

Quiz-based Mechanics for Long-term Retention in Game-based Learning

Trishala Jain and Zhenhua “Aaron” Yang

Iowa State University, Ames, USA

trishala@iastate.edu

aayang@iastate.edu

Abstract: Quiz-based interactions are a common design pattern in digital game-based learning (GBL), appearing in platforms such as Duolingo and Kahoot and in many serious educational games. They reliably generate short-term engagement, but evidence that they support durable knowledge retention is weaker and less consistent. A recurring problem is that learning effectiveness in educational games is often evaluated through indicators of motivation and participation, such as points, streaks, completion rates, and in-game performance, rather than measures of retention beyond gameplay. Educational games are therefore often designed to maximize engagement rather than durable learning, and their reported effects are misinterpreted. This paper conducts a PRISMA-guided systematic review of 66 empirical studies on quiz-based mechanics in GBL environments and defines quiz-based mechanics as gameplay interactions in which progression depends on active knowledge retrieval rather than on recognition or passive exposure. Drawing on research in game-based learning, instructional design models, and findings from cognitive psychology on retrieval practice, spacing, and corrective feedback, the review examines how these mechanisms are implemented in quiz-based gameplay and the conditions under which they support long-term retention. Across the reviewed studies, retrieval, spacing, and corrective feedback tend to support durable retention most reliably when combined, whereas evidence on whether adaptive difficulty and novelty contribute to long-term retention remains limited and inconclusive. Based on this synthesis, the paper proposes a six-layer mechanism-based design framework connecting learning theory, cognitive mechanisms, quiz-based learning mechanics, surrounding game mechanics, and learning outcomes, with implications for how educational games are designed and evaluated.

Keywords: Game-based learning, Quiz-based mechanics, Retrieval practice, Spaced practice, Corrective feedback, Long-term retention

1. Introduction

Game-based learning (GBL) is a widely adopted element of contemporary education, appearing across schools, universities, museums, and mobile applications (Baek & Whitton, 2013). While these systems increase learner engagement and participation (Manzano-León et al., 2021), their capacity to produce durable knowledge is far less established. Meaningful learning requires retention and transfer (Mystakidis, 2021), yet GBL assessments often rely on short-term indicators such as completion, performance, and satisfaction (Yu et al., 2025). Cognitive research instead highlights retrieval, spacing, and feedback as central to long-term retention (Dunlosky et al., 2013). However, these mechanisms are not always embedded in games, leaving them disconnected from pedagogical goals (Perrotta et al., 2013). Cognitive Load Theory (CLT) further suggests that interactive elements can impose extraneous load on deeper processing (Gkintoni et al., 2025), and novelty effects can inflate early gains that fade with familiarity (Sanchez et al., 2020).

Quiz-based mechanics (QBM) are among the most common interaction patterns in GBL (Zainuddin et al., 2020). They are the central gameplay loop of platforms such as Duolingo and Kahoot. QBM can be defined as gameplay interactions in which progression depends on active knowledge retrieval rather than recognition (Mikrouli et al., 2024). This structure aligns with cognitive mechanisms such as repeated retrieval and immediate feedback. Despite their widespread use, QBM remain underexamined in relation to long-term retention (Yu et al., 2025). Evidence on specific design features is also mixed.

This paper addresses these gaps through a PRISMA-guided systematic review guided by a research question: Which cognitive learning mechanisms most effectively support long-term knowledge retention in quiz-based game learning environments and under what conditions? The review synthesizes evidence on how retrieval, spacing and corrective feedback support durable retention and develops a six-layer design framework linking learning theory, cognitive mechanisms, QBM, game mechanics, and learning outcomes. By identifying these mechanisms, the paper shows how they can be intentionally structured within quiz-based educational games.

2. Literature Review

2.1 Game-based Learning

2.1.1 Distinguishing GBL from gamification and serious games

Distinguishing GBL, gamification and serious games is important for situating QBM within educational game design. GBL uses games as the primary medium of learning, with progression tied to applying targeted knowledge or skills (Plass, Homer, & Kinzer, 2015). Such games require learners to apply knowledge and make decisions (Adipat et al., 2021) and support higher-order skills like problem solving and critical thinking (Yulistiyan et al., 2025). Gamification, on the other hand, applies game elements such as points, badges and leaderboards to boost motivation and engagement (Ratinho & Martins, 2023). When these approaches are poorly aligned with learning goals, attention can shift from understanding to winning (Wright, 2024). Serious games are treated as a subset of GBL: complete game experiences built around explicit educational, training, health, or behavioral objectives, often in immersive, context-rich environments (Zohari et al., 2023). All serious games are GBL, but not all GBL reaches their level of complexity or immersion. However, across all three, reported benefits often reflect short-term engagement rather than durable learning (Manzano-León et al., 2021).

2.1.2 Instructional design models in GBL

Instructional design models explain how instruction in GBL must be structured to support knowledge gain, retention and transfer. Three models offer complementary perspectives: 1) *Gagné's Nine Events of Instruction* structures GBL instruction by sequencing attention, prior knowledge activation, learner performance, feedback and transfer (Habib, 2024). These stages are reflected through progressive challenges, repeated attempts, immediate feedback, and opportunities for retrieval and error correction (Azizan et al., 2019), supporting knowledge acquisition and skill development (Li et al., 2025). 2) *Merrill's First Principles of Instruction* emphasizes problem-centered learning through activation, demonstration, application, and integration (Rahadianto et al., 2023), aligning with GBL, where progression depends on cycles of action, feedback, and reapplication. It has been shown to improve mastery of learning objectives and is associated with higher achievement and motivation. 3) *Bloom's Taxonomy* addresses the depth of cognitive processing, from recall and understanding to analysis, evaluation, and creation (Ahmad & Hussin, 2017). This matters because durable learning depends not only on instructional structure but also on effortful processing (Binks, 2026).

Across these models, learning is supported by structured, performance-based progression rather than isolated activity. Progression translates the temporal and cognitive logic of these three models into gameplay. However, this is not sufficient; its learning value depends on whether it activates retrieval practice, spacing, and corrective feedback; otherwise it sustains engagement alone.

2.2 Cognitive Mechanisms Behind Long-term Retention

Long-term retention is supported by the combined effects of spaced practice, repeated retrieval, and corrective feedback (Franzoi et al., 2025). Evidence across laboratory, classroom, and training contexts shows that spaced practice is more effective than massed learning, retrieval strengthens memory, and feedback supports error correction (Yang & Ying, 2025). This section examines how these processes interact to inform the design of quiz-based educational systems.

2.2.1 Retrieval practice

Retrieval practice involves active recall rather than rereading (Roediger & Karpicke, 2006), forcing learners to reconstruct knowledge and strengthening memory (Karpicke, 2012). Empirical evidence shows this effect in game-based contexts. Yu et al. (2025) found that a retrieval-based Neurological Syndrome Card Game produced higher delayed retention than lectures at one, three, and six-week follow-ups. Engagement alone, however, is insufficient. Van den Broek et al. (2026) reported higher enjoyment under gamification but no advantage in delayed recall, suggesting motivational features contribute only when they reinforce effortful retrieval. Durable learning depends not only on repeated retrieval but also on feedback, particularly immediate feedback that supports error correction (Carr, 2017).

2.2.2 Feedback Mechanism

Immediate feedback allows learners to compare responses with correct answers, revise errors, and re-encode knowledge before misconceptions are reinforced (Maraver et al., 2022; Mullet & Marsh, 2016). It supports retrieval by reinforcing correct knowledge and preventing error rehearsal (Roediger & Butler, 2011). However,

its effectiveness varies and may reduce learning when poorly designed (Wisniewski et al., 2020). Effective feedback requires meaningful corrective information and learner engagement. Reward-based signals such as points or badges cannot replace corrective feedback, as they may increase participation without improving learning (Li & Fryer, 2024).

2.2.3 Spacing effect

The spacing effect suggests learning improves when practice is distributed over time rather than concentrated, partly due to reduced working-memory load and enhanced consolidation (Chen et al., 2018; Squire et al., 2015; Khalafi et al., 2024). Studies report higher recall under spaced practice in mathematics (Chen & Cao, 2021), with spaced groups outperforming lectures and gaps widening over time (Khalafi et al., 2024; Tomar et al., 2025). However, findings are not always consistent. Rogers & Cheung (2021) found no advantage for an 8-day vs. 1-day interval, and Kobaissi (2022) reported no retention benefit after 48 hours. These results suggest spacing is most effective when paired with active retrieval.

2.2.4 Combined mechanisms

Although spacing, retrieval, and feedback each support learning, their effects are strongest when coordinated (Agarwal & Bain, 2019). Spaced retrieval produces strong durable learning, with meta-analytic evidence showing large effects (Latimier et al., 2021) and studies confirming gains in delayed exams and real-world performance (Bego et al., 2017). Retrieval with feedback yields the highest final recall (Wallner et al., 2022) and becomes more effective over longer intervals, while algorithmic spacing achieves similar retention with less time (McHugh et al., 2021). Their effectiveness depends on design conditions that sustain engagement and repeated participation.

2.3 Quiz-based Mechanics (QBM) in GBL

QBM appear in three main forms: standalone quiz events, where quizzes are separate classroom activities (Apeah-Kubi, 2025); embedded quiz mechanics, where questions are integrated into a larger game system (Lameras et al., 2014); and combined-platform approaches, where multiple quiz tools are used within the same instructional sequence (Medina et al., 2024). Across these forms, common design features include immediate feedback, multiple-choice formats, anonymity, and competitive leaderboards (Mullet & Marsh, 2016). Immediate feedback reduces evaluation anxiety, while leaderboards appear more strongly linked to engagement than to learning (Aljabri, 2025). Although these features reliably increase short-term engagement (Lameras et al., 2014), interpretation is constrained because studies often bundle multiple design features together and use brief durations that may reflect novelty effects.

2.4 Factors Affecting Mechanism Implementation

Three instructional factors shape the implementation and success of cognitive learning mechanisms in game-based environments. Adaptive learning personalizes difficulty based on real-time performance, maintaining an optimal challenge level that aligns with theories of desirable difficulty and flow (Shi & Liu, 2025). While it promotes short-term efficiency, evidence for its impact on long-term retention remains limited but promising (Liu et al., 2020). Scaffolding such as hints and guided prompts manages cognitive load by temporarily supporting learners through demanding tasks (Wood et al., 1976). This support must gradually fade; otherwise, it inflates immediate performance while undermining the effortful recall necessary for retention (Belland et al., 2015). Finally, the novelty effect introduces a methodological confound. Although novel game elements initially boost attention and time-on-task, these gains decline with familiarity and do not guarantee durable learning (Lee et al., 2025). Sustained engagement ultimately relies on meaningful instructional structure rather than superficial novelty.

Long-term retention in game-based learning relies on activating retrieval, spacing, and feedback as an integrated system, rather than on superficial game features. To address existing implementations that conflate short-term engagement with learning without measuring delayed retention, this paper presents a layered design framework connecting cognitive mechanisms and game mechanics to ensure durable learning.

3. Methods

This study followed the PRISMA 2020 framework (Page et al., 2021) to ensure transparency and reproducibility. It reviewed how quiz-based mechanics are implemented in digital GBL environments and how cognitive mechanisms, including retrieval practice, spacing, and feedback, support short-term performance and long-term knowledge retention.

Searches were conducted in IEEE Xplore, ACM Digital Library, Google Scholar, SpringerLink, and ScienceDirect. The review was limited to peer-reviewed English-language journal and conference publications. The primary search string was: ("game-based learning" OR "serious games" OR "educational games") AND ("quiz-based learning" OR "quiz mechanics" OR "question-based learning" OR "retrieval practice" OR "testing effect") AND ("learning outcomes" OR "knowledge retention" OR "long-term retention" OR "memory" OR "performance"). Additional searches used terms related to spaced retrieval, corrective and elaborated feedback, adaptive difficulty, scaffolding, instructional design, and novelty effects. Search syntax was adapted to each database and restricted to title and abstract fields where possible. Studies were included if they examined game-based or gamified learning environments, incorporated quiz-based, retrieval-based interactions and reported empirical findings with measurable learning outcomes. Conceptual, theoretical, and review papers were excluded from the final analysis and used only to inform the broader literature review.

The search identified 1,287 records, reduced to 964 after duplicate removal. Title screening excluded 823 records, abstract screening excluded 42, and full-text assessment excluded 25 ineligible studies and 8 unavailable full texts. The final dataset included 66 studies. Each study was coded by learning context, cognitive mechanism, mechanism combination, assessment delay, and outcome type. Where relevant, population, research design, and digital environment were also recorded to contextualize the findings.

4. Results

4.1 Overview

Table 1 reports the distribution of the reviewed studies across mechanism, configuration, and implementation factors. Retrieval practice was the most represented mechanism (13 studies), followed by spacing (11) and corrective feedback (8). Most studies isolated a single mechanism; eight examined two mechanisms in combination, and two discussed all three together without testing the full combination empirically. Approximately 45% of the empirical evidence was situated within game-based environments.

Table 1: Overview of the study results

Cognitive Mechanisms		Combined Cognitive Mechanisms		Design and Implementation Factors	
Mechanism	# of Studies	Mechanism	# of Studies	Factor	# of Studies
Retrieval Practice	13	Retrieval + Spacing	6	Scaffolding	6
Spacing Effect	11	Retrieval + Feedback	2	Novelty Effect	2
Corrective Feedback	8	Retrieval + Spacing + Feedback (proposed, not empirically tested)	2	Instructional Design	2
				Quiz-Based Mechanics	5
				Adaptive Difficulty	4
Total	32	Total	10	Total	19
Contextual and Supporting Studies					11

Note: Categories are not mutually exclusive. Combination studies are also counted under each individual mechanism they examined, so columns should not be summed.

4.2 Cognitive Learning Mechanisms Supporting Long-term Knowledge Retention in QBM Learning Environments

Evidence across the 66 studies was unevenly distributed. Retrieval practice was the most extensively examined mechanism (8 delayed studies; 5 in game-based contexts), followed by spacing (7 delayed studies; 4 game-based) and corrective feedback (2 delayed studies; 6 game-based contexts). Only six studies examined retrieval and spacing in combination. Most studies measured outcomes immediately after instruction, with few extending beyond one month (see Table 2).

Table 2: Distribution of Studies by Assessment Timing

Delay	Studies
Immediate	13
48 hours – 1 week	6

Delay	Studies
2 weeks – 1 month	4
6 weeks	1
6 months	2
No retention assessment	40

Note: Studies are counted once by their longest assessment delay. Mechanism-level counts in Section 4.2 are non-exclusive, so a study examining two mechanisms contributes to both tallies while appearing only once here.

Findings indicate that single mechanisms yield only partial effects. Retrieval alone strengthens correct knowledge but does not reliably correct misconceptions (Roediger & Butler, 2011; Maraver et al., 2022); spacing acts as passive re-exposure unless paired with active recall (Khalafi et al., 2024); and immediate feedback reduces errors but offers limited retention benefits without effortful retrieval (Wisniewski et al., 2020; Carr, 2017). Conversely, combining mechanisms produces stronger, additive outcomes. Coupling retrieval with spacing enhances durable retention, and adding feedback improves error correction (Liu et al., 2022; Franzoi et al., 2025; Aljabri, 2025) with the most robust results when all three are coordinated (Atashpendar & Rothkugel, 2023). In contrast, adaptive difficulty yields inconsistent effects, showing stronger links to short-term engagement than delayed retention (Van den Broek et al., 2026).

4.3 Instructional Conditions Shaping the Effectiveness of Cognitive Learning Mechanisms

Beyond the presence of these mechanisms, retention outcomes were strongly shaped by how they were implemented. Effortful retrieval was rarely operationalized, with stronger delayed gains in studies that required active reconstruction (Yu et al., 2025), and the case for system-controlled scheduling rested on a single study (Schimanke, 2021). Longer assessment delays more often revealed retention advantages (Khalafi et al., 2024). Feedback effects depended on timing and quality, with corrective feedback improving recall and poorly designed feedback hindering it (Wallner et al., 2022). Optimal spacing intervals and the interaction between adaptive difficulty and retrieval effort remain largely untested. Thus, although the reviewed studies support cognitive psychology principles, they provide limited GBL-specific guidance for design.

4.4 Mechanism-based Design Framework for Quiz-Based Mechanics in GBL Environments

This study proposes a mechanism-based design framework, conceptualizing quizzes as cognitive learning interactions. As shown in Figure 1, the framework links six layers that move from theory to practice: Learning Theory, Cognitive Mechanisms, Quiz-Based Mechanics, Game Mechanics, Immediate and Long-Term Learning Outcomes, to explain how long-term retention is supported through four threads: memory, time, support, and challenge. The framework grounds the learning theories that produce cognitive mechanisms; each mechanism is expressed as a quiz-based mechanic, which is in turn operationalized by a game interaction design element. The four threads reach retention through two routes: the support and challenge threads produce the immediate learning outcomes, learning performance and knowledge transfer, while the memory and time threads consolidate those outcomes into long-term retention. This two-stage structure reflects the distinction between immediate performance and durable learning: strong performance during practice does not by itself guarantee retention unless it is consolidated through retrieval and spaced preexposure. In the memory thread, retrieval activates active recall, which appears as prompting and is organized by progression. Alongside, the time thread begins with spacing, which enables distributed practice, delivered through repetition and controlled by review scheduling. By contrast, the support and challenge threads improve learning performance and knowledge transfer. The support thread starts from cognitive support, which structures error correction, enacted via feedback and supported by faded scaffolding, which ensures learning performance. Lastly, the challenge thread starts from desirable difficulty, which sustains adaptive challenge, realized through sequencing and paced by mastery gating, which then ensures knowledge transfer.

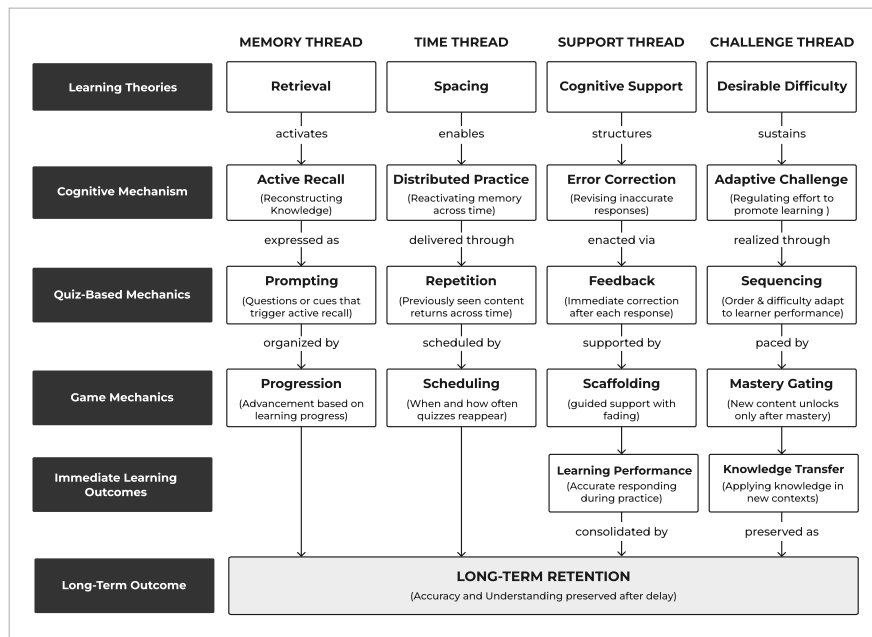


Figure 1: Design Framework

Because the chain runs in both directions, the framework is read downward when designing and upward when evaluating. Read downward, a quiz item should require reconstruction rather than recognition, pair a generative prompt with corrective feedback that determines whether the item is retired or rescheduled, return later at a calibrated difficulty, and be judged against delayed recall. Each link in this model has a corresponding failure mode: in the memory thread, prompts that permit recognition rather than reconstruction weaken active recall (Yu et al., 2025); in the time thread, repetition without recall collapses distributed practice into mere re-exposure (Khalafi et al., 2024) and in the support thread, poorly specified feedback limits error correction (Wallner et al., 2022).

5. Discussion

This review indicates that long-term retention in quiz-based GBL is best supported when retrieval practice, spacing, and corrective feedback are coordinated rather than implemented separately. Retrieval strengthens knowledge that is successfully recalled; spacing increases retrieval difficulty in ways that support consolidation; and feedback supplies information that was not retrieved. Across the reviewed studies, spacing without retrieval often functioned as passive re-exposure, retrieval without feedback risked reinforcing errors and feedback without retrieval provided limited opportunity for correction. Although the strongest retention outcomes appeared when all three mechanisms were present, no included study directly tested the full combination under delayed assessment. Adaptive difficulty, novelty and reward-based features support engagement, attention and short-term performance, but their effects on delayed retention remain inconsistent (Serra and Gilabert, 2021). These findings show that engagement can support learning conditions but should not be treated as equivalent to durable learning. Accordingly, the proposed framework separates its six layers, from learning theory through to long-term retention. This positions cognitive processes where durable retention is produced. However, the evidence base remains uneven, with few studies assessing retention beyond one month, testing mechanisms in combination or examining boundary conditions in GBL contexts.

6. Conclusion and Future Work

The main contribution is diagnostic rather than prescriptive. Organizing the evidence around cognitive mechanisms clarifies what is currently established and what remains uncertain. Existing research shows strong evidence for engagement, limited evidence for delayed retention, and little evidence on the combined effects of retrieval, spacing and feedback. Therefore, the proposed framework should be viewed as a structured hypothesis for future testing rather than a validated model. Progress in quiz-based GBL will depend on measuring durable retention over appropriate intervals, not simply adding new game features.

As most studies assess outcomes shortly after instruction, delayed assessments are needed to evaluate long-term retention and to identify the optimal spacing intervals for durable learning. Further work should clarify

whether elaborated or simple corrective feedback better supports retention, and whether adaptive difficulty produces sustained gains rather than only short-term improvements. Finally, future studies should also distinguish novelty-driven engagement from durable learning.

Ethics Declaration: Ethical clearance was not required, as this study is a systematic review of previously published literature and did not involve human subjects or personal data.

AI Declaration: AI-assisted tools supported language refinement, editing, and organizational drafting. All substantive decisions, including study design, literature selection, and interpretation, were made and approved by the author(s).

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