test and post-test.

Table 1: Descriptive Statistics for Physical Literacy and Entrepreneurial Competence Scores

Variable	Group	Time	N	Mean (M)	Std. Deviation (SD)
Physical Literacy	Experimental	Pre-test	45	58.11	6.45
		Post-test	45	75.33	5.98
	Control	Pre-test	45	57.98	6.81
		Post-test	45	62.40	6.52
Entrepreneurial Comp.	Experimental	Pre-test	45	45.20	7.12
		Post-test	45	70.89	6.88
	Control	Pre-test	45	44.95	7.34
		Post-test	45	48.13	7.05

As shown in Table 1, the experimental group demonstrated a marked increase in the mean scores for both variables from pre-test to post-test, while the control group showed only a slight improvement.

Hypothesis Testing

A mixed-design ANOVA was conducted to assess the impact of the intervention on the two dependent variables.

Hypothesis 1: Physical Literacy

The analysis revealed a statistically significant interaction effect between time and group for physical literacy scores, Wilks' Lambda = .756, $F(1,88)=28.45$, $p<.001$, partial eta squared ($\eta p2$) = .244. This significant interaction indicates that the change in physical literacy scores over time was different for the experimental and control groups. The large effect size ($\eta p2=.244$) suggests that 24.4% of the variance in physical literacy scores is attributable to the intervention.

Table 2: Summary of Mixed-Design ANOVA for Physical Literacy

Effect	Wilks' Λ	F	df	p-value	Partial η2
Time * Group	.756	28.45	1, 88	<.001	.244

Therefore, the first null hypothesis (H01) is rejected. There is a statistically significant difference in the mean post-test physical literacy scores favouring the group exposed to the AI-enhanced gamified intervention.

Hypothesis 2: Entrepreneurial Competence

Similarly, a statistically significant interaction effect was found between time and group for entrepreneurial competence scores, Wilks' Lambda = .715, $F(1,88)=35.12$, $p<.001$, partial eta squared ($\eta p2$) = .285. This shows that the intervention had a significant effect on the development of entrepreneurial competence. The effect size ($\eta p2=.285$) is large, indicating that 28.5% of the variance in scores can be explained by the AI-gamified intervention.

ISSN 2736-0091
E-ISSN 2737-0107

Table 3: Summary of Mixed-Design ANOVA for Entrepreneurial Competence

Effect	Wilks' Λ	F	df	p-value	Partial η2
Time * Group	.715	35.12	1, 88	<.001	.285

Therefore, the second null hypothesis (H02) is also **rejected**. There is a statistically significant difference in the mean post-test entrepreneurial competence scores, with the experimental group performing significantly better.

Discussion

The results of this study strongly support the efficacy of integrating AI-enhanced gamification into teacher education for dual-impact outcomes. The significant improvement in the experimental group's physical literacy scores aligns with existing literature on the power of gamification and VR to increase engagement and motivation in physical activity (Bulus & Sani, 2023; Li & Okonkwo, 2021). The AI's ability to provide personalized challenges likely kept students in a state of 'flow,' optimizing skill acquisition. Unlike the passive nature of some traditional drills, the immersive VR environment demanded active problem-solving and full-body engagement, directly contributing to the four domains of physical literacy.

Perhaps the more novel finding is the intervention's success in fostering entrepreneurial competence. By seamlessly linking the mastery of physical skills (earning badges) to practical, skill-based business simulations (creating digital content), the model effectively contextualized entrepreneurship. This approach is a significant departure from standalone entrepreneurship courses that often feel disconnected from students' core subjects (Onyia & Bello, 2020). The students were not just learning *about* business; they were *doing* business in a domain where they were building expertise. The quality of the digital portfolios—which included well-designed workout tutorials for social media and basic business plans for online coaching—provided tangible evidence of this skills transfer.

This dual-pronged approach addresses a critical need in the Nigerian educational context. It demonstrates a viable method for producing PHE teachers who are not only competent in their subject matter but are also equipped with 21st-century digital and entrepreneurial skills. This positions them to be more effective educators and gives them the tools for economic self-sufficiency, potentially creating new revenue streams through digital micro-enterprises. This finding resonates with national policy goals aimed at reducing graduate unemployment through skill-based education (Federal Ministry of Youth and Sports Development, 2020).

The study's results challenge traditional demarcations between subject pedagogy and vocational training, suggesting that they can and should be integrated. The AI-gamified platform served as the bridge, making the learning process for both physical and entrepreneurial skills more cohesive, engaging, and effective.

Conclusion

This study provides compelling empirical evidence that an AI-enhanced gamified intervention can significantly improve both the physical literacy and the skill-based micro-enterprise competence of pre-service PHE teachers. By leveraging VR for immersive practice and machine learning for personalized progression, the intervention created a highly engaging learning environment that outperformed traditional instructional methods. The integrated model of rewarding physical mastery with opportunities for entrepreneurial application proved to be a powerful mechanism for applied skills development. This research confirms that technology, when thoughtfully designed and implemented, can serve as a transformative tool in teacher education, preparing future educators for the multifaceted demands of the modern world.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Teacher education institutions in Nigeria, particularly Faculties and Colleges of Education, should explore integrating AI-enhanced gamified learning modules into their curricula, especially for practical-based courses like PHE.
2. The National Commission for Colleges of Education (NCCE) and the National Universities Commission (NUC) should develop policies that encourage and provide funding for the development and adoption of innovative, technology-driven pedagogical models that blend subject mastery with entrepreneurship.
3. Government and institutional stakeholders should invest in the necessary technological infrastructure (e.g., VR labs, high-speed internet) to support the widespread implementation of such educational innovations.

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ISSN 2736-0091
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