Designing AI-Enhanced Educational Digital Escape Room Games (EDERGs): A Framework for Teacher Implementation

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Abstract: In recent years, educational digital escape room games (EDERGs) have become a dynamic method for fostering problem-solving, collaboration, and engagement in learning environments. Simultaneously, artificial intelligence (AI) has emerged as a powerful tool to enhance personalization, adaptivity, and real-time feedback in educational contexts. While both domains hold significant pedagogical potential, teachers often lack accessible guidance on how to meaningfully integrate AI into the design of educational games. This study addresses this gap by proposing a design and development research (DDR) project aimed at constructing a step-by-step framework to support teachers in designing AI-enhanced EDERGs. The research explores the question: How can teachers design AI-enhanced EDERGs? Drawing on insights from previous professional development sessions with in-service teachers, this study adopts a qualitative approach to capture educators' experiences, needs, and reflections. Through iterative cycles of analysis, design, evaluation, and refinement, we develop a practical and theoretically grounded framework that combines game-based learning principles with AI-enhanced instructional strategies. The proposed framework outlines key design steps, including setting pedagogical goals, crafting meaningful narratives, designing puzzles aligned with learning outcomes, and integrating AI components such as adaptive hints, automated feedback, and learner analytics. Teacher feedback collected through interviews and reflection journals informs the refinement of the model, ensuring its usability and relevance in real classroom settings. This paper presents the initial version of the framework along with examples of how it can be applied by teachers with varying levels of technical expertise. By bridging the gap between game-based learning and AI integration, the framework aims to empower educators to create more engaging and responsive learning experiences. The study contributes to the field by offering both a practical design guide for educators and a foundation for future research on AI-supported educational game development.

Keywords: Educational digital escape room games, Game-Based learning, Artificial intelligence in education, Technology integration in education, Instructional framework

1. Introduction

In today's technology-rich classrooms, educators are constantly seeking new ways to foster student engagement, collaboration, and critical thinking. Educational digital escape room games (EDERGs) have emerged as a powerful strategy in this regard, transforming learning environments into interactive problem-solving adventures (Fotaris and Mastoras 2019). Simultaneously, AI has revolutionized educational possibilities by enabling real-time feedback, personalized pathways, and adaptive learning experiences (Luckin, Griffiths and Forcier, 2016).

While both game-based learning and AI offer unique pedagogical benefits, the meaningful integration of these two domains remains a significant challenge for educators. Teachers often lack structured, practical guidance on how to design AI-supported educational games—particularly when it comes to balancing pedagogical goals with technical implementation (Chassignol et al, 2018). This gap is even more pronounced when considering non-technical educators who may not have access to specialized development tools or AI expertise.

Despite the growing research on AI in education and the increasing use of educational games, few studies offer a comprehensive framework that supports teachers in designing AI-enhanced EDERGs. Most existing approaches focus either on game mechanics or AI functionalities, without offering a unified and teacher-friendly model that brings these elements together in a meaningful instructional design.

This study addresses this gap by asking: How can teachers design AI-enhanced educational digital escape room games? Using a design and development research (DDR) approach, the study draws on qualitative data collected during professional development sessions with teachers. The result is a practical and theoretically grounded framework that guides educators step-by-step through the process of integrating AI into EDERG design. By doing so, this study aims to bridge the gap between innovation and implementation, offering a solution that is both visionary and grounded in classroom realities.

2. Literature Review

To develop a meaningful framework for designing AI-enhanced educational digital escape room games, it is essential to examine existing literature across three key domains: game-based learning, artificial intelligence in education, and technology integration models. Each area provides a foundation for understanding the opportunities and challenges of combining pedagogy, technology, and instructional design in innovative ways. This review begins by exploring the pedagogical value and design principles of EDERGs, followed by an overview of the roles AI can play in educational contexts. Finally, the review discusses existing technology integration frameworks that inform the structure and scaffolding of the proposed model.

2.1 Educational Digital Escape Room Games (EDERGs)

Educational digital escape room games are gamified learning experiences in which students solve puzzles, interpret clues, and complete tasks within a narrative structure to achieve a specific learning goal. These games are typically time-bound, collaborative, and designed to promote problem-solving, critical thinking, and content mastery (Fotaris and Mastoras, 2019). As digital adaptations of physical escape rooms, EDERGs allow for greater flexibility in classroom use, especially when implemented through platforms such as Google Forms, Sites or Genially.

Recent studies have shown that EDERGs foster learner motivation and engagement, particularly when designed around meaningful challenges and authentic scenarios (Veldkamp et al, 2020). Their collaborative structure also aligns with social constructivist perspectives on learning, in which knowledge is co-constructed through dialogue and shared activity. Despite their growing popularity, many teachers face difficulties in designing EDERGs, especially when required to align gameplay with curricular goals and integrate digital tools. While template-based solutions exist, they often do not provide pedagogical or strategic support for meaningful instructional design (Borrego et al, 2017). Moreover, as noted in Kara (2021), there is a growing need for structured guidance that enables teachers to design these experiences independently, even without advanced technical expertise.

The integration of AI into escape rooms is a relatively new and underexplored area. Early experiments have shown that AI can support real-time scaffolding, adaptive hint systems, and data-informed personalization within game environments (Khine, 2024). However, most existing AI-enhanced escape rooms have been developed by researchers or developers—not teachers—highlighting the need for a framework that enables classroom educators to access and utilize such technologies in a pedagogically grounded way.

2.2 Artificial Intelligence in Education

Artificial intelligence (AI) has emerged as one of the most influential technologies shaping the future of education. In recent years, AI applications have expanded rapidly, enabling systems that can provide real-time feedback, personalize learning pathways, detect learner emotions, and assist in both assessment and content creation (Luckin, Griffiths and Forcier, 2016; Holmes, Bialik and Fadel, 2019). These technologies hold promise for making learning more adaptive, data-driven, and responsive to student needs.

AI-enhanced learning environments can support differentiated instruction by automatically adjusting the level of challenge or providing timely hints based on learner behaviour (Das and Ray, 2025). Moreover, intelligent tutoring systems and learning analytics platforms have been shown to improve student outcomes by identifying gaps in understanding and tailoring instruction accordingly (Baker and Inventado, 2014). In addition to cognitive support, AI has also been applied in the affective domain—for instance, by recognising learner frustration or disengagement and responding appropriately (Woolf, 2010).

Despite these advances, integrating AI into classroom practice remains complex. Many teachers lack both the technical knowledge and conceptual understanding needed to effectively implement AI tools (Zawacki-Richter et al, 2019). Concerns around ethics, data privacy, and transparency further complicate adoption, particularly in K–12 settings where student data sensitivity is a major consideration. Furthermore, much of the existing research and development in AI for education is geared towards system developers, not end-users such as teachers (Chassignol et al, 2018).

In the context of game-based learning, the potential of AI is only beginning to be explored. AI can enhance educational games by offering real-time scaffolding, tracking progress, and generating content dynamically (Khine, 2024). However, few frameworks exist to help educators integrate these tools meaningfully and pedagogically. As AI continues to evolve, there is a pressing need to develop practical, teacher-friendly

frameworks that align AI capabilities with instructional goals—especially in innovative formats like educational digital escape room games.

2.3 Technology Integration Models as Design Inspiration

Successfully integrating artificial intelligence into educational practices requires more than access to tools—it demands pedagogical frameworks that help educators make informed, purposeful design choices. Over the past two decades, several models have been proposed to guide technology integration in teaching and learning. Among the most influential are the TPACK framework, the SAMR model, and the Technology Integration Matrix (TIM). These models provide valuable conceptual foundations for designing a framework that supports teachers in creating AI-enhanced educational digital escape room games.

The Technological Pedagogical Content Knowledge (TPACK) framework emphasizes the intersection of content, pedagogy, and technology knowledge, suggesting that effective educational technology use arises when these domains are thoughtfully aligned (Mishra and Koehler, 2006). In the context of AI-enhanced EDERGs, TPACK offers a lens through which teachers can reflect on how AI tools support both disciplinary learning and instructional strategy within the game environment.

The SAMR model, developed by Puentedura (2006), provides a four-tier continuum of technology use in education: Substitution, Augmentation, Modification, and Redefinition. SAMR encourages educators to move beyond simple tool replacement and toward transformative practices. In game-based learning contexts, AI may begin as an augmentative tool (e.g., auto-generating clues) but has the potential to redefine the learning experience through adaptive gameplay and intelligent scaffolding.

The Technology Integration Matrix (TIM), developed by the Florida Center for Instructional Technology (2011), categorizes technology use across five levels of integration (Entry to Transformation) and five learning characteristics (active, collaborative, constructive, authentic, and goal-directed). TIM's focus on learning experience and student agency aligns well with the immersive and participatory nature of escape room games, and provides inspiration for how AI can be mapped onto different types of learning engagement.

Together, these models offer conceptual tools for building a framework that is not only technically grounded but also pedagogically meaningful and accessible to teachers. By drawing from these traditions, the proposed framework aims to help educators make thoughtful decisions about where, when, and how to integrate AI into the design of EDERGs.

3. Method

3.1 Research Design

This study adopts a design and development research approach, as outlined by Richey and Klein (2014), to systematically create and refine a framework for designing AI-enhanced educational digital escape room games. DDR is particularly suited to studies that aim to produce practical, usable educational interventions while grounding them in theoretical and empirical research (Richey, Klein and Nelson, 2003). The methodology involves iterative cycles of analysis, design, implementation and evaluation, enabling close collaboration with end-users - in this case, pre-service teachers - throughout the development process. A high-quality design and development study aligns instructional design practices with clearly defined research goals. The process typically follows an iterative cycle encompassing stages such as analysis, development, implementation, and evaluation. Throughout this cycle, researchers collaborate with participants to co-develop a product that holds scholarly value and contributes to the broader literature. The study not only assesses the effectiveness and practical relevance of the developed designs but also considers the time frame required for implementation. Additionally, a variety of research methods—each tailored to the specific phase of the design process—are employed and examined in detail (Design Based Research Collective, 2003; Kuzu, Çankaya and Mısırlı, 2011).

3.2 Participants

Participants were selected using purposeful sampling, focusing on teachers working in schools implementing game-based learning. Four workshops were held in this context. Information on the participants in these four workshops is given in Table 1.

Table 1: Participants

Workshop	Female	Male
First Session	15	5
Second Session	12	9
Third Session	10	8
Four Session	13	11

3.3 Data Collection Tools

To gain a comprehensive understanding of teachers' perspectives and experiences during the development of the AI-enhanced EDERG framework, multiple qualitative data sources were utilized. Semi-structured interviews were conducted at the beginning and conclusion of each design cycle to explore participants' initial expectations, their evolving design practices, and their reflections on the integration of AI elements into educational escape room games. In addition, observation notes were systematically gathered by the research team throughout the professional development workshops. These notes focused on teacher interactions, collaboration patterns, design-related decision-making, and engagement with AI tools. Together, semi-structured interviews and systematic observation notes provided rich, triangulated insights into the instructional design process and informed iterative improvements to the proposed framework.

3.4 Data Collection and Analysis

To explore how teachers engaged in the design of AI-enhanced EDERGs, qualitative data were primarily collected through systematic observation notes recorded during professional development workshops. The observations focused on key aspects of the design process, including narrative construction, puzzle development, time management, and the use of AI tools.

Following Creswell's (2016) guidelines for observation-based qualitative analysis, observation notes were systematically reviewed to identify recurring challenges, patterns of behaviour, and responses to AI integration. Findings were organized according to major components of the framework, ensuring that the analysis remained closely aligned with the practical design issues encountered by teachers. Triangulation was strengthened by combining observations with informal participant feedback collected during and after the workshops.

4. Findings

The findings of this study are organized around the key challenges, developments, and observations that emerged during the teacher workshops on designing AI-enhanced educational digital escape room games.

4.1 Initial Challenges in Game Design

Teachers generally demonstrated a good command of constructing narratives, likely due to their familiarity with student interests. However, despite this advantage, narrative construction was still reported as a time-consuming task. One of the most prominent challenges identified was the difficulty teachers experienced in creating meaningful connections between the storyline and the embedded puzzles. While storylines were developed, the clues and tasks often remained disconnected from the narrative, diminishing the overall coherence of the games. Additionally, participants faced significant issues with time management. Although designing an EDERG could theoretically be completed within a few hours, many teachers found themselves unable to finalize their games over several days, often leading to frustration and, ultimately, abandonment of the design process.

4.2 Revisions to Training Based on Feedback

In response to the identified challenges, the training program underwent several targeted revisions. Initially, detailed templates were introduced to guide teachers through each step of the design process. Hands-on demonstrations were incorporated to model the use of these templates. Subsequent feedback indicated a need for further support, particularly in aligning narratives with clues. As a result, examples of AI-generated

story and puzzle connections were shared, along with sample prompts that teachers could adapt. Additionally, sample games designed by the researcher were integrated into later workshops, allowing teachers to experience complete, well-structured EDERGs and better internalize the design principles.

These ongoing revisions based on direct feedback proved crucial in shaping the final instructional framework. By closely aligning training content with the evolving needs and challenges of teachers, the development process ensured that the framework was both practical and highly responsive to real-world classroom conditions. The iterative refinement of training materials not only enhanced participants' design competencies but also provided a solid empirical foundation for the structure and components of the final framework. Consequently, the framework evolved as a user-centered model, deeply rooted in authentic teacher experiences and validated through multiple cycles of observation, feedback, and revision.

4.3 Teacher Perceptions of AI-Supported Content Generation:

Participants were asked about their opinions regarding the use of AI tools for supporting the creation of storylines and puzzles during the design of educational digital escape room games. Their initial reactions and reflections on how AI-assisted design influenced their work were collected through interviews and workshop observations.

Teachers expressed overwhelmingly positive views toward AI-supported content generation. They noted that using AI tools made it possible to design games much faster and more efficiently. Several participants highlighted that the use of AI significantly reduced the time burden of game creation, which had previously been a major obstacle.

Teacher 1: "Now we can design many games very quickly."

Teacher 2: "I have already started creating games on my phone."

Following the introduction of AI tools into the training sessions, it was observed that the design process accelerated noticeably. In earlier workshops, participants struggled to complete their games within the allotted time; however, after the integration of AI tools, teachers were able to finalize their games more quickly and even had time to playtest them during the same session. Observations also indicated that teachers showed increased engagement and enthusiasm when using AI tools, as they appeared more motivated and confident in their ability to complete their projects.

4.4 Improvements Observed in Teachers' Design Practices

By the conclusion of the training cycles, significant improvements were observed in teachers' time management and design coherence. Teachers developed more consistent and engaging narratives and demonstrated a greater ability to create puzzles that were meaningfully integrated into the storyline. Furthermore, their ability to use AI tools, particularly in generating prompts and refining content, improved notably over time. Teachers became increasingly adept at crafting targeted and effective prompts to guide AI-generated outputs, enhancing the quality and relevance of their games.

4.5 Perceived Value of the Framework

Teachers reported that the final framework significantly accelerated their design process, enabling them to develop educational digital escape room games far more efficiently. They emphasized that, with the support of the framework and AI tools, game design became a feasible and time-efficient task. Importantly, participants highlighted that the framework addressed one of their primary concerns: minimizing the time burden associated with designing high-quality educational games, thus making the practice more sustainable and appealing for busy educators.

4.6 Visual Representation of the AI-Enhanced EDERG Framework

In order to clearly synthesize the findings obtained through teacher training sessions and to present the iterative structure of the framework developed in this study, a visual model of the AI-Enhanced EDERG Framework was designed. This visual representation emphasizes the continuous development cycle inherent in the framework and provides an accessible overview for educators aiming to design AI-supported educational escape room games. The circular design and the directional arrow at the bottom of the figure symbolize the ongoing, cyclical nature of the design process, highlighting that each implementation should lead to further reflection, revision, and enhancement.

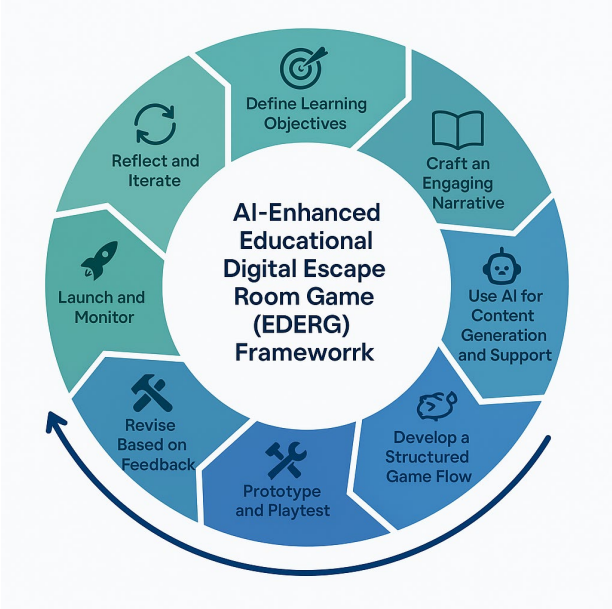

Figure 1: AI-Enhanced Educational Digital Escape Room Game Framework

The framework begins with defining clear and measurable learning objectives that are aligned with curriculum goals. This is followed by crafting an engaging narrative that features a coherent beginning, middle, and end structure tailored to students' interests and developmental levels. Teachers then design puzzles that are meaningfully integrated into the storyline, ensuring that each clue advances both the narrative and the learning outcomes. Artificial intelligence tools are utilized at this stage to support the generation of story ideas, puzzles, and adaptive hint systems, enhancing the creativity, personalization, and efficiency of the design process. A structured game flow is developed to organize the progression of gameplay and manage time effectively. Optionally, AI-enhanced features such as automated feedback, adaptive hints, and basic learning analytics are embedded to further enrich the learning experience. After initial prototyping and small-scale playtesting, teachers revise their designs based on participant feedback and observed challenges. The completed game is then launched in real classroom environments, where student engagement, collaboration, and learning are closely monitored. Finally, teachers engage in reflection and iteration, using insights gained from classroom implementation to refine and improve the design in future applications.

This visual framework not only encapsulates the iterative and user-centered approach emphasized throughout this study but also serves as a practical tool to support teachers in overcoming common challenges in AI-enhanced educational game design. By making the design process more structured, efficient, and adaptable, the framework contributes to bridging the gap between innovative pedagogical concepts and real-world classroom practices.

5. Discussion and Conclusion

The findings of this study highlight the transformative potential of integrating AI into the design of EDERGs to create more dynamic, adaptive, and engaging learning experiences. Teachers demonstrated strong capabilities in crafting narratives but faced challenges in aligning puzzles with storylines and managing time effectively during the design process. The introduction of AI tools notably addressed these challenges by streamlining content generation and enhancing the coherence between game narratives and learning objectives. Furthermore, participants' positive perceptions of AI-supported design suggest that, when provided with appropriate scaffolding, teachers can confidently and effectively leverage AI technologies within game-based instructional contexts.

These results align closely with existing research on EDERGs and AI in education. Previous studies, such as Fotaris and Mastoras (2019), emphasized that EDERGs foster learner motivation and engagement, particularly when designed around authentic and meaningful challenges. Similarly, Veldkamp et al (2020) underscored the importance of narrative coherence and the integration of puzzles into authentic scenarios for maximizing educational impact. The difficulties teachers faced in creating cohesive links between storylines and puzzles in the early stages of this study reflect the same challenges highlighted in prior literature. However, by

introducing AI support, this study extended previous findings by demonstrating how technological scaffolding can directly address narrative-puzzle alignment issues, an area that had been underexplored.

In terms of AI integration, the results corroborate previous observations by Luckin et al (2016) and Holmes, Bialik and Fadel (2019), who identified AI's potential to offer personalized feedback, adaptivity, and real-time support in educational settings. Moreover, Khine (2024) emphasized the role of AI in enhancing adaptive learning environments, particularly through real-time scaffolding—a role mirrored in this study, where AI tools helped teachers generate differentiated content and adaptive hints more efficiently. However, this study also echoes the concerns raised by Chassignol et al (2018) and Zawacki-Richter et al (2019) regarding the challenges non-technical educators face when adopting AI-based tools. Initially, several teachers expressed uncertainty or hesitance toward AI use, highlighting the ongoing need for accessible, teacher-friendly AI integration strategies.

The development of the AI-enhanced EDERG framework represents a meaningful contribution to the field by synthesizing insights from game-based learning, AI in education, and technology integration models such as TPACK (Mishra & Koehler, 2006) and SAMR (Puentedura, 2006). By emphasizing iterative reflection, adaptation, and practical design scaffolding, the framework provides a tangible, actionable guide for teachers seeking to meaningfully integrate AI into educational game development. Unlike prior template-based EDERG design models (Borrego et al, 2017), this framework centers not only on game mechanics but also on pedagogical alignment and technological augmentation, thereby bridging the gap between innovation and classroom reality.

In conclusion, this study demonstrates that when appropriately supported, teachers can successfully integrate AI technologies into educational digital escape room game design, leading to more efficient, coherent, and engaging learning experiences. The AI-enhanced EDERG framework offers a practical pathway for educators to incorporate AI into instructional design without requiring advanced technical expertise. Future research should further explore the longitudinal impacts of AI-enhanced EDERGs on student learning outcomes across diverse educational settings. Moreover, investigating the integration of emerging AI capabilities, such as generative AI and adaptive learning analytics, into the framework could unlock new possibilities for personalized and transformative educational experiences.

6. Limitations and Future Research Directions

This study provides valuable insights into the design of AI-enhanced educational digital escape room games, but several limitations must be noted. First, the participant group mainly included teachers who were already interested in game-based learning, which may limit the generalizability of the findings. Second, the study focused on short-term workshop outcomes and did not assess the long-term sustainability of the framework's application in everyday classrooms.

Future research could experimentally investigate the impact of EDERGs designed using this framework on student motivation, engagement, and academic performance. Additionally, applying the framework across multiple teacher training sessions, gathering further feedback, and iteratively refining the framework could strengthen its adaptability and effectiveness for broader educational contexts.

Ethics Declaration: The confidentiality and anonymity of all participants were strictly maintained. All collected data were stored securely and used solely for research purposes. No identifiable personal information was disclosed.

AI Declaration: As of the version dated 26.04.2025, this paper was prepared with the assistance of Chatgpt-4.0, which was employed to proofread, edit, and refine the text, enhancing clarity and coherence. The AI tool was used as a supplementary editorial aid, complementing the human editorial process by refining language while preserving the author’s original analysis and intent.

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