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Architecting Digital Educational Escape Rooms: A Framework for Instructional Orchestration, Role-Based Collaboration, and AI-Supported Learning

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ABSTRACT

Digital Educational Escape Rooms (DEERs) have increasingly emerged as innovative technology-enhanced learning environments that encourage engagement, motivation, and collaborative participation. When collaboration, progression, and learner support are not systematically orchestrated into the environment itself, their instructional effectiveness may be limited. Implementations often focus on gamification without embedding pedagogically aligned mechanisms that regulate interaction flow, interdependence, and reflection. To address these limitations, this paper presents the design, development, and evaluation of a DEER environment from a system perspective. The environment integrates conditional progression, collaboration and scaffolding supported by artificial intelligence within an instructional orchestration framework. The "Find Mr. X" DEER environment was developed on Wix using Velo Dev Mode, transforming a standard website into an event driven learning system. System-level mechanisms ensured that learners progressed only after completing the required tasks, across the five phases of the MCIEC model. A Jigsaw collaborative strategy was implemented through separate expert pathways and roles, while artificial intelligence tools provided optional metacognitive scaffolding. Findings from a pilot implementation involving 30 pre-service and in-service teachers demonstrate the operational reliability and pedagogical feasibility resulting in a 100% completion rate with no navigation errors. Participants rated the system positively for its contribution to mathematical understanding and learning (M = 4.30/5.00), as well as the embedded AI-supported scaffolding layers (M = 4.13/5.00). Conditional progression successfully reduced unstructured trial and error behavior, while Jigsaw promoted positive interdependence and productive collaboration. Finally, the study contributes a framework that links instructional affordances with technological affordances and learner competencies within the DEER environment.

Keywords: Digital educational escape rooms, Learning orchestration, Gamified learning, Jigsaw strategy, Artificial intelligence, Collaborative learning, Instructional design, Technology-enhanced learning, MCIEC model, Conditional progression

INTRODUCTION

Digital Educational Escape Rooms (DEERs) have attracted increasing attention in educational contexts because they combine narrative, challenge-based progression, collaboration, and problem solving. Their educational value,

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however, depends not only on game elements but also on how progression, collaboration, and support are organized within the environment (Veldkamp et al., 2020; Jiménez et al., 2020; Makri et al., 2021). When these elements remain loosely structured, learners may engage in superficial participation or adopt unproductive trial and error approaches to problem solving. Find Mr. X addresses this challenge by embedding pedagogical orchestration directly into the system architecture, ensuring that learner progression remains aligned with intended learning pathways and conceptual understanding (Dillenbourg, 2013; Prieto et al., 2015).

From a collaborative learning perspective, knowledge construction depends on how roles, responsibilities, and interdependencies are structured (Dillenbourg, 1999). The Jigsaw strategy is a well established example of structured collaboration in which learners become responsible for different parts of a shared task and the final solution depends on the combination of all contributions (Aronson et al., 1978). In Find Mr. X, Jigsaw is embedded directly within the system architecture through the assignment of distinct roles and differentiated interaction pathways, creating positive interdependence among group members .

At the same time, artificial intelligence (AI) has created new opportunities for learner support. While AI has frequently been used to generate narratives, hints, and puzzles within digital escape rooms (Stojšić, 2024), its role as a scaffold for reasoning and reflection remains less explored. When carefully integrated, AI can support learners in verifying intermediate steps, exploring alternative approaches, and reflecting on their reasoning without directly providing solutions, thereby functioning as a cognitive scaffold that promotes complex thinking and reflection (Zhai & Krajcik, 2024). Within Find Mr. X, AI tools are available throughout selected activities as optional sources of feedback and guidance, supporting learners as they navigate mathematical challenges and reflect on their problem solving processes.

Previous work on this environment examined its instructional design and pilot evaluation in relation to computational thinking, mathematical understanding, and AI supported scaffolding. The present study shifts the focus from learning outcomes to implementation, examining how pedagogical principles were translated into concrete interaction mechanisms within a Wix/Velo environment. The study therefore contributes a system oriented perspective on the design of AI enhanced digital educational escape rooms by illustrating how pedagogical orchestration can be embedded within platform architecture (Fotaris et al., 2023).

The contribution of this paper is design oriented. Specifically, it presents an orchestration framework that links pedagogical intentions with technological affordances and platform functionalities to support the development of targeted learner competencies within a Digital Educational Escape Room via a Wix/Velo learning environment.

CONCEPTUAL BACKGROUND

As digital learning environments become increasingly complex, attention has shifted from content delivery to learning orchestration. Orchestration refers to the deliberate design and regulation of interactions among learners, tools, and tasks to support pedagogical goals (Dillenbourg, 1999; Dillenbourg, 2013). Rather than allowing completely open ended participation, orchestrated environments structure interactions, sequence activities, and regulate access to resources through mechanisms such as conditional access, task dependencies, guided interaction flows, and controlled content visibility. In digital escape rooms, this implies that progression and interaction should be intentionally designed and technically supported rather than emerging solely from gameplay.

Collaboration is a central element of contemporary learning approaches, but its effectiveness depends on how roles and responsibilities are organized. The Jigsaw strategy provides a model of structured collaboration in which learners assume complementary roles and become responsible for different parts of a shared task, creating positive interdependence among group members (Aronson et al., 1978; Dillenbourg, 1999). In digital environments, implementing Jigsaw at the platform level requires mechanisms such as access based on learner roles, differentiated task spaces, and structured recombination phases, transforming collaboration from an instructional guideline into a feature of the system itself.

Digital escape rooms offer educational affordances including narrative immersion, sequential problem solving, immediate feedback, and collaborative engagement (Fotaris & Mastoras, 2019; Jiménez et al., 2020). However, these affordances support meaningful learning only when learning objectives, tasks, and interaction mechanisms are carefully aligned (Dillenbourg, 2013; Prieto et al., 2015). From a design perspective, this requires translating pedagogical affordances into concrete system mechanisms, such as conditional feedback, controlled navigation, and progression dependent on task completion.

Artificial intelligence is increasingly used in educational environments to provide guidance and support. While previous work has primarily examined AI as a design aid for generating puzzles, narratives, and hints (Stojšić, 2024), its role as an embedded learning scaffold remains less explored. When integrated within the interaction flow, AI can support learners in analyzing problems, reflecting on intermediate steps, and refining solution strategies without replacing their own reasoning. To function effectively as scaffolding, AI support should be carefully aligned with learning objectives and designed to encourage reflection without directly providing answers.

METHODOLOGY

Design Approach

Find Mr. X was developed as a Digital Educational Escape Room (DEER) designed to support instructional orchestration. Rather than evaluating learning outcomes, this study focuses on the contribution of translating pedagogical principles into a functional digital learning environment. As noted in recent literature, the effectiveness of such environments depends on how learning processes are structured within the digital space (Makri et al., 2021; Dillenbourg, 2013).

The environment was guided by three design priorities: structured progression, collaboration based on specific learner roles, and integrated scaffolding. Progression is regulated through task completion, ensuring that advancement remains contingent upon the successful completion of learning activities. Collaboration is embedded within the system architecture through access based on specific learner roles, operationalizing a Jigsaw structure in which successful completion depends on the combined contributions of all group members (Aronson et al., 1978). Finally, guidance provides through artificial intelligence is integrated directly into the activity flow, supporting reflection and verification of intermediate reasoning without providing direct solutions (Stojšić, 2024; Zhai & Krajcik, 2024). These principles informed the Wix/Velo implementation presented in the following sections.

Instructional to System Mapping

A central aspect of the environment's architecture is the translation of pedagogical affordances into technological affordances within a Wix and Velo learning environment. Rather than evaluating learning outcomes, this study focuses on how pedagogical strategies were implemented through platform functionalities and aligned with the development of targeted learner competencies.The macro-structure of Find Mr. X is guided by the MCIEC model (Ahn & Edwin, 2018), whose five phases—Motivation, Context, Interactivity, Evaluation, and Connectivity—are reflected in the sequence of escape room activities. Each phase is associated with specific progression requirements, ensuring that advancement remains contingent upon task completion.

The design adopts a unified orchestration model in which progression, collaboration, and support operate as interconnected components (Prieto et al., 2015; Dillenbourg, 2013). The Jigsaw structure distributes complementary roles among learners, making collaboration a technical requirement for advancement, while hints, peer interaction, and AI-assisted guidance are embedded directly within the activity flow. Through conditional access, sequential interaction constraints, and structured support mechanisms, the system aligns platform behavior with intended learning pathways. Table 1 presents the proposed orchestration framework which illustrates how instructional strategies embedded within the MCIEC model give rise to specific educational affordances, how these affordances are implemented through platform functionalities and technological affordances within Wix/Velo, and how they ultimately support the development of targeted competencies.

Table 1: Instructional orchestrational framework.

Strategy	Educational Affordances	Technological Affordances	Wix/Velo Implement	Competencies
Motivation Phase				
Narrative engagement	Curiosity arousal, immersion, emotional engagement, learner identification.	Guided exploration, narrative progression	Hidden navigation, event triggered transitions, persistent robot/ notebook UI.	Engagement, motivation, initial problem orientation

(Continued)

Table 1: Continued.

Strategy	Educational Affordances	Technological Affordances	Wix/Velo Implement	Competencies
Goal setting & reinforcement	Self efficacy support, positive reinforcement, sustained motivation	Progress tracking, achievement visibility	Code based progression, hidden pages. badge colle-ction,cumulative rewards.	Goal orientation, perseverance, self regulation
Initial scaffolding	Reduced cognitive overload, guided entry, confidence.	Supported entry into learning	Pre test tasks, asynchronous forum, workspace instructions.	Readiness, confidence, computational thinking readiness
Context Phase				
Anchored instruction	Contextua-lized under standing, real world connection, authentic environment,	Context-aware interaction	Narrative prompts,clicka-ble interaction elements,condi-tional page navigation.	Conceptual understanding, computational thinking
Conceptual scaffolding	Guided compre-hension,structured inquiry multimodal support,	Progressive information access	Sequential content, visibility control, scaffolded interaction flow.	Concept formation, inquiry skills
Guided exploration (retry logic)	Error reflection, exploratory learning, self monitoring.	Adaptive support pathways	Retry mechanisms, conditional progression, staged clue revelation.	Critical thinking, inquiry, self-monitoring
Interactivity Phase				
Jigsaw collabora Tion	Positive interdependence, collaborative reasoning, peer learning.	Distributed knowledge, role-specific access	Role based navigation, differentiated paths, collaboration spaces.	Collaboration, communication, knowledge integration, AI supported reasoning,
Active learning / problem solving	Active participation, problem solving, reflective reasoning.	Interactive task engagement	Event driven flow, controlled navigation, embedded worksheets.	Problem solving, computational thinking
AI-supported scaffolding (AI expert role)	AI Role-based access,prompts, AI guided activities, AI mediated group knowledge sharing	AI-assisted reasoning, contextual feedback	Assisted reasoning, reflection, alternative solution exploration, decision making	AI supported reasoning, critical thinking, reflection, human-AI collaboration

(Continued)

Table 1: Continued.

Strategy	Educational Affordances	Technological Affordances	Wix/Velo Implement	Competencies
Shared collaborative spaces	Knowledge recombination, coordination, reflective dialogue.	Knowledge sharing, collaborative coordination	Shared note-book, forum interaction, integration checkpoints.	Collaboration, communication, knowledge integration
Evaluation Phase				
Peer feedback & reflection	Reflective thinking, formative assessment.	Collaborative reflection	Specialized spaces, asynchronous discussions, feedback loops.	Reflection, communication, critical thinking
Authentic assessment	Goal oriented assessment, validation of understanding.	Performance verification	Final code validation, progression checkpoints, conditional access.	Reasoning, computational thinking, Reflection
Connectivity Phase				
Knowledge integration	Knowledge transfer, synthesis, integrated problem solving.	Collaborative knowledge integration	Group recombination, cumulative validation, collaborative spaces.	Knowledge integration, problem solving
Final completion	Shared accomplishment, reflective closure, equitable participation.	Outcome validation	Final reward validation, exit confirmation, tracking system.	Reflection, autonomy, sense of achievement

Phase Execution Logic and Recovery Scaffolding

The technical implementation of each phase in Find Mr. X follows a standardized execution pattern, illustrated in Figure 1. Learners attempt a task, and the system evaluates their response against predefined phase requirements. Successful completion generates a progression code that unlocks the next phase, whereas unsuccessful attempts activate structured recovery pathways.

This design treats failure as a constructive element of the learning process. Rather than terminating the activity, unsuccessful attempts redirect learners to support mechanisms, including collaboration documents, peer feedback, forum-based discussion, and AI-assisted hints. These recovery pathways encourage learners to reflect on their reasoning, address misconceptions, and retry the task before advancing.

The execution logic is operationalized through completion criteria and support mechanisms associated with each MCIEC phase. Progression remains contingent upon task completion, ensuring that code issuance and phase transitions occur only after the corresponding requirements have been satisfied. Figure 1 presents the generic execution cycle that governs progression across all phases of the environment. Table 2 subsequently details the completion criteria and recovery mechanisms associated with each MCIEC phase.

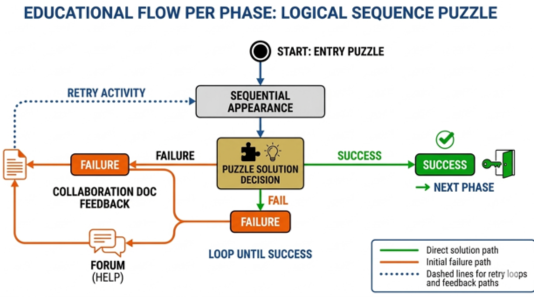

Figure 1: Generic phase execution logic.

Table 2: Phase completion criteria and recovery logic.

Phase	Success Criterion	Failure Support	Output
Motivation	Entry task completed	Hints / retry	Code1
Context	Contextual puzzle solved	Feedback / retry	Code 2
Interactivity	Expert task + recombination	Forum / retry	Code 3
Evaluation	Assessment completed	Reflection / correction	Code 4
Connectivity	Final synthesis achieved	Retry	Code 5

SYSTEM IMPLEMENTATION

Technical Architecture

Find Mr. X was implemented on the Wix platform using Velo Dev Mode, enabling custom scripting, event driven behavior, and conditional navigation. To preserve the escape-room logic, the main navigation menu was restricted, while progression was managed through hidden pages, event triggers, and conditional redirection. Interface elements, tools, and navigation options are progressively revealed based on user actions, creating a sequential interaction flow aligned with the phase execution logic presented in Figure 1.

Access to subsequent stages is regulated through a code based progression mechanism. Learners enter access codes obtained through task completion, triggering validation processes that determine transitions between phases. This approach ensures that progression remains tightly coupled with task completion and preserves the intended instructional sequence. In cases of unsuccessful validation, Velo scripts redirect learners to the recovery pathways described in Table 2. The overall workflow of the environment is illustrated in Figure 2.

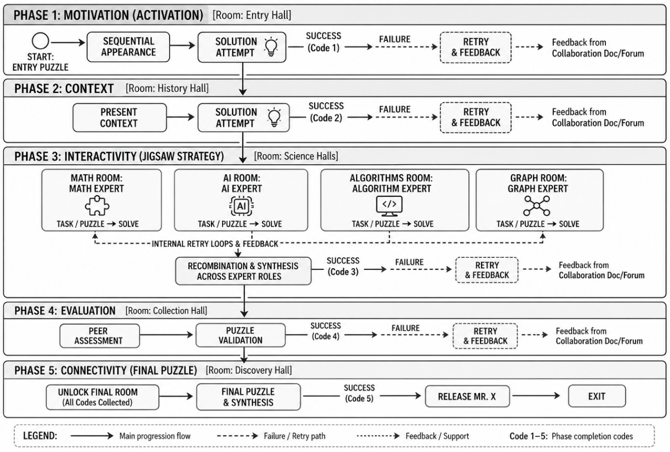

Figure 2: Workflow of the find Mr. X environment.

Interaction Design and Controlled Progression

Learners interact with the environment through three persistent interaction anchors: a speaker, a robot, and a notebook. The speaker provides instructions associated with each room, the robot enables access to discussion spaces, and the notebook serves as a workspace for recording intermediate solutions and access codes. Together, these elements support guidance, collaboration, and information management throughout the activity. Additional elements are initially hidden and progressively revealed through visibility control mechanism based on predefined constraints. Interaction events trigger the appearance of new clues, objects, and task components, enforcing a structured interaction sequence and reducing reliance on trial and error strategies.

Role Based Collaboration and Embedded Support

Collaboration is implemented through a Jigsaw structure. Learners are assigned to groups of four and take on distinct expert roles (Math, AI, Algorithm, and Graph), creating parallel but interdependent learning trajectories. The AI Expert role was responsible for validating intermediate solutions and exploring alternative solution pathways through AI-assisted reasoning activities, while the remaining expert roles focused on algebraic, procedural, and graphical representations of the problem. Recombination into the original group is required for final task completion. Access to resources and interaction spaces was regulated through visibility controls and conditional access mechanisms associated with each role, ensuring that learners engage with complementary aspects of the activity. This structure reinforces interdependence by requiring learners to exchange information across expert roles before progressing to the final synthesis phase. Learners are supported through multiple pathways, including retry mechanisms, hints, peer discussion, and embedded AI-supported guidance. These pathways provide support while preserving the structured progression of the activity.

Implementation Observations and Evaluator Perceptions

Although this study does not provide a formal experimental evaluation of student learning outcomes, observations at the system level and expert evaluation data were collected to examine operational behavior and pedagogical feasibility. System logs indicated that all participants completed the full interaction sequence, suggesting that the conditional progression and validation mechanisms supported uninterrupted navigation across stages without any structural routing errors. Regarding participant perceptions, the descriptive statistical analysis reflected a highly positive reception of the environment's structural attributes. Participants positively evaluated the environment's contribution to mathematical understanding and learning ($M = 4.30$, $SD = 0.50$), while the scaffolding provided through artificial intelligence was similarly perceived as effective support ($M = 4.13$, $SD = 0.50$).

DISCUSSION

The findings suggest that embedding pedagogical principles directly into the technical architecture of the environment can support a more structured and coherent learning experience. The proposed design integrates hidden navigation, conditional progression, collaboration based on learner roles, and scaffolding provided through artificial intelligence within a unified orchestration framework. Rather than functioning as independent features, these mechanisms collectively regulate learner progression, interaction, and access to support. In particular, the Jigsaw structure transforms collaboration into a requirement of the system, while artificial intelligence is positioned as a scaffolding resource that supports reasoning and reflection rather than providing direct solutions. Overall, the study supports the view that the educational value of digital escape rooms depends not only on gamification elements but also on how progression, collaboration, and support are orchestrated through the underlying system architecture.

CONCLUSION

This paper presented the design and implementation of Find Mr. X, a Digital Educational Escape Room developed on the Wix platform using Velo Dev Mode. The proposed architecture integrates guided progression, collaboration based on learner roles, embedded communication tools, and scaffolding provided through artificial intelligence within a unified orchestration framework.

The main contribution of the study is the presentation of a framework that links pedagogical affordances, technological affordances, and learner competencies within a digital educational escape room. By demonstrating how pedagogical intentions can be translated into platform functionalities and technical mechanisms, the framework provides a structured approach for designing collaborative and technology enhanced learning environments. Future work should investigate the educational impact of the proposed framework through classroom implementations involving larger populations and explore its adaptation to other disciplinary contexts and digital learning platforms.

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