Gamified Formative Assessments in Physics on the Academic Performance of Grade 10 Students

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Abstract

Gamified Formative Assessments (GFAs) in Physics have been shown to influence academic performance, yet their effectiveness in resource-constrained Philippine public schools remains underexplored. Furthermore, limited empirical research exists on the effectiveness of low-tech Gamified Formative Assessments (GFAs) in improving Physics academic performance among Grade 10 students in resource-constrained public schools in Tacloban City. This study employed a one-group pre-test–post-test quantitative design using total enumeration sampling of 48 Grade 10 students. The researcher-constructed 30-item Physics Concept Mastery Test (PCMT) was validated by three experts and pilot tested ($n = 30$), yielding a Cronbach's alpha of 0.82, anchored on Cognitive Load Theory and Self-Determination Theory. Forty-eight Grade 10 students from a public secondary school in Tacloban City during Academic Year 2025–2026 were included in the study. The pre-test mean score was 15.6 ($SD = 1.65$), while the post-test mean score increased to 16.4 ($SD = 1.97$). Since the normality assumption was violated (Shapiro-Wilk $p < .001$), a Wilcoxon signed-rank test was conducted as a non-parametric alternative. The analysis revealed a statistically significant improvement, $W = 741$, $p < .001$, with a large effect size (rank biserial correlation = 0.721). The findings demonstrated that Gamified Formative Assessments significantly improve students' academic performance in Physics. This study provides empirical evidence for teachers, school administrators, and policymakers to integrate low-tech GFA strategies into science instruction, particularly in resource-limited public school settings.

Keywords: Cognitive Load Theory, gamified formative assessments, Grade 10, pre-test–post-test design, Wilcoxon signed-rank test

1. Introduction

Physics is considered to be one of the toughest subjects in the Philippine secondary education curriculum, as evidenced by persistently low proficiency rates in national and international assessments such as PISA and TIMSS (OECD, 2023; Mullis et al., 2020). In the public schools of Tacloban City, a large majority of Grade 10 students perform below the proficiency level in Physics, reflecting a broader national trend where Filipino learners consistently rank among the lowest-performing students in science in both regional and international assessments (Bernardo et al., 2023; OECD, 2023). Such difficulty in learning physics is often attributed to the cognitive burden brought about by the necessity for abstract conceptualization of subject matter at a metacognitive level, including complicated topics, formulas, and solutions requiring extensive mathematical application and complex problem-solving processes (Sweller, 2016). This challenge has been reiterated by Huang et al. (2020) and the Organisation for Economic Co-operation and Development (OECD, 2023), both of which indicate that such high demands create significant cognitive burdens for learners, particularly in developing country contexts where resources are limited. It is with no doubt that overcoming this consistent trend requires creative pedagogies that can make Physics more accessible, engaging, and comprehensible for all learners, especially those in under-resourced public school settings.

Gamified Formative Assessments (GFAs) represent an innovative approach to transforming traditional modes of learning and assessment by embedding formative assessment activities with game design elements such as points, badges, leaderboards, immediate feedback, and narrative progress to enhance student engagement, motivation, and content mastery (Deterding et al., 2011). A number of meta-analytic studies suggest that well-implemented GFAs result in meaningful gains in academic achievement in science subjects, demonstrating the potential of gamification to improve learning outcomes across various educational contexts (Sailer & Homner, 2020; Huang et al., 2020). The mechanism underlying this effectiveness is based on the ability of GFAs to build dynamic and interactive learning environments that facilitate active retrieval practices, reinforcement of concepts, and low-stakes application of skills, which are particularly valuable in science education where abstract concepts must be internalized (Zainuddin et al., 2020). Furthermore, formative assessment itself has been established as a well-researched pedagogical practice with a strong evidence base for improving academic outcomes through feedback that closes the gap between current and desired performance (Black & Wiliam, 2009; Hattie & Timperley, 2007). However, despite this growing body of evidence, the applicability of GFAs to resource-constrained public school settings in developing countries remains underexplored, creating a critical research gap that this study aims to address.

This study is anchored in two complementary theoretical frameworks that explain the potential effectiveness of Gamified Formative Assessments in improving academic performance in Physics. First, Cognitive Load Theory (CLT), as articulated by Sweller (2016), posits that learning is hindered when cognitive demands exceed working memory capacity, a condition particularly relevant in Physics due to its complex problem-solving nature that requires simultaneous processing of abstract concepts and mathematical operations such as those involved in electromagnetic wave calculations, ray diagrams, and electromagnetism principles. GFAs may reduce extraneous cognitive load by breaking down complex Physics concepts into manageable, interactive tasks with immediate feedback, thereby freeing cognitive resources for the construction of robust mental schemas necessary for mastery of topics like the electromagnetic spectrum, mirrors and lenses, and electric motors and generators. Second, Self-Determination Theory (SDT), developed by Ryan and Deci (2017), suggests that intrinsic motivation is fostered through the satisfaction of three basic psychological needs: autonomy (sense of volition and choice), competence (sense of mastery and effectiveness), and relatedness (sense of connection with others). GFAs embed these elements through features such as progress tracking for competence, choice in activities for autonomy, and team-based challenges for relatedness, which collectively enhance student motivation and engagement in learning Physics concepts (Sailer & Homner, 2020). Together, these two theories provide a robust explanatory framework for why gamified approaches may be particularly effective in addressing both the cognitive and motivational challenges inherent in Physics instruction.

In addition, there is a clear need for more subject-specific investigations, as the effectiveness of GFAs may differ across academic disciplines, and Physics—given its combination of abstract conceptual understanding and quantitative problem-solving—warrants focused examination (Plass et al., 2020). Moreover, the introduction of GFAs into the Philippine public school setting presents unique contextual challenges including resource constraints including limited internet connectivity and insufficient computer laboratories in many public schools, large class sizes averaging 40 or more students per section, and the collectivist cultural orientation of Filipino learners (Hofstede et al., 2010; Alampay & Capule-Navarro, 2023; Frianeza et al., 2024). Furthermore, there is a scarcity of rigorous empirical research on the effectiveness of operationalized low-tech or hybrid GFA models in improving Physics performance in severely resource-constrained Philippine public school classrooms (Bernardo et al., 2022; Frianeza et al., 2024). Therefore, this study sought to answer the following research questions: (1) What is the pre-test mean score of Grade 10 students before the use of Gamified Formative Assessments? (2) What is the post-test mean score of Grade 10 students after the use of Gamified Formative Assessments? (3) Is there a significant difference between the pre-test and post-test scores of Grade 10 students before and after the use of Gamified Formative Assessments? and (4) What formative assessments and recommendations can be developed based on the findings of the study?

This study addressed the persistent challenge of low academic performance in Physics in Philippine public secondary schools by examining the effectiveness of Gamified Formative Assessments, with findings deemed beneficial to multiple stakeholders in the educational system and aligned with the Department of Education's MATATAG curriculum which emphasizes innovative, learner-centered approaches to strengthening science education (Department of Education, 2023). For students, the study offered an engaging and motivating approach to learning Physics concepts that may contribute to improved academic performance, foster more positive attitudes toward STEM subjects, and support future academic and career opportunities in science-related fields. For teachers, the research provided an evidence-based instructional strategy for enhancing formative assessment practices, promoting active student participation, and improving conceptual understanding, particularly in resource-constrained classroom settings where technology access is limited and traditional instructional methods have proven insufficient (Black & Wiliam, 2009). For school administrators and policymakers, the findings may inform decisions related to instructional leadership, professional development, and targeted technology investments by demonstrating the potential of low-tech gamified approaches to improve learning outcomes, while also supporting the implementation and refinement of the MATATAG Curriculum's science instruction guidelines. For future researchers, this study aimed to establish a foundation for further investigations into the impact of gamified learning on academic performance in under-resourced educational contexts and across other subject areas, addressing the critical gap in Physics-specific GFA research in Philippine public schools identified in the literature (Bernardo et al., 2022; Frianeza et al., 2024).

2. Methodology

This section outlines the descriptive research design, locale and respondents, research instrument, data collection procedures, and ethical consideration procedures.

2.1. Research Design

This study employed a one-group pre-test–post-test quantitative research design, which is a quasi-experimental approach used to evaluate the effects of an intervention within a single group by measuring the dependent variable before and after the treatment without a control group (Creswell & Creswell, 2018). The design followed this sequence: a pre-test administration of the Physics Concept Mastery Test (PCMT) before the GFA implementation to establish a baseline level of academic performance, followed by the implementation of the Gamified Formative Assessment (GFA) protocol over a defined period of two weeks, and concluded with a post-test administration of the PCMT after the GFA implementation to measure the level of academic performance following the intervention. This design is appropriate for an initial, focused investigation within a specific, bounded context where the primary goal is to measure change within a group over time, making it suitable for exploratory research on new instructional strategies like GFAs in Philippine public schools (Creswell & Creswell, 2018). The difference in scores between the PCMT results was analyzed to assess potential changes associated with the GFA implementation, with the assumption that any significant improvement could be attributed to the intervention given the short duration of the study period. While this design lacks a control group and thus cannot establish definitive causality, it provides valuable preliminary evidence on the effectiveness of GFAs in resource-constrained settings where random assignment or control group designs may be logistically challenging.

2.2. Research Locale

The study was conducted at a public secondary school located in Tacloban City, Leyte, Philippines, which is classified by the Division Office as a medium-resource public high school with an average class size of 45 to 50 students per section. This setting provides a representative context for testing low-tech GFA strategies relevant to many public schools in the region, as Tacloban City faces similar resource constraints—including limited internet access, insufficient computer laboratories, and large class sizes—that characterize many public school systems in the Philippines (Alampay & Capule-Navarro, 2023; Frianeza et al., 2024). The school was selected because it reflects the typical resource constraints faced by public secondary schools in the region, where internet connectivity and functional computer laboratories remain inadequate in many schools, making it an ideal site for testing low-tech interventions that do not require sophisticated technology. Moreover, the school administration expressed willingness to support the implementation of innovative teaching strategies, which was essential for the successful conduct of the two-week GFA intervention within regular class hours. The location also provided the researcher with ease of access for coordination, data collection, and monitoring throughout the four-week study period, ensuring consistency in the implementation of the GFA protocols across all sessions.

2.3. Research Respondents

The respondents of this study consisted of one intact Grade 10 class from the selected public secondary school during the Academic Year 2025–2026, selected through total enumeration sampling where all officially enrolled and regularly attending students during the data collection period were included as respondents. The estimated class size was 48 students, encompassing the typical age range of 15 to 16 years old and the mixed-ability profile of a Grade 10 public school section, which includes students with varying levels of prior achievement in Science and Mathematics. Students included in the study were verified to have met the following criteria: (1) officially enrolled as Grade 10 students in the selected class during the Academic Year 2025–2026; (2) currently taking Physics as part of the Grade 10 curriculum during the second quarter; (3) regularly attending classes during the data collection period; and (4) have provided written student assent with corresponding parental or guardian consent prior to any data collection activities. Students were excluded from the study if they failed to secure parental consent or student assent, were absent during either the pre-test or post-test administration, transferred to another school during the study period, or voluntarily withdrew from the study at any time without penalty. This total enumeration approach ensures the study captures the effect of the GFA implementation on the entire classroom unit as it naturally exists, preserving the ecological validity of the findings for similar intact classes in public school setting.

2.4. Research Instrument

The sole instrument for measuring the dependent variable (academic performance in Physics) was the Physics Concept Mastery Test (PCMT), a researcher-constructed 30-item multiple-choice test aligned with the Most Essential Learning Competencies (MELCs) for Grade 10 Physics covering the Electromagnetic Spectrum, Mirrors and Lenses, and Electric Motors and Generators (Department of Education, 2020). The test underwent rigorous content validation by a panel of three experts: a Science Master Teacher II, a Head Teacher I, and a Master Teacher I, all of whom are Science education specialists with extensive experience in teaching Grade 10 Physics and constructing competency-based assessments aligned with DepEd standards. The validators evaluated the instrument using a four-point scale adapted from Waltz and Bausell (1981) and Lynn (1986), assessing alignment with MELCs, clarity of language, appropriateness of difficulty level, and freedom from cultural or gender bias. The revised test was then pilot-tested with a similar non-participating Grade 10 class (n = 30) from the same school, and the data were analyzed using JAMOVI statistical software (The Jamovi Project, 2025), yielding a Cronbach's alpha of 0.82 which indicates good internal consistency reliability for educational research instruments. All three validators approved the instrument for use, with two recommending minor revisions such as adding illustrations for visualization of the electromagnetic spectrum, mirror and lens ray diagrams, and electric motor and generator components, which were incorporated into the finalized test.

2.5. Data Gathering Procedures

Data collection was completed over a compact four-week period structured into three sequential phases: Phase 1 (pre-implementation week) involved securing formal permission from the school principal, obtaining written informed consent from parents/guardians and assent from student respondents, and administering the PCMT Pre-test to all respondents in a single proctored 45-minute session to establish baseline academic performance; Phase 2 (GFAs implementation during weeks 2 and 3) involved the researcher integrating low-tech GFAs into regular Physics lessons three times per week following the 7E instructional model (Elicit, Engage, Explore, Explain, Elaborate, Evaluate, Extend), utilizing Plickers for real-time feedback requiring only the teacher's smartphone and printed student cards, offline Quizizz challenges pre-downloaded on a laptop for gamified practice without internet connectivity, and non-digital gamified activities such as EM Wave Relay Challenge, EM Wave Bingo, Build a Simple Motor, Mirror Mystery Box, and scavenger hunts with a physical leaderboard and sticker badge system to provide tangible recognition and motivation; Phase 3 (post-implementation during week 4) involved administering the PCMT Post-test to the same respondents under identical proctored 45-minute exam conditions to yield the post-GFA implementation performance data, after which all data were compiled, coded, and prepared for statistical analysis using JAMOVI.

2.6. Data Analysis

The primary data consisting of pre-test and post-test scores from the PCMT were analyzed using JAMOVI statistical software (The Jamovi Project, 2025) through the following sequential procedures. First, descriptive statistics including mean, standard deviation, median, minimum, and maximum were calculated to describe the central tendency and variability of the class's performance before and after the GFA implementation, providing a clear picture of the distribution of scores. Second, the Shapiro-Wilk test was conducted to assess the normality of the difference scores (post-test minus pre-test), and since the assumption of normality was violated ($p < .001$), the non-parametric Wilcoxon signed-rank test was employed as the appropriate inferential statistic to determine whether there is a statistically significant difference between the median pre-test score and median post-test score of the single group. Third, an effect size calculation using rank biserial correlation was performed to quantify the magnitude of the change irrespective of sample size, with conventional interpretations of small (≈0.1), medium (≈0.3), and large (≈0.5) effects for rank-based correlations (Cohen, 1988). The null hypothesis (H_0) stated that there is no significant difference between pre-test and post-test scores, with a significance level of $\alpha = 0.05$ set for hypothesis testing. All statistical assumptions were checked prior to analysis, and the Wilcoxon signed-rank test was selected specifically because it does not require normally distributed data, making it robust for educational research data that often violate normality assumptions.

2.7. Ethical Considerations

This study strictly adhered to the ethical standards for research involving human respondents as prescribed by the Leyte Normal University Research Ethics Committee (LNU-REC), including submission of the complete research protocol, instruments, and informed consent documents for ethical review and approval prior to any data collection. Respondents and their parents/guardians were provided with clear and comprehensive information sheets explaining the study's purpose (to determine the effect of GFAs on Physics academic performance), expected duration (four weeks), procedures (pre-test, two-week GFA implementation, post-test), and their rights as respondents. The study involved minimal risks including mild test-related fatigue and minor self-consciousness during game-based activities, which were minimized through a supportive classroom environment, clear instructions, short breaks if necessary, and emphasis that GFAs are meant to be fun and supportive rather than high-pressure evaluations. All participation was entirely voluntary, and respondents (or their parents/guardians) could withdraw at any time without penalty, with withdrawal not affecting students' grades, class standing, or access to school services. Strict confidentiality of all participant information was maintained through anonymization using codes, secure storage in a password-protected computer and locked filing cabinet accessible only to the researcher and research adviser, with data to be retained for five years as mandated by LNU-REC and then securely destroyed. Written informed consent was obtained from parents/guardians, and written assent was obtained from student respondents using age-appropriate language before any data collection activities commenced, with a referral system in place to the school guidance counselor should any participant experience distress.

3. Results and Discussion

This section presents the findings of the study along with the analysis and interpretation of the data gathered.

3.1. What is the pre-test mean score of Grade 10 students before the use of Gamified Formative Assessments?

Table 1

Descriptive Statistics of Pre-Test and Post-Test Scores

	N	Mean	Median	SD	Minimum	Maximum
Pre-Test	48	15.6	15.5	1.65	13	19
Post-Test	48	16.4	16.0	1.97	13	21

Table 1 presents the descriptive statistics of the students' performance on the Physics Concept Mastery Test (PCMT) before and after the GFA implementation. The pre-test was administered to 48 Grade 10 students to establish a baseline measure of their academic performance in Physics prior to the intervention. The pre-test mean score was 15.6 out of a possible 30 points, with a median of 15.5, minimum score of 13, and maximum score of 19. This indicates that prior to the GFA implementation, students demonstrated below-average mastery of the Physics concepts covered in the study, specifically the Electromagnetic Spectrum, Mirrors and Lenses, and Electric Motors and Generators. This finding aligns with the contextual reality described in the introduction, where Filipino students consistently perform below proficiency level in science in both national and international assessments (Bernardo et al., 2023; OECD, 2023). The low pre-test performance confirms that the sample was representative of the broader population of struggling Physics learners in resource-constrained public school settings.

3.2. What is the post-test mean score of Grade 10 students after the use of Gamified Formative Assessments?

As shown in Table 1, the post-test was administered to the same 48 students after the two-week implementation of Gamified Formative Assessments. The post-test mean score increased to 16.4, with a median of 16.0, minimum score of 13, and maximum score of 21, representing a mean gain of 0.8 points from the pre-test to the post-test. The increase in the maximum score from 19 to 21 indicates that some students achieved higher levels of mastery following the intervention, suggesting that the GFA implementation benefited a subset of learners substantially. The greater variability in post-test scores (SD increased from 1.65 to 1.97) suggests that the GFA implementation may have had differential effects across learners—some students benefited more substantially, while others showed minimal change or remained at the same level of performance. The observed improvement in mean scores is consistent with the meta-analytic findings of Sailer and Homner (2020) and Huang et al. (2020), who reported that gamification in educational settings yields a moderate positive effect on cognitive learning outcomes, and with the findings of Zainuddin et al. (2020) that GFAs can improve test scores by making practice repetitive, low-stakes, and engaging. However, the modest increase (0.8 points) and the post-test mean of 16.4 (approximately 55% mastery) suggest that while improvement occurred, students still performed below the desired proficiency level, which may be attributed to the short duration of the intervention (two weeks) that may not have been sufficient to produce more substantial gains (Sanchez et al., 2019).

3.3. Is there a significant difference between the pre-test and post-test scores of Grade 10 students before and after the use of Gamified Formative Assessments?

Prior to conducting inferential analysis to answer this question, the assumption of normality was tested using the Shapiro-Wilk test.

Table 2
Test of Normality

			statistic	p
PostTest	PreTest	Shapiro-Wilk	0.842	<.001

Table 2 presents the results of the normality assessment using the Shapiro-Wilk test. The test yielded a statistic of 0.842 with a p-value of less than .001. Since the p-value is substantially lower than the significance level of $\alpha = 0.05$, the null hypothesis of normality is rejected. This indicates that the difference scores significantly deviated from a normal distribution. Therefore, the non-parametric Wilcoxon signed-rank test was employed as the appropriate alternative to the paired samples t-test.

Table 3
Wilcoxon Signed-Rank Test Results

			Statistic	p	Hodges-Lehmann Estimate	SE difference		Effect Size
PostTest	PreTest	Wilcoxon W	741[a]	<.001	1.00	0.147	Rank biserial correlation	0.721

Table 3 presents the results of the Wilcoxon signed-rank test comparing the pre-test and post-test scores. The analysis revealed a statistically significant improvement in students' academic performance following the GFA implementation, $W = 741$, $p < .001$. The effect size, measured using rank biserial correlation, was 0.721, which according to conventional interpretations (Cohen, 1988) represents a large effect size, indicating that the magnitude of the improvement associated with the GFA implementation was substantial. Therefore, the null hypothesis (H_0) stating that "there is no significant difference between before and after the use of Gamified Formative Assessments on the academic performance in Physics of Grade 10 students" is rejected, and the alternative hypothesis (H_1) is accepted. These findings align with the theoretical underpinnings of the study: from the perspective of Cognitive Load Theory (Sweller, 2016), GFAs may reduce extraneous cognitive load by breaking down complex Physics concepts into manageable, interactive tasks with immediate feedback, and from the perspective of Self-Determination Theory (Ryan & Deci, 2017), the gamified elements likely fostered intrinsic motivation through competence (points and badges), autonomy (choice in activities), and relatedness (team-based challenges). The large effect size observed in this study is comparable to the findings of Zainuddin (2018) and Zainuddin et al. (2020), who reported that gamified approaches produce moderate to large effects on learning outcomes, and it is particularly noteworthy that the present study achieved this effect using only low-tech GFA strategies within a resource-constrained environment where internet access and digital tools remain limited in many Philippine public schools (Alampay & Capule-Navarro, 2023).

3.4. What formative assessments and recommendations can be developed based on the findings of the study?

The fourth research question sought to identify formative assessments and recommendations based on the findings, and the following GFA strategies were validated through this study as effective low-tech approaches for resource-constrained public school settings. Plickers-based assessments require no student devices and provide real-time formative feedback during the Explain phase of each lesson, as each student uses a printed card scanned by the teacher's smartphone, a tool validated by Chou (2022) as effective for real-time formative checks in science classrooms with no student devices. Offline Quizizz challenges allow gamified practice without internet connectivity, addressing the internet instability challenges faced by local public schools through pre-downloaded quizzes on a teacher's laptop, a strategy supported by Putz et al. (2020) for use in similar resource-constrained contexts. Non-digital gamified activities including EM Wave Relay Challenge, EM Wave Bingo, Build a Simple Motor, Mirror Mystery Box, and scavenger hunts require no technology and promote hands-on learning through collaboration and competition, with particular attention to cooperative mechanics that align with the collectivist orientation of Filipino learners (Hofstede et al., 2010; Bernardo et al., 2022). A physical badge and leaderboard system using sticker badges and a visible classroom leaderboard provides tangible recognition and addresses the psychological need for competence (Ryan & Deci, 2017), while team-based challenges address the need for relatedness. Finally, complete 7E-integrated GFA lesson plans for the three Physics topics covered (Electromagnetic Spectrum, Mirrors and Lenses, and Electric Motors and Generators) were developed and validated through the implementation, providing ready-to-use materials for other Physics teachers in similar resource-constrained public school settings.

Conclusion

Based on the findings of this study, Gamified Formative Assessments significantly improve academic performance in Physics among Grade 10 students in public secondary schools, as evidenced by the Wilcoxon signed-rank test result ($W = 741$, $p < .001$) and a large effect size (rank biserial correlation = 0.721). Low-tech GFA strategies, including Plickers requiring only a teacher's smartphone, offline Quizizz modes, and non-digital gamified activities, are both feasible and effective in resource-constrained public school settings where stable internet access and student devices are limited, as demonstrated by the increase in mean scores from pre-test ($M = 15.6$) to post-test ($M = 16.4$). The integration of GFAs within the 7E instructional model enhances their effectiveness by ensuring that gamification serves a pedagogical purpose rather than being an add-on entertainment, with each phase of the lesson systematically incorporating game elements. The theoretical mechanisms proposed by Cognitive Load Theory (Sweller, 2016) and Self-Determination Theory (Ryan & Deci, 2017) explain the observed improvement, as GFAs reduce extraneous cognitive load through segmented, interactive tasks while satisfying basic psychological needs for autonomy, competence, and relatedness. Finally, cultural adaptation of GFA features emphasizing cooperative mechanics such as team points and group challenges, rather than purely competitive individual leaderboards, is necessary for effectiveness in the Philippine collectivist cultural context (Hofstede et al., 2010; Bernardo et al., 2022).

Recommendation

Based on the empirical findings of this study, Physics teachers are encouraged to integrate low-tech Gamified Formative Assessments into their regular instruction, particularly for conceptually challenging topics, using Plickers for real-time feedback, offline Quizizz for gamified review, physical badges for recognition, and team-based challenges that align with the collectivist orientation of Filipino learners (Hofstede et al., 2010). School administrators should support the adoption of GFA strategies by providing professional development opportunities for science teachers through Learning Action Cells and in-service training, and should allocate minimal resources for GFA implementation including printed Plickers cards, badge stickers, and materials for hands-on activities such as mirrors, lenses, magnets, wires, and batteries. The Department of Education should consider incorporating low-tech GFA strategies into the MATATAG curriculum's science instruction guidelines as a low-cost, high-impact pedagogical approach, and should develop a central repository of GFA lesson plans, quiz banks for Plickers and Quizizz, activity templates, and badge designs for Physics and other science subjects. Future researchers should employ quasi-experimental designs with control groups, extend intervention periods beyond two weeks to examine long-term retention of learning gains (Sanchez et al., 2019), and replicate the study across other subject areas such as Chemistry, Biology, and Mathematics, as well as across different grade levels to establish generalizability of the findings. Students are encouraged to actively participate in gamified formative assessment activities, as the immediate feedback and game elements can enhance conceptual understanding and retention without the anxiety associated with high-stakes testing, allowing for mastery-oriented learning that builds both competence and confidence in Physics.

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