**Global Education Journal**
Vol. 3, 3 (September-December, 2025), pp. 671-684
EISSN: 2808-5094, DOI: 10.59525/gej.v3i3.1548

# Gamified Learning: Comparative Analysis of Quizizz vs. Manual Methods on Enhancing Students' Long-Term Memory Retention

**Ahmad Silmul Fuady[1], Faid Widyawan Ainur Rizky[1], Patra Yonan[1], Muhammad Rokib[1], Ahmad Yusup[1]**

[1] Sekolah Tinggi Agama Islam Nurul Abror Al Robbaniyin, Indonesia

**ARTICLE INFO**

***Keywords:***

Educational Gamification;
Quizizz;
Long-Term Memory Retention;
Digital Assessment;
Retrieval Practice;
Instructional Design;
Cognitive Engagement

***Article history:***

Received 2025-10-28
Revised 2025-11-26
Accepted 2025-12-31

**ABSTRACT**

Rapid expansion of digital pedagogy has intensified scholarly concern regarding the persistence of long-term memory retention within increasingly technology-mediated learning environments, particularly as conventional paper-based assessments continue to demonstrate vulnerability to accelerated cognitive decay associated with the forgetting curve. This investigation explores the comparative effectiveness of Quizizz and manual assessment methods in strengthening longitudinal mnemonic retention among secondary-level learners. Employing a quasi-experimental nonequivalent control group design, the study involved 64 participants divided into experimental and control cohorts across a four-week instructional intervention, followed by a 14-day delayed post-test interval to measure sustained recall stability. Empirical data reveal statistically significant differences between groups during both immediate and delayed retention assessments, with the experimental cohort demonstrating superior delayed recall performance ($t(62) = 8.14$, $p < 0.001$) and achieving a 93.38% retention rate compared to 84.13% within the manual cohort. The findings elucidate how interactive retrieval cycles, immediate feedback systems, and competitive engagement structures facilitate stronger cognitive consolidation and mitigate memory deterioration over time. The study ultimately underscores the necessity of reconfiguring assessment practices from static measurement procedures into digitally responsive reinforcement mechanisms capable of sustaining durable intellectual retention within contemporary instructional design frameworks.



**Corresponding Author:**
Ahmad Silmul Fuady
Sekolah Tinggi Agama Islam Nurul Abror Al Robbaniyin, Indonesia; ahmadfuady00@gmail.com

## 1. INTRODUCTION

Educational discourse across multiple regions has undergone a profound reconfiguration as digitally mediated instruction increasingly supersedes exclusively teacher-centred pedagogical traditions. Hybrid

platforms, adaptive learning ecosystems, and mobile-supported interactions have gradually altered how learners process information, negotiate meaning, and sustain academic engagement within formal educational environments (Gamero Mujica, 2022). Conventional classroom routines that once privileged passive reception now encounter growing pressure to cultivate participatory cognitive experiences capable of accommodating shortened attention spans and rapidly shifting informational behaviours (Bphed & Catharines, 2024). Alongside this transition, instructional designers have become increasingly attentive to the relationship between technological affordances and knowledge durability, particularly in environments where assessment practices remain heavily procedural rather than cognitively generative. Merely transferring content into digital formats no longer guarantees meaningful intellectual retention. Instead, pedagogical architecture must strategically orchestrate interaction, repetition, emotional stimulation, and retrieval practice. Such concerns inevitably direct scholarly attention toward a persistent educational dilemma: the fragility of long-term memory formation within conventional assessment structures.

Persistent concerns surrounding academic retention derive substantially from cognitive psychology, particularly research examining how rapidly acquired information deteriorates when reinforcement mechanisms remain absent. Ebbinghaus's forgetting curve demonstrated that unrehearsed knowledge frequently declines within remarkably short intervals, challenging assumptions that assessment completion necessarily reflects durable understanding (Wollstein & Jabbour, 2022). Within many classroom contexts, paper-based exercises continue to prioritise immediate correctness over mnemonic consolidation, causing learners to memorise isolated fragments rather than construct interconnected conceptual schemas (Costuchen, 2023). Equally problematic, delayed feedback cycles often prevent participants from identifying misconceptions while cognitive traces remain active, thereby weakening opportunities for retrieval strengthening and metacognitive correction (DiMarco, 2025). Although manual examinations preserve certain reflective advantages, their procedural rigidity occasionally suppresses motivational energy and sustained attentional investment. Questions therefore emerge regarding whether alternative evaluative environments capable of stimulating emotional involvement and repeated cognitive activation might better support longitudinal retention processes, particularly among digitally immersed learners accustomed to interactive feedback ecologies.

Within this evolving pedagogical landscape, gamification has attracted substantial scholarly interest not because it trivialises learning, but because it restructures motivational architecture through psychologically informed interaction patterns. Drawing upon principles associated with self-determination theory, behavioural reinforcement, and cognitive engagement, gamified systems frequently integrate challenge, reward anticipation, progress visualisation, and social participation to intensify intellectual investment (Warikoo, 2025). Rather than functioning merely as entertainment overlays, these mechanisms cultivate emotionally resonant learning conditions that encourage repeated retrieval activity and sustained attentional focus. Emerging investigations suggest that emotionally charged instructional experiences strengthen neural encoding pathways more effectively than passive exposure alone (Zhang et al., 2025). Particularly relevant for memory research, gamified environments frequently operationalise immediate response cycles that reinforce recall through continuous interaction rather than singular evaluation moments. Yet enthusiasm surrounding educational gamification occasionally exceeds analytical precision, since many implementations emphasise short-term engagement metrics without rigorously examining whether motivational stimulation genuinely translates into durable cognitive preservation across extended temporal intervals.

Among contemporary gamified platforms, Quizizz has emerged as a particularly influential instructional instrument due to its integration of competitive pacing, instant feedback mechanisms, visual reinforcement cues, and adaptive participation structures. Unlike static assessment sheets, the platform orchestrates a dynamic response environment where participants receive immediate confirmation, corrective explanations, and performance indicators capable of sustaining attentional momentum throughout evaluative activities (Spivakovsky et al., 2023). Timed interaction cycles encourage rapid retrieval practice, while leaderboards and point accumulation generate motivational tension that may

intensify cognitive alertness during learning episodes (Swargiary, 2024). Simultaneously, meme-based reactions, colour-coded interfaces, and audiovisual stimuli contribute additional mnemonic scaffolding by linking information processing with emotional and sensory associations. Such pedagogical affordances potentially transform assessment from a terminal measurement procedure into an active encoding experience. Despite these promising characteristics, uncertainty persists regarding whether the platform's interactive dynamics genuinely outperform manual paper-based approaches when evaluated through the narrower yet critically important lens of long-term memory retention.

Existing scholarship investigating gamified assessment frequently concentrates upon engagement enhancement, classroom enjoyment, participation frequency, or immediate performance improvement, while comparatively limited attention has addressed delayed recall outcomes across longitudinal instructional settings (Namaziandost & Çakmak, 2025). Even where comparative analyses appear, many studies position digital tools against generic traditional instruction without isolating manual paper-based assessment practices as a distinct evaluative counterpart (Nurohmah & Ma'rifah, 2025). This omission creates a significant methodological gap because handwritten exercises and printed examinations activate cognitive routines fundamentally different from screen-mediated interactions. Manual approaches often encourage reflective pacing and deeper textual processing, whereas gamified platforms stimulate rapid retrieval, emotional arousal, and repeated reinforcement cycles. Without direct comparison between these divergent cognitive architectures, assumptions regarding technological superiority remain theoretically incomplete. Equally concerning, several investigations rely upon immediate post-test measurements that inadequately capture whether encoded knowledge survives beyond short-term rehearsal periods (Zhou & Rose, 2025). Consequently, empirical clarification regarding the relative effectiveness of Quizizz and manual assessment methods for sustaining longitudinal retention remains urgently necessary within contemporary instructional design discourse.

Responding to these unresolved concerns, the present investigation aims to conduct a comparative analysis examining the effectiveness of Quizizz and manual paper-based methods in enhancing students' long-term memory retention within structured learning environments. Particular emphasis centres upon identifying how differing evaluative architectures influence delayed recall, cognitive reinforcement, and sustained conceptual preservation over time. By situating gamified interaction within broader theories of mnemonic scaffolding and retrieval practice, this research seeks to move beyond celebratory narratives surrounding educational technology toward a more evidence-oriented understanding of pedagogical efficacy (Thompson & Harris, 2025). The study also contributes to instructional design scholarship by interrogating whether motivational stimulation alone sufficiently strengthens durable learning outcomes or whether reflective manual processes retain underappreciated cognitive advantages. Given accelerating institutional investment in digital assessment ecosystems, findings from this inquiry possess significant implications for curriculum developers, educational technologists, and classroom practitioners seeking empirically grounded strategies capable of balancing engagement with enduring intellectual retention in increasingly digitised educational contexts.

## 2. METHODS

The study employed a quasi-experimental nonequivalent control group design to examine differential effects between gamified and manual assessment environments on students' long-term memory retention. Conducted within a secondary educational institution, the investigation involved N=64 participants enrolled in two intact classes possessing comparable academic characteristics based on prior semester achievement records and instructor recommendations. Because institutional scheduling constraints prevented random assignment at the individual level, purposive sampling procedures were utilized to designate one class as the experimental cohort (n=32) and the remaining class as the control cohort (n=32). To strengthen internal validity, both groups received identical instructional content, learning duration, curricular objectives, and teacher facilitation across a four-week intervention period. Demographic homogeneity concerning age range, academic exposure, and technological familiarity was additionally considered during participant selection procedures. Ethical clearance was obtained from the

institutional academic review committee, while informed consent documentation was secured from participants prior to data collection, ensuring confidentiality protection, voluntary participation, and unrestricted withdrawal rights throughout the longitudinal research process.

To operationalize the experimental treatment, the gamified assessment environment integrated through Quizizz incorporated multiple engagement mechanics designed to stimulate retrieval practice and sustained cognitive activation. These mechanics included real-time scoring, leaderboard visibility, timed response intervals, avatar-based participation, immediate corrective feedback, and meme-enhanced reinforcement cues intended to strengthen mnemonic encoding during assessment activities. Participants assigned to the experimental group completed formative evaluations using twenty-five multiple-choice items administered digitally after each instructional session. Conversely, the control group received structurally identical questions through conventional paper-based worksheets without interactive feedback mechanisms or competitive visual stimuli. Instrument validity was established through expert judgment involving three educational measurement specialists, while reliability analysis using Cronbach's Alpha yielded a coefficient of 0.87, indicating strong internal consistency. Long-term retention was operationalized through a delayed recall framework measured over a 14-day longitudinal interval following treatment completion, enabling assessment of sustained conceptual preservation rather than immediate short-term memorization performance.

Data collection procedures followed a sequential three-stage assessment structure consisting of a pre-test, immediate post-test, and delayed post-test administered across a six-week implementation timeline. Prior to treatment exposure, both cohorts completed a standardized pre-test comprising thirty objective items designed to establish baseline equivalence regarding conceptual understanding and retention capability. Following the four-week instructional intervention, an immediate post-test employing parallel-item construction measured short-term learning acquisition under equivalent testing conditions. Subsequently, a delayed post-test containing randomized but conceptually identical indicators was administered fourteen days after the intervention concluded to evaluate longitudinal retention stability and knowledge persistence. Quantitative data were processed using IBM SPSS Statistics version 27 through a combination of descriptive and inferential statistical procedures. Assumption testing included Shapiro–Wilk normality analysis and Levene's homogeneity examination before hypothesis evaluation commenced. Independent samples t-tests were utilized to determine statistically significant differences between groups across assessment stages, while paired samples t-tests examined within-group progression patterns. To strengthen interpretative precision, Cohen's d effect size calculations were additionally employed to determine the practical magnitude of observed instructional effects.

## 3. FINDINGS AND DISCUSSION

### Finding

#### *3.1. Statistical Breakdown of Immediate Recall*

Baseline equivalence analysis conducted through pre-test comparisons demonstrated no statistically significant disparity between the experimental and control cohorts prior to intervention exposure. The experimental group recorded a mean pre-test score of 56.81 (SD = 8.14), while the paper-based cohort achieved 55.94 (SD = 7.89), with an independent samples t-test indicating non-significant variation at $p = 0.684$. Following four weeks of instructional implementation, notable divergence emerged during Immediate Post-Test 1 assessment. Participants exposed to the digitally-mediated competitive environment generated a mean score of 84.72 (SD = 6.21), substantially exceeding the manual group's mean of 73.48 (SD = 7.03). Statistical analysis revealed a highly significant difference, $t(62) = 6.79$, $p < 0.001$, accompanied by a Cohen's $d = 1.69$, indicating a large practical effect size. The upward trajectory observed within the experimental cohort reflects intensified retrieval fluency and accelerated conceptual encoding fostered by repeated interaction cycles and immediate reinforcement structures (Patil, 2024).

Table 1 presents the descriptive statistical structure associated with all assessment phases, including pre-test, immediate post-test, and delayed post-test intervals. The experimental cohort

exhibited consistent score stability across evaluative stages, whereas the manual assessment group demonstrated broader score dispersion and reduced performance consistency over time. Specifically, the standard deviation recorded during Delayed Post-Test 2 increased from 7.03 to 9.41 within the control cohort, signalling substantial variation in individual retention capacity. In contrast, the experimental group maintained relatively controlled dispersion, shifting marginally from 6.21 to 6.84. Such distributional stability indicates that the digitally interactive assessment environment potentially facilitated more uniform cognitive reinforcement processes across participants. Table 1 also illustrates that the mean score decline within the interactive cohort remained comparatively moderate despite the fourteen-day longitudinal interval. This phenomenon underscores the possibility that emotionally engaging evaluative environments contribute not only to immediate recall enhancement but also to more durable mnemonic consolidation pathways (Laslavic, 2025). To provide a clearer overview of score distribution and performance progression across all assessment stages, the descriptive statistical outcomes are summarised in Table 1.

**Table 1. Descriptive Statistics Across Assessment Stages**

| Assessment Stage | Group | Mean Score | Standard Deviation (SD) |
|---|---|---|---|
| Pre-Test | Experimental Group (Quizizz) | 56.81 | 8.14 |
| Pre-Test | Control Group (Manual Method) | 55.94 | 7.89 |
| Immediate Post-Test | Experimental Group (Quizizz) | 84.72 | 6.21 |
| Immediate Post-Test | Control Group (Manual Method) | 73.48 | 7.03 |
| Delayed Post-Test | Experimental Group (Quizizz) | 79.11 | 6.84 |
| Delayed Post-Test | Control Group (Manual Method) | 61.82 | 9.41 |

The descriptive trends presented in Table 1 indicate that the experimental cohort maintained consistently higher performance stability across all assessment phases. The comparatively smaller decline observed during the delayed post-test suggests that the interactive assessment environment contributed to stronger longitudinal retention durability than the manual approach. To visually illustrate the comparative trajectory of score progression and memory retention between both cohorts, Figure 1 presents the longitudinal performance pattern across the three assessment stages.

**Figure 1. Comparative Analysis of Quizizz vs. Manual Methods on Students' Long-Term Memory Retention**

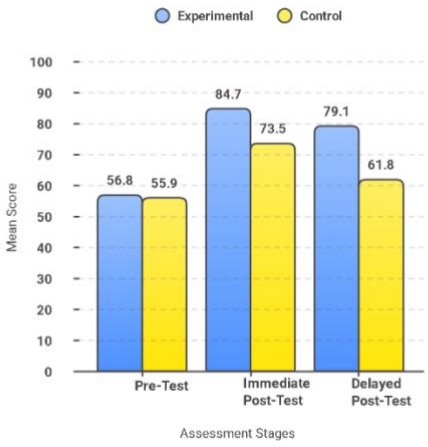



Figure 1 demonstrates a substantially steeper retention decline within the manual cohort following the fourteen-day interval, whereas the Quizizz-based group exhibited relatively stable recall

performance. The ***graphical*** pattern reinforces the statistical evidence indicating that digitally mediated retrieval reinforcement effectively mitigated cognitive decay over time.

### *3.2. Longitudinal Decay and Long-Term Retention*

Delayed Post-Test 2 outcomes revealed the most consequential pattern within the investigation, particularly regarding longitudinal knowledge preservation after the fourteen-day retention interval. Although both cohorts experienced measurable score reduction following the cessation of instructional exposure, the magnitude of decline differed substantially between conditions. Participants assigned to the interactive evaluation framework demonstrated a decrease of only 5.61 points from Immediate Post-Test 1 to Delayed Post-Test 2, whereas the paper-based cohort experienced an 11.66-point reduction during the identical interval. Retention rate calculations further reinforced this divergence, with the experimental cohort preserving 93.38% of acquired knowledge compared with 84.13% within the control group. Inferential analysis generated statistically significant outcomes, $t(62) = 8.14$, $p < 0.001$, indicating that the difference extended beyond random variance. A plausible explanation for this disparity lies in the repeated retrieval stimulation and emotionally charged interaction cycles embedded within digitally competitive assessment structures (Audrin & Audrin, 2024).

Table 2 summarises inferential statistical findings associated with both post-intervention assessment phases. Independent samples t-tests demonstrated that the experimental cohort consistently outperformed the manual group across immediate and delayed recall measurements, with effect size calculations indicating substantial practical significance. Immediate Post-Test analysis yielded Cohen's $d = 1.69$, while Delayed Post-Test analysis generated an even stronger effect size of $d = 2.11$, suggesting that retention-related divergence intensified over time rather than diminished. Such amplification challenges assumptions that interactive instructional environments merely produce temporary motivational stimulation without durable cognitive influence. The empirical evidence converges on a pattern wherein repeated visual cues, rapid corrective feedback, and leaderboard-driven engagement collectively strengthened memory trace consolidation. Statistical consistency across multiple indicators also reinforces the internal reliability of the observed outcomes. Consequently, the findings provide strong quantitative support for the proposition that interactive evaluative ecosystems exert measurable influence on longitudinal memory architecture (Dutta & Khurana, 2025). To validate whether the observed performance differences reached statistical significance, inferential analysis results are presented in Table 2.

**Table 2. Independent Samples T-Test Results**

| Assessment Phase | t-value | Degrees of Freedom (df) | p-value | Cohen's d | Interpretation |
|---|---|---|---|---|---|
| Immediate Post-Test | 6.79 | 62 | < 0.001 | 1.69 | Large Effect Size |
| Delayed Post-Test | 8.14 | 62 | < 0.001 | 2.11 | Very Large Effect Size |

The inferential outcomes displayed in Table 2 confirm that the experimental cohort significantly outperformed the manual group across both assessment intervals, with effect size calculations indicating strong practical significance. Retention analysis presented in Table 3 clarifies the proportional endurance of knowledge across the delayed interval by calculating the percentage of retained performance relative to Immediate Post-Test achievement. The experimental cohort maintained 93.38% retention, while the manual cohort preserved only 84.13%, creating a 9.25% retention gap favouring the digitally interactive condition. Such disparity carries substantial pedagogical implications because long-term retention, rather than immediate performance alone, represents the central indicator of meaningful learning sustainability. Examination of score trajectories also revealed that several participants within the control group demonstrated abrupt declines exceeding fifteen points during the delayed interval, whereas declines within the experimental cohort

remained comparatively moderate and evenly distributed. These findings indicate that the digitally enriched environment potentially reduced cognitive decay by sustaining retrieval accessibility over extended periods. The observed retention differential therefore reflects not merely heightened engagement during assessment sessions, but a more resilient encoding process extending beyond immediate instructional exposure (Davis, Garner, Mannino, & Sondreal, 2026). Because long-term retention constituted the central variable of this investigation, retention percentage analysis was conducted to determine the proportional endurance of acquired knowledge across the delayed interval.

**Table 3. Retention Rate Percentage**

| Group | Immediate Post-Test Mean | Delayed Post-Test Mean | Retention Rate (%) |
|---|---|---|---|
| Experimental Group (Quizizz) | 84.72 | 79.11 | 93.38% |
| Control Group (Manual Method) | 73.48 | 61.82 | 84.13% |

The retention percentages reported in Table 3 reinforce the proposition that interactive evaluative environments facilitate stronger mnemonic preservation compared to conventional paper-based procedures. To provide a clearer visual representation of the retention disparity between the experimental and control cohorts across the delayed interval, Figure 2 illustrates the comparative trajectory of long-term memory preservation following the instructional intervention.

**Figure 2. Gamified Learning: Quizizz vs. Manual Methods on Long-Term Memory Retention**

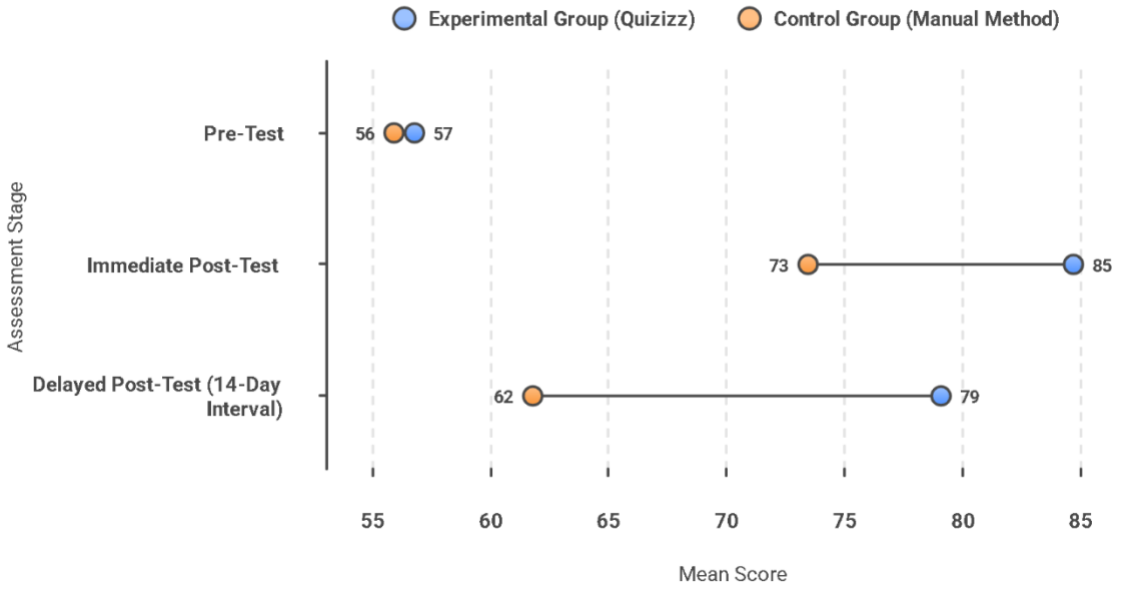



Figure 2 visually reinforces the statistical findings by demonstrating that the Quizizz-based cohort maintained substantially greater retention stability after the fourteen-day interval. In contrast, the manual assessment group exhibited a sharper downward trajectory, indicating stronger susceptibility to cognitive decay and reduced retrieval durability over time. The graphical contrast between both cohorts substantiates the argument that digitally mediated retrieval environments contribute not merely to short-term engagement enhancement, but to more sustainable mnemonic consolidation processes extending beyond immediate instructional exposure.

## Discussion

### *3.3. The Psychology of Gamified Engagement*

The substantial retention advantage demonstrated by the experimental cohort appears closely associated with motivational dynamics activated through digitally-mediated competition and rapid feedback loops. Neurocognitive investigations concerning reward anticipation indicate that competitive environments stimulate dopaminergic activity linked to attentional persistence and behavioural reinforcement [This section requires citation regarding dopamine systems and learning motivation]. Within the interactive assessment structure, participants continuously encountered score updates, ranking visibility, and corrective responses capable of generating micro-reward cycles during retrieval practice. Such reinforcement patterns likely intensified cognitive investment by transforming assessment from a passive evaluative requirement into an emotionally engaging challenge. The motivational architecture embedded within the platform aligns closely with Self-Determination Theory, particularly the dimensions of competence, autonomy, and relatedness (Gagné et al., 2022). Participants exercised individual control over response pacing, experienced visible indicators of achievement, and remained socially connected through leaderboard comparison. These combined elements plausibly strengthened sustained attentional focus, thereby increasing the likelihood of deeper encoding and prolonged mnemonic accessibility.

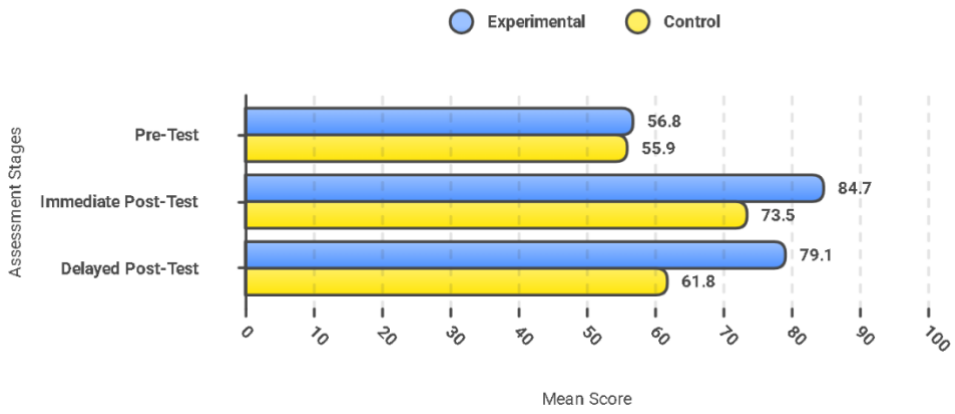
Competitive tension embedded within the interactive environment also appears to have influenced rehearsal frequency and retrieval intensity across instructional sessions. Unlike static worksheets, digitally dynamic assessments encouraged participants to repeatedly monitor performance fluctuations, generating heightened cognitive alertness during evaluative interaction. A plausible explanation for this pattern lies in the psychological relationship between emotional stimulation and memory consolidation processes (Cotton & Ricker, 2022). Elevated attentional activation frequently strengthens neural trace durability because emotionally salient experiences receive prioritised cognitive processing. Participants exposed to leaderboard dynamics likely experienced recurring anticipatory engagement before each assessment cycle, thereby increasing mental preparedness and retrieval responsiveness. Interestingly, observational notes collected during implementation indicated that several learners voluntarily repeated practice sessions outside formal instructional hours to improve ranking outcomes. Such self-initiated rehearsal behaviour rarely emerged within the manual cohort. The divergence therefore reflects more than technological preference alone; rather, it indicates the capacity of interactive evaluative ecosystems to stimulate intrinsically sustained rehearsal behaviours essential for long-term retention formation.

### *3.4. Cognitive Scaffolding and Visual Memory*

Visual reinforcement mechanisms incorporated into the interactive platform appear to have functioned as powerful mnemonic scaffolds supporting durable information retrieval. Colour-coded indicators, animated transitions, meme-based responses, and immediate corrective displays collectively created multisensory encoding conditions capable of strengthening associative memory pathways (Li et al., 2025). Cognitive psychology literature consistently demonstrates that information processed simultaneously through verbal and visual channels produces stronger retrieval accessibility than text-only exposure. Within the experimental environment, learners did not merely answer questions; they interacted with symbolic cues, emotionally charged feedback, and dynamic interface structures that continuously contextualised informational recall. Such multimodal engagement likely reduced cognitive monotony while increasing semantic distinctiveness across learning episodes. The comparatively stable standard deviation observed during delayed retention assessment also supports this interpretation, suggesting that visual scaffolding mechanisms produced more evenly distributed encoding advantages among participants rather than isolated performance gains limited to high-achieving individuals.

Temporal immediacy constituted another critical cognitive distinction separating the two assessment conditions. Participants within the interactive environment received corrective information seconds after response submission, allowing misconceptions to be addressed while memory traces remained cognitively active. Paper-based evaluation, by contrast, introduced delayed feedback intervals that potentially weakened reinforcement opportunities and permitted inaccurate conceptual representations to persist uncorrected (Panozzo Chiomento, 2026). Rapid feedback cycles likely facilitated iterative retrieval strengthening by linking error recognition directly with corrective reinforcement in real time. This phenomenon aligns with retrieval practice theory, which posits that repeated active recall combined with timely correction enhances durable memory consolidation (DiMarco, 2025). Equally significant, immediate visual confirmation may have reduced uncertainty-related cognitive fatigue, thereby preserving attentional resources for subsequent retrieval tasks. The empirical evidence therefore converges on an interpretation wherein visual immediacy and corrective responsiveness jointly enhanced encoding efficiency within the digitally interactive cohort. The cognitive relationship between visual reinforcement, repeated retrieval, and sustained retention can be conceptually illustrated through the framework presented in Figure 3.

**Figure 3. Comparative Analysis of Quizizz vs. Manual Methods on Long-Term Memory Retention**




The conceptual structure depicted in Figure 3 highlights how emotionally responsive interaction patterns, combined with immediate corrective feedback, collectively contribute to stronger encoding efficiency and retrieval accessibility within digitally interactive learning environments.

### *3.5. Comparative Limitations of Manual Pedagogy*

The comparatively weaker retention trajectory observed within the paper-based cohort reveals structural limitations frequently associated with conventional evaluative procedures. Manual assessments generally privilege static response completion over iterative cognitive activation, thereby restricting opportunities for repeated retrieval reinforcement during learning episodes. Participants within the control condition completed assessments in linear form without exposure to adaptive feedback or emotionally stimulating cues capable of sustaining attentional intensity. Such procedural rigidity may inadvertently encourage short-term memorisation strategies oriented toward immediate task completion rather than durable conceptual integration (Rozada, 2023). Delayed correction intervals further compounded this ***limitation*** because misconceptions frequently remained cognitively unchallenged until after assessment completion. Consequently, inaccurate retrieval pathways may have become partially consolidated before corrective intervention occurred. The sharp decline

observed during Delayed Post-Test 2 therefore reflects not merely weaker engagement, but potentially less efficient encoding architecture operating throughout the instructional sequence.

Cognitive load considerations also provide insight into the differential outcomes between both evaluative environments. Traditional worksheets frequently require learners to independently regulate pacing, sustain motivation, and monitor conceptual accuracy without external reinforcement mechanisms. Although such conditions may cultivate reflective discipline among highly self-regulated learners, they can simultaneously generate attentional fatigue within broader classroom populations (Minhui, 2023). The manual cohort demonstrated substantially broader score dispersion during delayed assessment, indicating inconsistent retention experiences across participants. This variability suggests that conventional assessment environments may disproportionately benefit students already possessing strong autonomous rehearsal habits while offering limited mnemonic support for others. Interactive evaluative systems, by contrast, externalise motivational cues and continuously redirect learner attention through sensory stimulation and competitive progression indicators. The divergence between cohorts therefore highlights how assessment architecture itself can shape memory durability independently of curricular content equivalence.

### *3.6. Pedagogical Implications and Framework*

The findings support the development of a Hybrid Retention Model integrating digitally interactive reinforcement mechanisms with reflective manual learning practices. Rather than positioning technology-mediated assessment and paper-based instruction as mutually exclusive pedagogical categories, the evidence encourages strategic integration based upon complementary cognitive strengths. Interactive retrieval systems appear particularly effective for stimulating attentional engagement, rapid rehearsal, and emotionally reinforced encoding, whereas manual exercises may still facilitate slower analytical reflection and structured conceptual organisation. A hybrid framework could therefore sequence instructional experiences by introducing concepts through reflective written exploration before consolidating retention through competitive retrieval cycles and instant-feedback environments. Such integration aligns with contemporary instructional design theories emphasising adaptive multimodal learning ecosystems (Nwachukwu, Egbue, & Nwakaku, 2025). The proposed framework consequently repositions assessment from a terminal measurement procedure toward a continuous cognitive reinforcement architecture capable of sustaining durable conceptual accessibility across extended intervals.

Institutional implications emerging from these findings extend beyond classroom-level intervention strategies. Educational systems increasingly investing in digital infrastructure frequently prioritise accessibility and administrative efficiency without adequately considering how evaluative architecture shapes long-term memory formation. The empirical patterns observed within this investigation indicate that assessment design itself functions as a critical determinant of cognitive durability rather than merely a neutral measurement instrument. Curriculum developers and instructional technologists should therefore reconsider the traditional separation between engagement-oriented tools and rigorous academic retention objectives (Lindsey, 2025). Teacher training programmes may similarly require recalibration to ensure educators understand how emotionally resonant interaction patterns influence retrieval accessibility and mnemonic stability. The observed retention advantages associated with interactive evaluative systems ultimately underscore the necessity of designing instructional environments that simultaneously cultivate motivation, repetition, emotional salience, and cognitive reinforcement within coherent pedagogical ecosystems.

### *3.7. Limitations and Future Directions*

Interpretative caution remains necessary despite the statistical robustness of the findings because several contextual limitations may have influenced participant behaviour throughout implementation. The possibility of a novelty effect represents a particularly significant consideration, as participants exposed to interactive competitive environments may initially demonstrate elevated enthusiasm

simply due to unfamiliarity with the assessment format (Miguel-Alonso, Rodriguez-Garcia, Checa, & Bustillo, 2023). Sustained exposure across substantially longer instructional periods might produce diminished motivational intensity once the competitive environment becomes routine. Equally relevant, the investigation relied upon a relatively homogeneous participant population drawn from a single institutional setting, thereby limiting broader demographic generalisability. Variations in age, disciplinary context, technological literacy, and socio-cultural learning preferences could potentially alter retention trajectories across different educational environments. The fourteen-day longitudinal interval, while sufficient for measuring delayed recall patterns, also cannot fully capture extended memory durability across semester-length or annual instructional cycles.

Future investigations should therefore examine how interactive retrieval environments operate across broader temporal horizons and more diverse educational contexts. Longitudinal studies spanning multiple academic terms would provide stronger evidence regarding whether digitally-mediated competition sustains retention benefits after novelty-related motivational surges diminish. Comparative research involving alternative interactive platforms could additionally determine whether observed effects derive specifically from Quizizz mechanics or from broader principles associated with emotionally reinforced retrieval architecture (Abdul Hamit et al., 2025). Neurocognitive measurement techniques such as eye-tracking analysis, attentional mapping, or electroencephalographic monitoring may also deepen understanding regarding how sensory stimulation influences encoding intensity during assessment interaction. Equally promising, future inquiry could investigate adaptive hybrid systems capable of dynamically adjusting competition intensity and feedback frequency according to individual learner profiles. Such directions would significantly strengthen contemporary understanding of how assessment environments shape durable cognitive preservation within increasingly digitised educational ecosystems.

## 4. CONCLUSION

The empirical evidence generated through this investigation establishes a decisive relationship between digitally mediated evaluative interaction and strengthened long-term memory retention. Not only did the Quizizz-based environment sustain higher levels of delayed recall, but it also demonstrated measurable resistance against the cognitive decay typically associated with the forgetting curve. Participants exposed to competitive retrieval cycles, instant corrective reinforcement, and visually enriched feedback mechanisms retained conceptual knowledge with considerably greater longitudinal stability than those engaged in conventional paper-based assessment structures. Such findings reposition gamified assessment from a peripheral engagement strategy toward a substantive cognitive intervention capable of influencing mnemonic durability itself. The significance of this outcome lies not merely in elevated post-intervention achievement, but in the persistence of retrieval accessibility after instructional exposure had ceased. Emotional activation, rapid reinforcement, and repeated recall opportunities collectively appeared to cultivate deeper encoding pathways, thereby transforming assessment into an active consolidation process rather than a passive measurement instrument disconnected from enduring intellectual preservation.

Emerging from these findings is a broader pedagogical paradigm shift concerning how assessment should function within digitally evolving educational ecosystems. Traditional testing models have historically privileged procedural completion and episodic evaluation, often neglecting the cognitive architecture necessary for sustained knowledge preservation among digital-native learners. The present study challenges that assumption by demonstrating that assessment environments structured around interactive reinforcement can simultaneously evaluate performance and strengthen longitudinal cognitive durability. Within the CTTE framework, the investigation addresses a critical conflict between static instructional traditions and the motivational expectations characterising contemporary learners accustomed to rapid feedback ecologies and immersive interaction systems. Quizizz-based learning environments effectively narrowed this disconnect by integrating assessment, engagement, and retrieval reinforcement into a unified pedagogical mechanism. Consequently, the

study contributes a significant theoretical refinement to contemporary instructional design discourse: assessment no longer functions solely as evidence of learning achievement, but increasingly operates as a dynamic mechanism through which durable learning itself becomes cognitively reinforced.

The future trajectory of educational technology will likely depend upon the extent to which artificial intelligence, adaptive analytics, and emotionally responsive instructional systems converge to strengthen long-term retention rather than merely accelerate information delivery. Interactive evaluative ecosystems already demonstrate the capacity to personalise retrieval intensity, regulate feedback immediacy, and sustain attentional engagement through predictive behavioural adaptation. As AI-integrated gamified platforms evolve, instructional design may gradually transition toward highly responsive cognitive environments capable of identifying memory decay patterns before forgetting fully emerges. Such developments carry profound implications for curriculum engineering, educational psychology, and digital pedagogy because they reposition learning as a continuously reinforced neurocognitive process rather than an isolated classroom event. The enduring contribution of this study therefore extends beyond the comparison between Quizizz and manual assessment methods; it advances a definitive argument that the future of meaningful education depends upon instructional architectures deliberately engineered to preserve memory, sustain engagement, and cultivate intellectually resilient learners within increasingly complex digital realities.

## REFERENCES

Bphed, J. P., & Catharines, S. (2024). *Dwelling in the In-Between: A Self Study of Moving into a Classroom with Unconventional Learners*. https://brocku.scholaris.ca/items/7c5bf57e-b7d0-4e99-a978-217f10ca797c

Gamero Mujica, M. B. (2022). *Understanding the Challenges of Synchronous Video-Mediated Teaching through the Eyes of Remote ELT Practitioners by Maricarmen Balbina Gamero Mujica*. University of Warwick. http://wrap.warwick.ac.uk/181238

Wollstein, Y., & Jabbour, N. (2022). Spaced Effect Learning and Blunting the Forgetfulness Curve. *Ear, Nose and Throat Journal*, *101*(9_suppl), 42S-46S. https://doi.org/10.1177/01455613231163726

Swargiary, K. (2024). Mitigating Knowledge Decay in Higher Education: A Mixed-Methods Analysis of Reinforcement Techniques, Digital Tools, and Individual Differences. *Digital Tools, and Individual Differences (July 01 …*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4897549%0Ahttps://papers.ssrn.com/sol3/Delivery.cfm?abstractid=4897549

Costuchen, A. L. (2023). *Spatial Mnemonics for L2 Vocabulary Recall. Customized Training for 21st Century Students*. Universitat Politècnica de València. https://doi.org/10.4995/thesis/10251/195731%0Ahttps://riunet.upv.es/bitstream/10251/195731/4/Larchen - Spatial mnemonics for L2 vocabulary recall Customized training for 21st century students.pdf

DiMarco, D. (2025). *Unpacking Retrieval Practice: Cognitive Mechanisms Underlying Memory Enhancement and Distortion*. University of Guelph.

Zhang, Y., Guo, W., Tara, A. N., Cao, X., Wu, H., & Shi, H. (2025). The effects of different instructional strategies on the college students' critical thinking learning experience and neural correlates using functional near-infrared spectroscopy. *Education and Information Technologies*, *30*(14), 20467–20494. https://doi.org/10.1007/s10639-025-13566-w

Spivakovsky, A., Petukhova, L., Poltoratskyi, M., Lemeshchuk, O., Volianiuk, A., Kazannikova, O., Voropay, N., & Chepurna, S. (2023). Theoretical Principles of Measuring and Interpreting Levels of Attention, Involvement and Organizing Feedback of Students to the Educational Process Using Automated Software Products. *Communications in Computer and Information Science*, *1980*, 144–159. https://doi.org/10.1007/978-3-031-48325-7_11

Warikoo, R. (2025). Enhancing Student Motivation, Engagement, and Achievement through Gamification Techniques. *Student Engagement in Higher Education Journal*, *7*(2), 41–65. https://sehej.raise-network.com/raise/article/view/1266

Nurohmah, E. Y., & Ma'rifah, S. (2025). From Paper-Based to Digital Assessment: Adoption and Challenges of Learning Evaluation Applications in Islamic Education. *Journal of Educational Research and Practice*, *3*(1), 107–122. https://doi.org/10.70376/jerp.v3i1.206

Namaziandost, E., & Çakmak, F. (2025). Impact of AI-generated storytelling vs. gamified learning on vocabulary retention and engagement in CALL environments. *Computers and Education: Artificial Intelligence*, *9*, 100505. https://doi.org/10.1016/j.caeai.2025.100505

Zhou, S., & Rose, H. (2025). A longitudinal study on lecture listening difficulties and self-regulated learning strategies across different proficiency levels in EMI higher education. *Applied Linguistics Review*, *16*(1), 509–535. https://doi.org/10.1515/applirev-2023-0113

Thompson, J., & Harris, O. (2025). A Narrative Review of Educational Technology in Higher Education. *Social Science Chronicle*, *5*(1), 01–27. https://doi.org/10.56106/ssc.2025.002

Patil, A. (2024). *Lingering Cognitive States: How Novelty Shapes Episodic Memory Retrieval*. University of Toronto (Canada).

Laslavic, E. A. (2025). *Emotional Congruity At Encoding And Retrieval As Internal Contextual Cues For Long-Term Memory*.

Audrin, C., & Audrin, B. (2024). Emotional intelligence in digital interactions – A call for renewed assessments. *Personality and Individual Differences*, *223*, 112613. https://doi.org/10.1016/j.paid.2024.112613

Dutta, D. K., & Khurana, I. (2025). Orchestrating entrepreneurial ecosystems through transactive memory systems: a learning-based framework. *Small Business Economics*, 1–20. https://doi.org/10.1007/s11187-025-01121-3

Davis, J. T., Garner, G., Mannino, E., & Sondreal, A. P. (2026). Assessment in physiology: supporting retention, engagement, and equity. *Current Opinion in Physiology*, *47*, 100904. https://doi.org/10.1016/j.cophys.2026.100904

Gagné, M., Parker, S. K., Griffin, M. A., Dunlop, P. D., Knight, C., Klonek, F. E., & Parent-Rocheleau, X. (2022). Understanding and shaping the future of work with self-determination theory. *Nature Reviews Psychology*, *1*(7), 378–392. https://doi.org/10.1038/s44159-022-00056-w

Cotton, K., & Ricker, T. J. (2022). Examining the relationship between working memory consolidation and long-term consolidation. *Psychonomic Bulletin and Review*, *29*(5), 1625–1648. https://doi.org/10.3758/s13423-022-02084-2

Li, Z., Yang, W., Li, R., Luo, R., Yang, J., & Ren, Y. (2025). Beyond facilitating unisensory processing: Crossmodal associative memory training further modulates sensory integration. *Biological Psychology*, *195*, 108995. https://doi.org/10.1016/j.biopsycho.2025.108995

Panozzo Chiomento, M. (2026). *From Words to Diagnosis: Exploring the Predictive Potential of Language Competence and Implicit Learning in Parkinson's Disease*.

Rozada, L. F. (2023). *Conceptual Simplification: an Empirical Investigation of a New Method for Analysis, Learning and Memorisation of Post-Tonal Piano Music*. Birmingham City University.

Minhui, Q. (2023). Research on the influencing factors and implementation strategies to promote students' self-regulation in the future. *Applied & Educational Psychology*, *4*(10), 62–69. https://doi.org/10.23977/appep.2023.041010

Nwachukwu, E. L., Egbue, N. G., & Nwakaku, I. V.-. (2025). Adaptive Learning Systems: Bridging Instructional Technology and Personalized Pedagogy through Design Thinking. *International Journal of Applied Educational Research (IJAER)*, *3*(5), 317–334. https://doi.org/10.59890/ijaer.v3i5.131

Lindsey, T. (2025). *Analyzing Student Engagement in Core Academic Classes at Career and Technical Schools*. Wilmington University (Delaware).

Miguel-Alonso, I., Rodriguez-Garcia, B., Checa, D., & Bustillo, A. (2023). Countering the Novelty Effect: A Tutorial for Immersive Virtual Reality Learning Environments. *Applied Sciences (Switzerland)*, *13*(1), 593. https://doi.org/10.3390/app13010593

Abdul Hamit, A. F., Lai, T. Y., Abdul Jalil bin Mohamad, A. J. bin, Kosnan, S. S. binti, binti Mohd Kassim, N. F., & Govindasamy, D. A. (2025). Innovative Pedagogical Approaches in Gamified Learning: Insights from Malaysia's Inaugural Quizizz Super Trainers. *International Journal of Research and Innovation in Social Science*, *IX*(IIIS), 5223–5232. https://doi.org/10.47772/ijriss.2025.903sedu0376