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Learning Design Architecture of Visual Feedback and Gamified Design in Secondary Mathematics: Effects on Student Learning and Performance

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Abstract. Digital learning platforms in secondary mathematics frequently employ visual cues such as correctness icons, hints, and progress bars to guide student thinking and motivation. These elements constitute a learning architecture that influences how students process information and solve mathematical problems. Despite the widespread use of visual feedback and gamified features in digital mathematics tools, research remains fragmented and lacks a theory-guided synthesis focused specifically on secondary mathematics, particularly concerning cognitive demands. This study presents a systematic review, conducted in accordance with PRISMA 2020, to investigate how visual feedback and gamified design impact motivation, cognitive engagement, and problem-solving in secondary mathematics environments. Three academic databases (ERIC, ScienceDirect, and SpringerLink) were searched for studies published between 2018 and 2025. Studies were screened based on a mathematics focus, secondary school level, and the utilisation of visual or gamified feedback in digital settings. A total of 32 studies met the inclusion criteria and were analysed through a narrative, theory-guided synthesis informed by Cognitive Load Theory. The findings reveal that layered hints, immediate correctness signals, and clear progress indicators facilitate mathematical reasoning by reducing extraneous cognitive load, while high-salience competitive prompts may increase distraction during multi-step tasks. Based on these findings, the review proposes a visual-feedback design framework grounded in Cognitive Load Theory, which elucidates how digital design choices shape learning processes in secondary mathematics. Practical implications are outlined for teachers, instructional designers, and researchers aiming to create visually efficient and student-supportive learning environments.

Keywords: Cognitive Load Theory; digital learning environments; gamification; secondary mathematics; visual feedback

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1. Introduction

Digital tools are now a common part of secondary mathematics classrooms (Alkan & Korkmaz, 2021; Bryant, 2024). Many platforms utilise visual elements to guide students during learning activities, including correctness icons, hints, progress bars, badges, and leaderboards (Balci et al., 2022; Luarn et al., 2023; Chen et al., 2024). These features create a visual environment that shapes how students approach mathematical tasks in areas such as algebra, calculus, and data analysis. In this paper, this structured visual environment is described as a learning architecture, referring to the intentional arrangement of visual cues and feedback systems used in digital mathematics platforms. Research shows that well-designed feedback can support attention, working memory, and self-regulated learning (Panjaburee et al., 2024; Cosentino et al., 2025).

The significance of visual feedback in mathematics lies in its ability to assist students in processing symbols, equations, graphs, and multiple solution steps (Edusei, 2022; Cosentino et al., 2025). Clear visual cues can direct attention, reduce confusion, and enable students to concentrate on reasoning rather than searching for information (Demedts et al., 2025). Conversely, poorly designed visuals, excessive animations, or frequent interruptions may heighten cognitive load and distract students, particularly those who experience mathematics anxiety (Denden et al., 2024; Reiter, 2025).

Gamified features are also prevalent in digital mathematics platforms as a means to enhance engagement (Celasun & Kaya, 2025). Elements such as points, levels, and badges are designed to motivate students and promote persistence (Bai et al., 2022; Ortiz-Rojas et al., 2025). When these features align with educational objectives, they can facilitate meaningful participation. However, an overemphasis on rewards may lead students to prioritise speed or competition over a deep understanding of mathematical concepts (Luo, 2023; Slamet et al., 2025).

Despite the growing interest in gamification and digital feedback, research linking visual feedback design, cognitive demands, and learning outcomes in secondary mathematics remains limited (Saleem et al., 2022). Many studies concentrate on other subjects or investigate engagement without considering how visual features impact attention and working memory in mathematically complex tasks (Aydin et al., 2023; Wang et al., 2024). Secondary mathematics imposes significant cognitive demands on students, making it essential to understand how visual and gamified feedback can support, rather than hinder, learning. In the absence of clear design guidance, schools risk adopting digital tools that may appear engaging but could increase cognitive load or weaken mathematical reasoning, particularly for students who are already struggling with complex content.

However, existing reviews seldom elucidate how visual feedback and gamified design interact with cognitive load to influence learning and performance in secondary mathematics. This gap is significant because secondary mathematics encompasses complex, multi-step reasoning, and poorly designed digital tools can exacerbate cognitive load and undermine understanding instead of facilitating it.

In this paper, cognition refers to the mental processes involved in understanding and solving mathematics problems, including attention, working memory, reasoning, and problem-solving (VandenBos, 2016; Ormrod, 2006). The review examines how visual feedback and gamified design affect student learning and performance in secondary mathematics (Ortiz-Rojas et al., 2025; Muchuweni et al., 2025). Here, student learning and performance denote students' motivation, cognitive engagement, and problem-solving capabilities (Bryant, 2024; Cosentino et al., 2025). This systematic review is informed by Cognitive Load Theory and aims to organise existing evidence to support the design of effective visual feedback and gamified learning environments in secondary mathematics. With a focus on student learning and performance, the study addresses the following research questions:

1. What visual feedback and gamified design elements are used in secondary mathematics learning environments?
2. How do visual feedback and gamified design elements influence student learning and performance in secondary mathematics?

2. Literature Review

This section reviews existing literature on visual feedback and gamified design within secondary mathematics learning environments. Instead of merely enumerating digital platforms, this review synthesises previous research to identify common design patterns and analyse how these features correlate with student learning outcomes pertinent to the present study. Section 2.1 outlines the visual and gamified features typically employed in digital mathematics platforms, while Section 2.2 investigates the relationship between these features and student engagement and learning.

2.1 Visual and Gamified Features in Secondary Mathematics Platforms

Saleem et al. (2022), Ekici (2021), Meng et al. (2024), and Wang et al. (2024) demonstrate that mathematics learning platforms employ various categories of visual and game-based elements. Common features encompass correctness icons, hints, progress bars, rewards, and interactive visual supports, such as graphs or step sequences (Chen et al., 2024; Mimouni, 2022; Panjaburee et al., 2024; Holguin-Alvarez et al., 2025). These platforms frequently highlight errors, display partial solutions, or present the subsequent algebraic step in order to guide students (Chen et al., 2024; Cosentino et al., 2025). Additionally, certain systems utilise animated tokens, sound effects, or level badges to signify success (Bai et al., 2022; Bryant, 2024).

Gamified elements are often layered over practice tasks. Examples include badges and scoring systems (Balci et al., 2022), point accumulation (Luarn et al., 2023), collaborative challenges (Kingsley & Grabner-Hagen, 2023), and competitive features such as leaderboards (Slamet et al., 2025). Some systems integrate visual scaffolds with adaptive difficulty, offering hinted feedback that adapts to student choices (Demedts et al., 2025; Maryono et al., 2025).

In mathematics-specific tools, visual supports frequently comprise number lines, equation steps, graph overlays, and symbolic hints aimed at bolstering algebraic reasoning (Alkan & Korkmaz, 2021; Edusei, 2022). Research has also noted an increasing utilisation of AI-generated feedback and multimodal interfaces, including interactive graph-based environments and AI-supported feedback systems (Cosentino et al., 2025; Hirschi et al., 2025; Yang et al., 2023). The literature indicates that secondary mathematics platforms typically amalgamate instructional visual feedback—such as hints, step cues, and error indicators—with gamified signals, including points, badges, and leaderboards. These elements constitute a visual feedback learning architecture that structures how students receive guidance, feedback, and motivational cues during mathematics tasks.

These studies reveal that secondary mathematics platforms depend on a combination of instructional visual feedback and gamified signals to steer student engagement. However, the majority of studies delineate these features separately or at a platform level, with insufficient focus on how they interact with the cognitive demands of multi-step mathematical reasoning. This gap underscores the necessity for a focused synthesis that concurrently examines visual feedback and gamified design, particularly in relation to cognitive load in secondary mathematics.

2.2 Gamified Design and Student Engagement in Mathematics

Evidence (Ortiz-Rojas et al., 2025; Wang et al., 2024) indicates that clear visual feedback enhances mathematical understanding by minimising confusion, directing attention, and facilitating student persistence in complex tasks. Hints and structured, step-by-step support enhance accuracy and confidence during algebraic and calculus activities (Chen et al., 2024; Holguin-Alvarez et al., 2025). Immediate error feedback and scaffolded prompts further improve student focus and alleviate working-memory strain during symbolic reasoning (Cosentino et al., 2025; Panjaburee et al., 2024).

Gamification can enhance persistence and task engagement when rewards are aligned with learning objectives (Bai et al., 2022; Ortiz-Rojas et al., 2025). Platforms such as Quizizz demonstrate that structured game mechanics can improve motivation and participation when congruent with educational goals (Muchuweni et al., 2025). Students report increased motivation when points and badges reflect genuine mathematical progress rather than speed alone (Bryant, 2024; Denden et al., 2025). However, competitive mechanics may distract students and divert attention from mathematical sense-making, particularly among those with lower confidence in mathematics (Luarn et al., 2023; Jost et al., 2023).

Studies also indicate mixed effects when game features are overused. Frequent badges or animations can overload attention and diminish deep thinking (Slamet et al., 2025). Excessive rewards may promote short-term performance at the expense of long-term understanding (Fanfarelli, 2020). In contrast, visual supports that scaffold symbolic reasoning or step sequencing consistently enhance performance in tasks requiring algebraic manipulation and function analysis (Alkan & Korkmaz, 2021; Edusei, 2022). Essentially, prior research demonstrates that visual feedback is generally beneficial for mathematical reasoning, while the effects of gamified features depend on their alignment with learning goals and task complexity. However, few studies interpret these mixed findings using a shared cognitive framework. This limitation motivates the present review's application of Cognitive Load Theory to elucidate when and why visual and gamified design features support or hinder learning in secondary mathematics.

Table 1 consolidates representative platforms and maps their visual feedback and gamified features to typical mathematical uses in secondary classrooms, providing concrete examples for the design patterns described in this section.

Table 1: Examples of Visual & Gamified Features in Secondary Mathematics Tools

Platform	Visual Feedback	Gamification	Mathematical Use
Classkick	Auto-check right/wrong answers, error highlights, teacher ink/voice/text feedback, digital stamps	Stickers, progress indicators	Algebra steps, geometry diagrams, and worked-example support
Amplify	Step guides, auto-marked answers, visual correctness cues (cards, MCQs), class board highlights	Experience-point (XP)-style progress indicators, completion markers	Expressions, functions, card sorts, structured practice
GeoGebra	Graph overlays, dynamic sliders	Badges (some versions)	Calculus slopes, transformations
Blooket	Correct/incorrect colours	XP, badges, power-ups	Mathematics Review practice
Gimkit	Live hints, scoreboard	Energy mode, upgrades	Linear functions drills
Kahoot / Quizizz	Correct colours, timers	Leaderboards, streaks	Mathematics concept review, vocabulary

3. Theoretical Framework

This study uses Cognitive Load Theory to explain how visual feedback and gamified design elements influence learning in secondary mathematics. Cognitive Load Theory, introduced by Sweller (1988), explains that students have limited working memory and that learning becomes difficult when materials contain unnecessary distractions or poorly organised information (Sweller et al., 2019). Effective instructional design reduces unnecessary mental effort so that students can focus on understanding mathematical ideas (Paas & van Merriënboer, 2020).

Secondary mathematics involves demanding tasks such as solving algebraic equations, interpreting graphs, and applying calculus rules. These tasks require students to process multiple pieces of information simultaneously. When visual feedback or gamified elements are poorly designed, they can overload working memory and reduce mathematical performance (Denden et al., 2024; Jost et al., 2023). Cognitive Load Theory distinguishes three types of cognitive load. Intrinsic load refers to the inherent difficulty of the mathematics content itself (Sweller et al., 2019). Extraneous load refers to mental effort caused by unnecessary or distracting features, such as excessive animations or frequent rewards (Paas & van Merriënboer, 2020). Germane load refers to mental effort that supports learning, such as working through examples or using helpful hints (Sweller et al., 2019).

Visual feedback features commonly used in digital mathematics platforms, including error highlights, hints, step-by-step guidance, and progress indicators, can reduce extraneous load and support germane load by directing attention to important steps in problem-solving (Chen et al., 2024; Panjaburee et al., 2024). Research shows that clear and immediate feedback enhances attention and mathematical reasoning (Chen et al., 2024; Cosentino et al., 2025). Gamified elements can support motivation, but when rewards are too frequent or overly competitive, they may distract students from mathematical thinking and increase unnecessary cognitive effort (Luarn et al., 2023; Slamet et al., 2025). Figure 1 presents the framework used in this study. It illustrates how visual feedback and gamified design elements relate to intrinsic, extraneous, and germane cognitive load, and how these relationships influence student learning and performance in secondary mathematics. This framework guides the analysis of the studies included in this review.

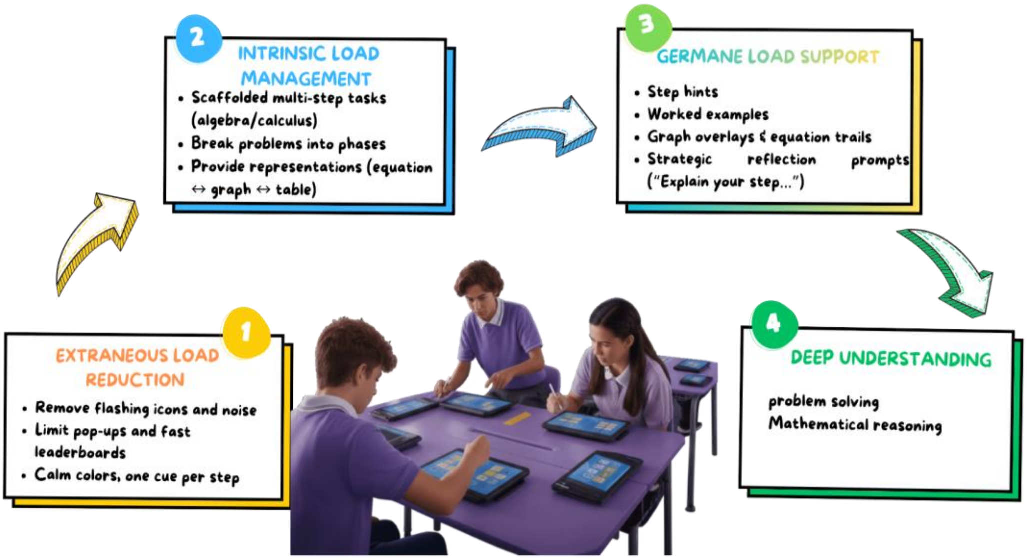

Figure 1: Visual feedback and gamification model for mathematics learning

4. Methodology

This study followed the PRISMA 2020 guidelines to collect, screen, and synthesise research on visual feedback and gamified design in secondary mathematics learning environments (Page et al., 2021). A systematic literature review was selected because the aim was to synthesise existing research rather than collect new empirical data. This design is appropriate for identifying patterns, strengths, and gaps across studies that examine visual feedback, gamified design, and learning outcomes in secondary mathematics. A structured literature search was conducted in ERIC, ScienceDirect, and SpringerLink, as these databases provide extensive coverage of research in education and mathematics education. The search focused on studies published between 2018 and 2025 to reflect recent developments in digital learning design.

Search terms were synthesised using Boolean operators to enhance accuracy and comprehensiveness. The primary search strings comprised combinations such as "visual feedback" AND mathematics, "gamified design" OR gamification AND secondary mathematics, "digital mathematics learning" AND cognitive load, and "game-based learning" AND secondary school mathematics. Additionally, related terms and synonyms were employed to ensure that pertinent studies were not excluded.

The review included studies that involved secondary or high school students, examined digital mathematics learning environments, and used visual feedback or gamified design features (Saleem et al., 2022; Bryant, 2024). Only peer-reviewed journal articles, conference papers, and doctoral studies written in English were included. Studies were excluded if they focused solely on primary or tertiary education, were not related to mathematics, involved non-digital learning activities, or did not report learning outcomes linked to motivation, engagement, or problem-solving performance (Mahat et al., 2023; Wang et al., 2024). Figure 2 presents the inclusion and exclusion criteria used in the review.

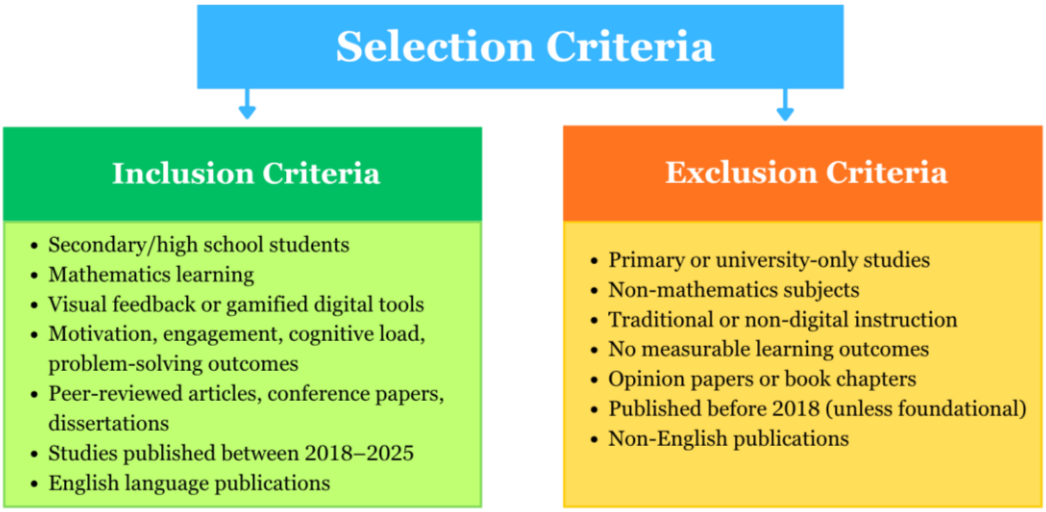

Figure 2: Inclusion and exclusion criteria for selecting studies on visual feedback and gamified design in secondary mathematics education

Screening was conducted in three stages. First, titles and abstracts were reviewed to eliminate studies that were not relevant. Second, the full texts of potentially relevant studies were examined to verify their alignment with the review's purpose. Third, the selected studies were coded based on the type of visual feedback used, the gamified design elements included, the mathematics content addressed, and the reported effects on student motivation, cognitive engagement, and problem-solving. Data extracted from each study included information about participants, digital platforms, visual feedback features, gamified elements, learning outcomes, and reported effects on student learning. Study quality was assessed based on the clarity of the research aims, the appropriateness of the research design, the transparency of data analysis procedures, and the relevance to secondary mathematics education (Ortiz-Rojas et al., 2025). Validity and reliability were addressed through transparent study selection and synthesis procedures. Only studies with clearly reported methods and learning outcomes were included, and quality checks ensured that findings were credible and consistent across studies.

The included studies were analysed using a thematic synthesis guided by Cognitive Load Theory. The selected studies employed established quantitative, qualitative, and mixed methods designs commonly used in mathematics education research, making them suitable for examining learning, motivation, and problem-solving outcomes. Only studies that met acceptable quality standards were included in the final synthesis. A PRISMA 2020 flow diagram was used to document the number of studies identified, screened, excluded, and included at each stage of the review process, as shown in Figure 3.

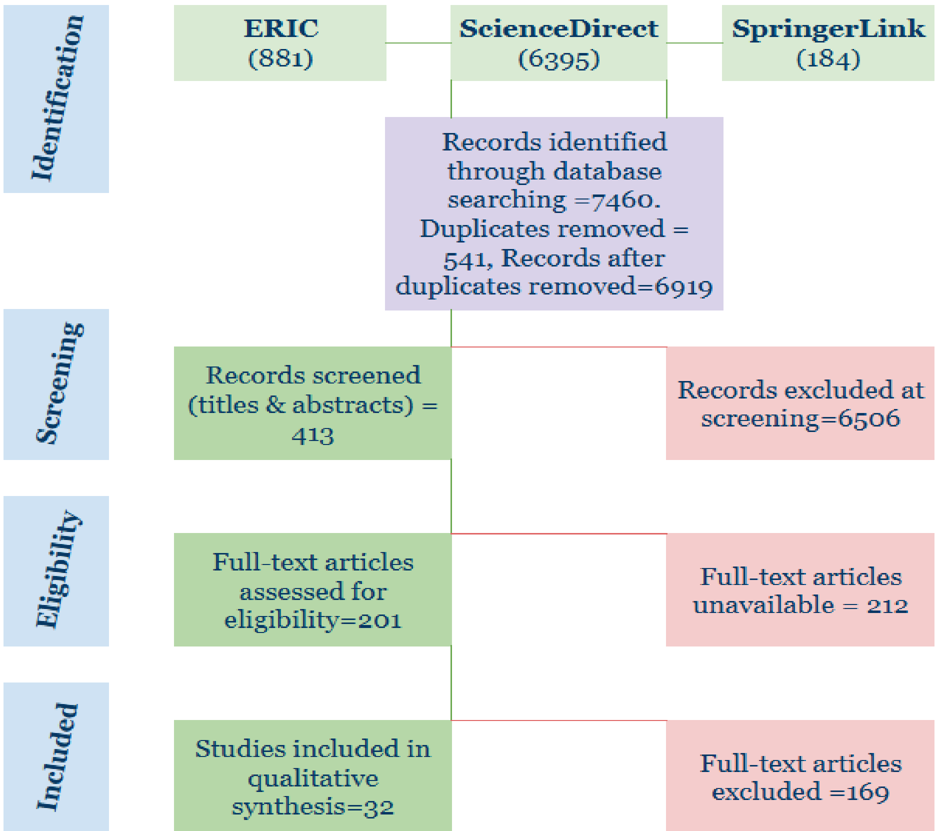

Figure 3: PRISMA 2020 flow diagram of study selection from ERIC, ScienceDirect, and SpringerLink

5. Results

This section presents findings derived from the 32 studies included in the review. Section 5.1 addresses the first research question by identifying the visual feedback and gamified design elements utilised in secondary mathematics learning environments. Section 5.2 addresses the second research question by examining how these elements influence student learning and performance, with a focus on motivation, cognitive engagement, and problem-solving performance. Figure 4 organises the principal types of visual feedback identified across the reviewed studies, such as correctness signals, error highlights, and step hints, to illustrate how these cues structure student attention during multi-step problem solving.

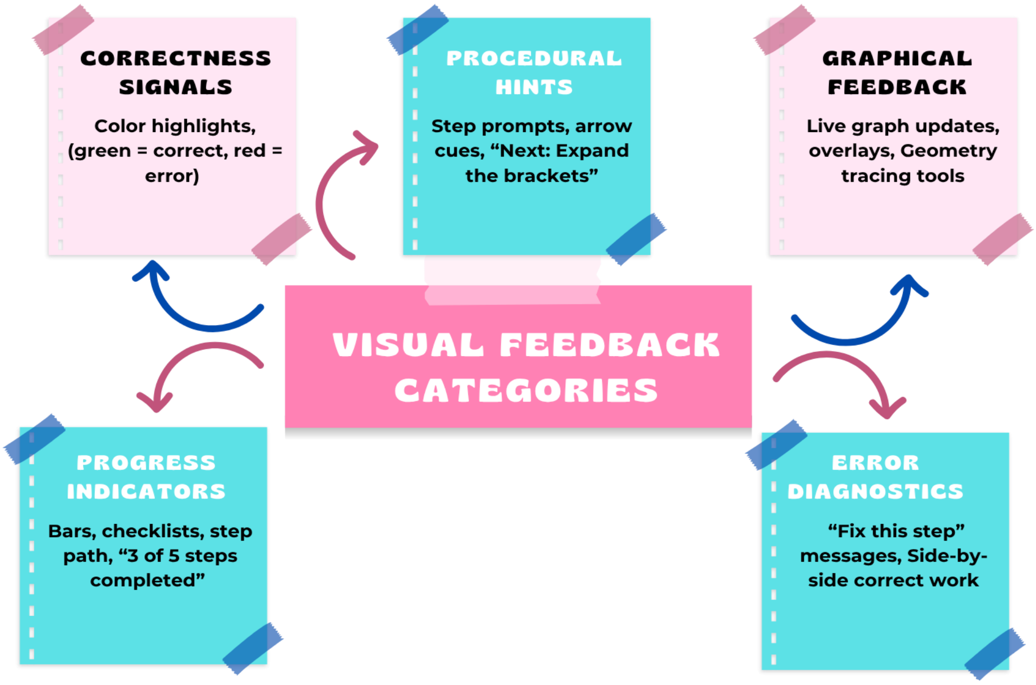

Figure 4: Major types of visual feedback used in secondary mathematics platforms

5.1 Visual Feedback Structures in Mathematics Learning Tools

The first set of findings, including those by Chen et al. (2024), Cosentino et al. (2025), and Alkan & Korkmaz (2021), elucidates the types of visual feedback utilised in secondary mathematics environments. Most tools, such as Classkick, Amplify, and GeoGebra, incorporate correctness signals, error highlights, step hints, worked solutions, equation-path indicators, and progress bars. These features direct students' attention and assist them in tracking their progress while solving algebraic and calculus tasks (Chen et al., 2024; Cosentino et al., 2025). Hints and worked-example prompts contribute to reducing confusion and enhancing accuracy by illustrating the next steps or comparing students' answers to expected formats (Holguin-Alvarez et al., 2025; Panjaburee et al., 2024).

Some platforms, such as GeoGebra and Amplify, include dynamic graphing options and symbolic overlays that help students visualise changes in functions or transformations of expressions (Alkan & Korkmaz, 2021). Immediate correctness feedback appears in almost all reviewed systems, and adaptive feedback is increasingly common, offering targeted hints based on student actions (Demedts et al., 2025; Maryono et al., 2025). A small number of systems use multimodal cues, such as gesture- and voice-supported feedback, within interactive environments (Cosentino et al., 2025). Across the reviewed studies

(Chen et al., 2024; Panjaburee et al., 2024), these visual feedback features are reported to support step-by-step reasoning by making mathematical structures more visible and reducing unnecessary searches for information.

The findings indicate that visual supports function as scaffolding structures that facilitate the processing of complex symbolic and graphical information, particularly during step-by-step problem solving. This pattern aligns with Cognitive Load Theory, which posits that clear visual guidance can alleviate extraneous cognitive load during complex tasks (Sweller et al., 2019; Paas & van Merriënboer, 2020). To further illustrate the discussion of correctness-based feedback systems, Figure 5 provides a classroom example from the Blooket platform. The screenshot is intended solely for illustrative and explanatory purposes to demonstrate common visual feedback mechanisms.

Figure 5: Illustrative example of a correctness-feedback interface in a digital secondary mathematics platform

5.2 Effects of Visual Feedback and Gamified Design on Student Learning and Performance

Gamified elements, such as badges, streak meters, point systems, and progress levels, affected student learning and performance in various ways. In many platforms, "XP" (experience points) represents progress earned by completing tasks or solving problems, allowing students to gradually "level up" over time. Studies by Bryant (2024) and Ortiz-Rojas et al. (2025) show that these systems increased persistence when rewards reflected genuine learning progress, such as solving a sequence of algebra problems or completing lessons with accurate reasoning. Collaborative challenges, such as those found in Blooket team mode and Gimkit cooperative modes, also supported motivation among lower-anxiety students, while reward structures that emphasised consistency over speed fostered more accurate problem solving (Kingsley & Grabner-Hagen, 2023).

Conversely, competitive leaderboards and frequent reward notifications have been found to heighten distraction and performance pressure for certain students, particularly those with lower confidence in mathematics (Luarn et al., 2023; Jost et al., 2023). Several studies (Fanfarelli, 2020; Denden et al., 2024) report that when rewards are not accompanied by meaningful feedback, students tend to focus on accumulating points rather than comprehending mathematical concepts, thereby diminishing conceptual learning.

Reward systems, such as XP badges in Blooket, power-ups in Gimkit, and feedback stamps in Classkick, promote learning when they encourage sustained attention, careful thinking, and reflection during mathematical problem-solving. They are less effective when they incentivise speed, peer comparison, or reward-driven behaviours that detract from mathematical reasoning. Figure 6 summarises the principal gamification elements identified across the reviewed studies and illustrates how these elements correlate with persistence, focus, and potential distraction within secondary mathematics learning environments.

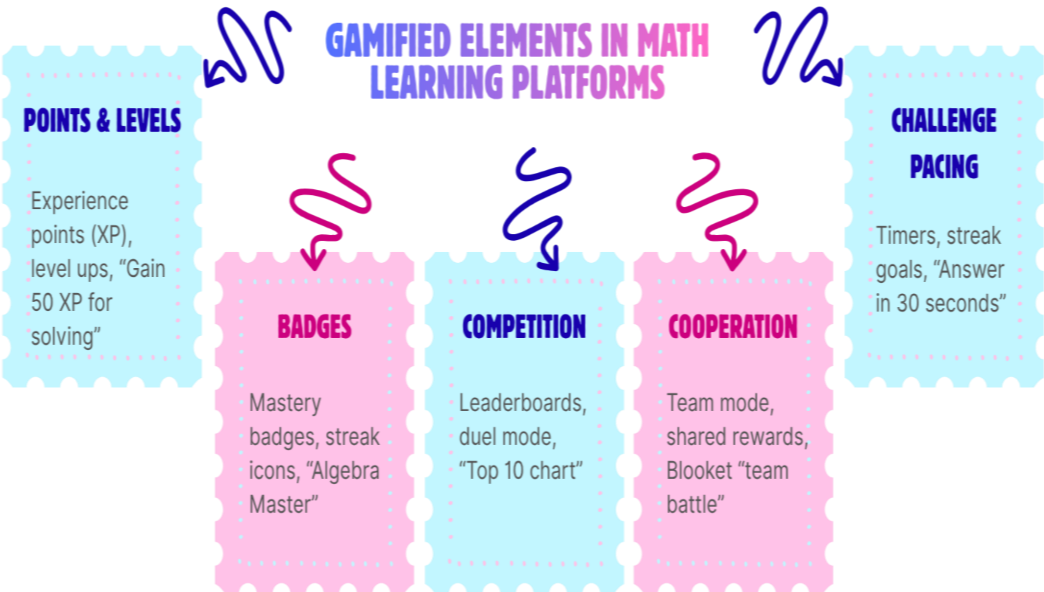

Figure 6: Common gamification elements used in secondary mathematics learning platforms

6. Discussion

This section discusses the findings of the review using Cognitive Load Theory. The findings indicate that visual feedback helps students focus on important steps and manage cognitive effort during mathematics tasks, while gamified design features influence motivation and persistence depending on how well they support learning goals. Figure 7 synthesises the reviewed findings using Cognitive Load Theory and is presented as an interpretive model rather than a results table. It illustrates how visual feedback and gamified design features connect with cognitive load and mathematical reasoning as part of a learning design architecture for secondary mathematics. Section 6.1 focuses on the role of visual feedback in supporting mathematical reasoning, while Section 6.2

examines how gamified design features affect student motivation and problem-solving performance.

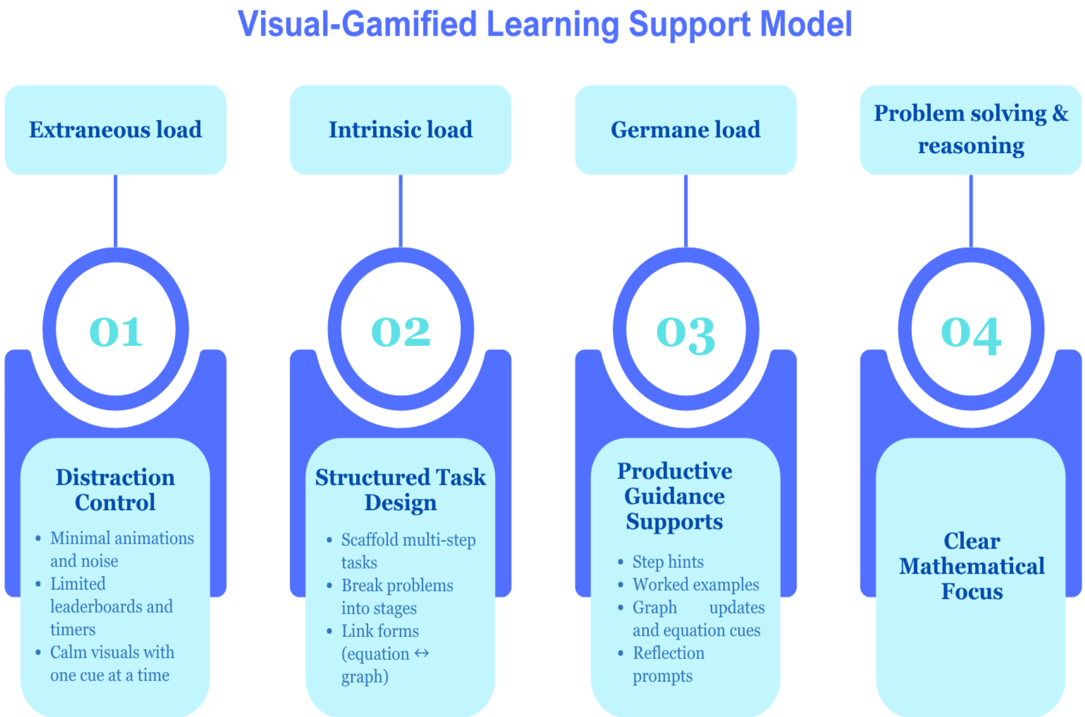

Figure 7: Cognitive Load-aligned instructional design pyramid for digital mathematics learning

6.1 Cognitive Architecture of Visual Feedback in Mathematics Tools

Studies in this review, such as Chen et al. (2024) and Cosentino et al. (2025), suggest that clear and well-structured visual feedback helps students manage the mental demands of mathematical problem-solving. Through the lens of Cognitive Load Theory, these supports reduce unnecessary effort by removing guesswork, clarifying errors, and highlighting essential steps. Showing equation transformations, pointing to the next algebraic move, or updating graphs as students enter values keeps attention focused on meaningful information (Alkan & Korkmaz, 2021).

Mathematics often requires shifting between symbols, numbers, graphs, and explanations. Without support, moving from an algebraic function to a graph or from a derivative rule to an application can overwhelm working memory. In the studies reviewed, structured visual cues acted as anchors that slowed the pace, broke complex processes into parts, and made invisible ideas visible. This supports CLT's view that design should reduce clutter and highlight logic (Sweller et al., 2019). From a design perspective, these findings suggest that visual systems may be most effective when they follow a clear pathway, like a guided lesson. Instead of adding icons or animations for appearance, intentional cues placed at key steps help students remain focused. In secondary mathematics, environments that feel clean, predictable, and supportive appear to encourage students to stay engaged in challenging tasks, such as solving systems or analysing functions, aligning with CLT principles that prioritise clarity and cognitive efficiency. By making task structure explicit, these visual supports help manage intrinsic cognitive load while reducing extraneous load during complex mathematical problem solving (Sweller et al., 2019; Paas & van Merriënboer, 2020).

6.2 Motivational Design Features and Their Effects on Student Learning in Mathematics

Gamified structures influence motivation in ways that depend on their connection to learning. When points, levels, and badges recognise true mathematical progress, they reinforce effort and persistence. In this manner, motivational cues function as part of the learning system, supporting deeper thinking rather than replacing it (Bryant, 2024; Ortiz-Rojas et al., 2025). From a Cognitive Load Theory perspective, these structures support productive effort by encouraging students to reflect, retry, and stay engaged when challenges arise (Denden et al., 2024).

Competitive features such as rapid timers, public leaderboards, or frequent pop-ups can create pressure and distraction, particularly for students with lower confidence (Luarn et al., 2023; Jost et al., 2023). Instead of monitoring their steps, checking reasoning, or connecting methods, students may rush for speed or chase rewards. This shifts attention from learning towards performance and adds extraneous cognitive load that interferes with mathematical reasoning. Designers can avoid this by implementing mastery-focused systems that reward consistency, accuracy, and improvement.

Viewed through the lens of Cognitive Load Theory, these patterns highlight the value of calm, structured, and intentional gamified design in mathematical tools. Visual cues and rewards are most effective when they support attention, build understanding step-by-step, and motivate effort rather than competition, reinforcing the importance of aligning gamification mechanics with cognitive and motivational goals. The implications of these findings for classroom practice, digital learning design, and future research are discussed in Section 9, while the limitations of the review are outlined in Section 7.

7. Limitations

This review has several limitations. It included only studies published in English, so relevant research in other languages may not be represented. The review also focused on studies from 2018 to 2025, reflecting current practice but potentially excluding earlier work on feedback and gamification. The included studies used different platforms, teaching contexts, and research designs, which may affect the consistency of the findings. Most studies measured short-term engagement or performance, limiting the understanding of long-term effects on mathematical learning.

Additionally, some studies had small sample sizes or limited reporting of methods, which may weaken the strength of the evidence. As this review focused solely on secondary mathematics, the findings may not apply to primary or university settings, which further limits the extent to which the learning architecture examined here can be generalised. To mitigate the impact of these limitations, the review followed PRISMA guidelines, applied clear inclusion and exclusion criteria, and compared findings across different study types and digital platforms. Patterns were interpreted cautiously and reported only when supported by multiple studies. These limitations indicate that the findings should be interpreted with caution, particularly concerning long-term learning effects and causal claims.

8. Conclusion

This systematic review examined the impact of visual feedback and gamified design elements on student learning and performance in secondary mathematics. Guided by Cognitive Load Theory, the review addressed two research questions focused on the types of visual feedback and gamified features utilised in secondary mathematics and their influence on student motivation, cognitive engagement, and problem-solving performance. The findings collectively indicate that digital design choices play a critical role in shaping how students think, persist, and reason during complex mathematical tasks. Across the reviewed studies, visual feedback features such as step-by-step hints, error highlights, and progress indicators consistently supported learning by guiding attention, clarifying procedures, and reducing unnecessary cognitive effort. These supports enabled students to manage the demands of multi-step algebraic and graphical tasks, resulting in a stronger understanding and increased persistence.

Conversely, the influence of gamified design elements on learning was more varied. When points, levels, and progress systems were closely aligned with mathematical goals, they encouraged effort and sustained engagement. In contrast, competitive features such as leaderboards and time pressure often increased distraction and diverted attention from reasoning, particularly for students with lower confidence. In answering the research questions, this review demonstrates that effective secondary mathematics learning relies not solely on the presence of visual or gamified features, but on the extent to which these features align with cognitive principles. The central theme of this study is that visual feedback and gamified design together create a learning design architecture that can either support or hinder mathematical thinking. When grounded in Cognitive Load Theory, this architecture can guide attention, reduce cognitive strain, and facilitate meaningful learning.

9. Implications and Recommendations

The findings of this review have clear implications for classroom practice, digital learning design, platform development, and future research. Based on these implications, Table 2 summarises key recommendations for each stakeholder group.

Table 2: Design Recommendations Summary

Stakeholder	Key Actions
Teachers	Choose tools with clear steps, limited competition
Designers	Favor calm cues, slow-paced scaffolds
Platforms	Reward accuracy and persistence, not speed
Researchers	Study long-term conceptual outcomes

Building on these summary recommendations, the reviewed studies indicate that digital mathematics tools are most effective when they provide visual feedback and gamified features that reduce cognitive load, guide attention, and promote meaningful engagement rather than emphasising speed or competition. These insights lead to practical actions that can enhance the selection, design, and study of digital mathematics tools.

In classroom practice, teachers play a crucial role in shaping how students interact with digital mathematics tools. The findings suggest that students benefit most when visual feedback fosters clear mathematical thinking through step-by-step hints, worked examples, and progress cues linked to understanding rather than speed. Visual scaffolds, such as equation walkthroughs, graph overlays, and structured feedback messages, can reduce confusion and help students concentrate on reasoning. By limiting highly competitive features and promoting personal progress and reflection, teachers can further support students who may experience mathematics anxiety. Additionally, teachers can facilitate learning by encouraging students to use feedback purposefully, such as pausing to check each step or comparing their reasoning with worked examples before proceeding.

The review also highlights significant implications for learning designers. Feedback systems are most effective when they minimise unnecessary cognitive load and direct attention towards key mathematical concepts. Clear layouts, consistent visual cues, and gentle pacing help students stay focus during complex problem-solving tasks. Gamified features should reward effort, strategic use, and improvement rather than speed or mere accuracy. Adaptive hints, staged problem-solving paths, and calm progress indicators can support deeper learning without overwhelming students. Furthermore, visual elements should be seamlessly integrated into the mathematical process rather than merely added as decoration. Designers should also consider incorporating short reflection pauses before hints or rewards appear to promote careful reasoning and reduce unnecessary cognitive load.

Conflicts of Interest
The authors declare that there are no conflicts of interest associated with this study.

Acknowledgement
The authors acknowledge the use of ChatGPT (OpenAI) solely for language editing and clarity. The tool did not contribute to the study's design, data analysis, theoretical framing, or interpretation. All ideas, methods, and conclusions are entirely the authors' own.

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