Gamification in Education Using the WOWCube®: A Tangible Mixed-Reality Learning Device

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Abstract. This paper presents the WOWCube® system, a mixed-reality educational device that combines a physical 2×2 puzzle cube with interactive digital gameplay. By uniting tangible manipulation with on-cube visual feedback, WOWCube supports puzzle-based learning aimed at strengthening spatial reasoning, problem solving, and sustained attention while avoiding distractions common to general-purpose mobile devices. We describe the device architecture and authoring workflow, highlighting how educators can create and adapt content for classroom or at-home use. We further introduce an AI-augmented edition in which a friendly digital character provides personalized, data-driven feedback based on in-game performance metrics, offering encouragement, hints, and adaptive difficulty.
The paper contributes: (i) a system description and design rationale for a tangible user interface that delivers mixed-reality learning experiences; (ii) a use case and sequence of interactions for AI-mediated feedback from a digital tutor; (iii) empirical observations from an exploratory, in-person pilot and a large-scale online ideation exercise, used to derive user needs and content directions; (iv) a comparison with adjacent TUI/AR approaches; and (v) an expanded roadmap for future classroom studies, accessibility features, and teacher-facing authoring tools. We argue that WOWCube aligns with current e-learning priorities by offering a safe, engaging, and authorable platform for gamified learning in formal and informal settings.

Keywords: Gamification, Tangible User Interfaces (TUI), Mixed Reality, Educational Technology, WOWCube®, Cognitive Development, Artificial Intelligence in Learning, Virtual Learning Environments (VLEs), Authoring Tools, Augmented Reality in Education.

1 Introduction

Gamification, broadly defined as the integration of game mechanics into non-game contexts, has gained significant traction within education over the past two decades. Numerous studies have shown that the use of points, levels, challenges, and narrative elements in digital learning platforms can enhance learner motivation and engagement by appealing to intrinsic and extrinsic motivational factors [1], [2]. For example, game-

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like elements have been successfully applied to online learning systems, resulting in improved retention and active participation [3].

At the same time, the widespread adoption of mobile devices has reshaped the delivery of educational content. While smartphones and tablets have enabled access to a wide range of interactive applications, they have also introduced well-documented challenges. Among the most prominent are distraction, cognitive overload, and reduced attention spans, often associated with continuous exposure to multi-purpose digital ecosystems [4], [5]. Recent research highlights concerns about short-form video consumption and its correlation with diminished executive control and attentional capacity [6]. These findings underscore the need for alternative platforms that retain the motivational strengths of digital games without the negative side effects of general-purpose mobile devices.

Within this context, tangible user interfaces (TUIs) and mixed-reality devices offer a promising avenue for educational innovation. By embedding computation into physical objects, TUIs enable learners to manipulate digital information through embodied interaction, providing a bridge between abstract content and hands-on activity [7]. Puzzle-based TUIs, in particular, combine problem-solving with tactile engagement, fostering spatial reasoning, logical thinking, and persistence. Classic examples such as the Rubik's Cube have long been associated with improvements in mental rotation, problem-solving strategies, and fine motor coordination [8], [9].

The WOWCube® platform exemplifies this integration of gamification, physical manipulation, and digital content. Conceptualized as a mixed-reality puzzle device, it combines the cognitive benefits of physical puzzles with the dynamic adaptability of digital games. Unlike smartphones, the WOWCube® provides a focused learning environment, free from external distractions such as messaging, social media, or short-form video platforms. At the same time, unlike static puzzles, it can deliver a variety of adaptive games and educational scenarios. This paper examines the role of WOWCube® as a tool for gamified learning, its cognitive potential, and its future extension into AI-assisted personalized education.

2 Background and Related Work

2.1 Gamifica'on and Educa'onal Outcomes

Gamification in education has been consistently shown to increase student motivation and learning performance by introducing elements such as scoring, competition, feedback, and narrative framing [1], [2]. Well-designed educational games provide immediate feedback, clear objectives, and a safe environment for trial-and-error learning, making them effective tools across STEM and language learning domains [3]. Mayo [4] demonstrated that game-based learning can significantly improve retention in science education, while more recent work emphasizes the role of gamification in building persistence and self-regulated learning skills [5].

Mobile learning platforms have further accelerated the adoption of gamified education. However, alongside benefits such as portability and multimedia richness, scholars warn about the risks of distraction and "cognitive overload" when learning activities occur on multi-purpose devices [6], [7]. Ward et al. [8] showed that even the mere presence of a smartphone can negatively affect attentional control and task performance. This challenge has been amplified by the rise of short-form video applications, with several studies linking their overuse to attentional fragmentation and reduced executive control [9].

2.2 Tangible and Mixed-Reality Learning Tools

Traditional educational technologies typically rely on either fully digital or fully physical formats. Tangible User Interfaces (TUIs) provide a hybrid model, embedding computational logic into physical objects that can be manipulated directly. Ishii and Ullmer [10] were among the first to articulate the educational potential of TUIs, noting that bodily interaction with digital content can improve comprehension, collaboration, and engagement. Subsequent research confirmed that TUIs are especially effective for kinesthetic learners and for teaching abstract concepts such as geometry, programming, or logic [11], [12].

Mixed-reality extensions of TUIs include devices that blend physical puzzles with digital displays. Early examples such as Sifteo Cubes demonstrated how physical manipulation could be integrated with digital interactivity [13]. Osipov [14] introduced the concept of "transreality puzzles," a new category of entertainment and learning devices that blur the boundary between physical and digital play. In such systems, there is no single "primary game space"; instead, the puzzle exists simultaneously in tangible and digital dimensions. The WOWCube® is a notable realization of this concept, combining physical twisting mechanics with interconnected digital displays.

2.3 Cognitive Benefits of Puzzle Solving

Puzzle-based learning has a long tradition in cognitive psychology and education. The Rubik's Cube, in particular, has been studied for its effects on spatial reasoning, working memory, and logical problem-solving [15], [16]. Lee et al. [17] found that fluid intelligence predicted the rate of skill acquisition in Rubik's Cube solving, indicating strong links between puzzle proficiency and cognitive aptitude. Studies in STEM education also report that practicing with 3D puzzles enhances mental rotation abilities, a skill strongly associated with success in mathematics and engineering [18].

Beyond formal research, anecdotal evidence from puzzle enthusiasts suggests benefits for concentration, patience, and stress reduction. Competitive "speedcubers" further highlight improvements in fine motor coordination and hand–eye dexterity [19]. These findings underscore the enduring value of puzzles as educational tools, while also pointing to the limitations of static puzzles for the digital-native generation. Devices such as the WOWCube® extend this tradition by embedding puzzle-solving in a digital, adaptive framework.

3 The WOWCube® Mixed-Reality Gaming Device

The WOWCube® is a novel interactive platform designed as a tangible and digital hybrid. Structurally, it resembles a 2×2×2 Rubik's Cube, where each of the eight modules contains a digital display, microcontroller, and sensors interconnected through magnetic contacts. This configuration results in 24 active screens covering the device's external surface.

Players interact with the cube through tangible manipulations—twisting, tilting, and flipping— which simultaneously alter the digital content displayed on the cube's surfaces. The design principle aligns with Tangible User Interfaces (TUIs), where physical manipulation becomes the primary medium for digital interaction [10], [13]. Unlike static puzzles, the WOWCube® allows dynamic reconfiguration of digital games spanning multiple faces. Unlike general-purpose mobile devices, the platform is fully sandboxed, providing a curated ecosystem of puzzle, logic, and educational games free from distracting or inappropriate content.

Figure 1 illustrates the structural design of the WOWCube®, highlighting its modular configuration and distributed network of screens.

From an educational perspective, the device combines puzzle-solving mechanics with multimodal feedback:

1. Spatial reasoning is trained by mapping 2D content onto a rotating 3D object.
2. Problem-solving is reinforced through puzzle-based games requiring algorithmic strategies.
3. Attention and concentration are cultivated due to the absence of external notifications.
4. Fine motor skills are strengthened by frequent and precise manipulations.

Together, these characteristics position the WOWCube® as a promising platform for gamified learning that bridges the cognitive benefits of puzzles with the adaptability of digital environments [14].

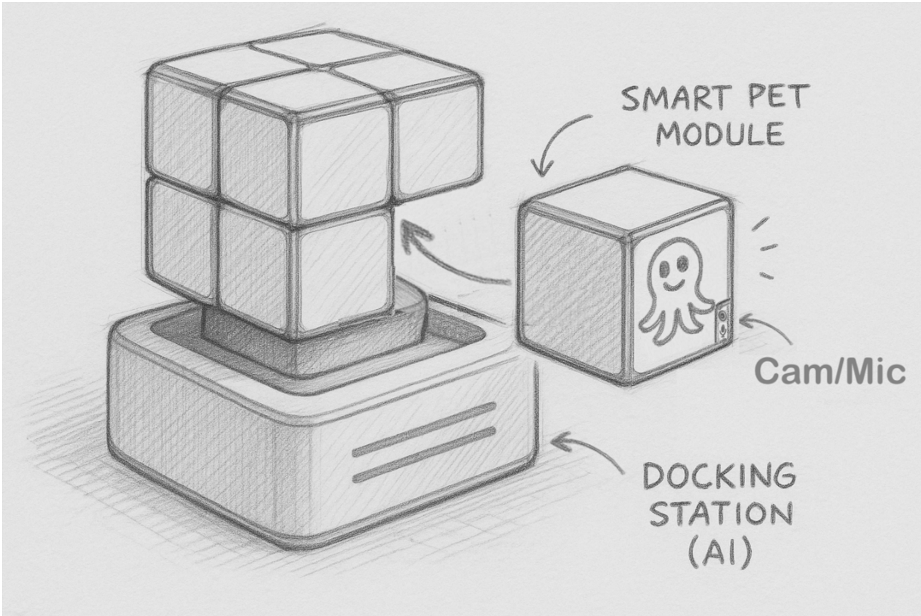

Fig. 1. The WOWCube® device (2×2×2 modular cube) showing digital content across faces; primary control via physical rotations.

4 Empirical Data and User Feedback

To complement conceptual analysis, two exploratory studies were conducted to capture user perceptions and community-driven innovation.

4.1 CES 2023 Field Study

During the CES 2023 technology exhibition in Las Vegas, 43 participants interacted with the WOWCube® for the first time at the company's booth. Instead of structured surveys, the team employed an open-question approach: attendees were encouraged to manipulate the device freely and ask any questions that arose. The goal was to identify the most salient concerns and interests of first-time users.

Key findings:

1. Retail Price: The most frequently asked question, raised by 39 participants (≈90%), concerned the expected retail cost.
2. Battery Life: 22 participants (≈51%) asked about battery longevity.
3. Game Availability: 13 participants (≈30%) inquired whether additional games could be downloaded beyond the pre-installed set.
4. Other Questions: Fewer than five participants asked about hardware durability, educational applications, or multiplayer functionality.

These results highlight that prospective users primarily focus on economic and practical aspects (price and battery), followed by content extensibility. Such concerns should inform communication strategies and design priorities for future development.

4.2 Reddit Game Idea Contest

A complementary data source emerged from a large-scale community engagement effort on the Reddit r/gadgets forum. In a giveaway and brainstorming contest, users were invited to propose new game ideas for the WOWCube®. The post attracted approximately 20,000 comments, including more than 120 distinct and viable game proposals.

Ideas were diverse and ranged from simple puzzle variations to advanced multi-cube collaborative games. A thematic analysis grouped suggestions into the following categories:

1. Classic Puzzle Adaptations (e.g., Sudoku, Tetris-like mechanics).
2. STEM Learning Games (e.g., math drills, chemical bonding simulations).
3. Adventure/Exploration Games (narrative-driven puzzles).
4. Fitness and Reflex Games (reaction-based challenges requiring fast rotations).
5. Social and Multiplayer Games (networked competitions, collaborative problem-solving).

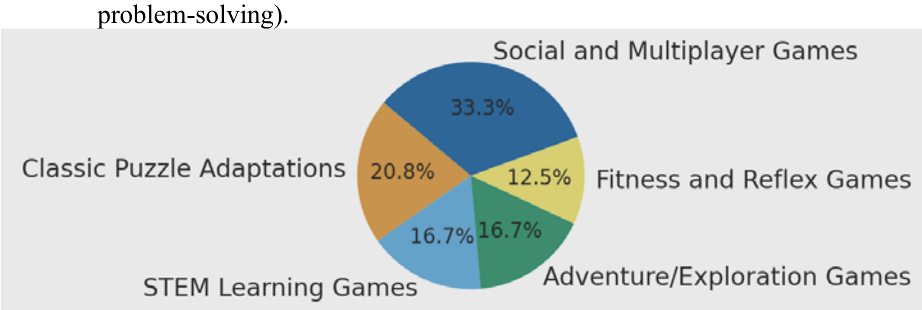

Fig. 2. presents a visualization of these categories, illustrating the relative frequency of each idea type.

This large-scale engagement demonstrates that the WOWCube® fosters strong community creativity. The prevalence of educational and puzzle-based suggestions indicates that the device resonates with users as a learning-oriented gaming tool, supporting its positioning within gamified education.

5 Educational and Cogni've Impact of WOWCube

5.1 Fostering Cognitive Skills through Play

The WOWCube® gameplay environment engages multiple cognitive domains simultaneously by requiring learners to manipulate a reconfigurable 3D object whose digital content spans interconnected displays. This mode of interaction parallels classic mental rotation tasks, which are strongly associated with the development of spatial reasoning skills relevant to mathematics, engineering, and natural sciences [6], [15]. Unlike conventional flat-screen games, the WOWCube demands constant alignment between physical motion and digital representation, providing embodied practice that strengthens visuospatial processing.

Puzzle-based mechanics embedded in WOWCube games further promote problem-solving and algorithmic thinking. Many games require players to plan moves in advance, detect patterns, and execute stepwise strategies, mirroring computational thinking practices central to computer science education [3], [16]. As learners progress through incrementally challenging levels, the system naturally fosters persistence, resilience, and a growth mindset, as players learn to approach complex problems through repeated trials and gradual mastery.

Attention and concentration are also actively trained. Unlike mobile phones, which expose users to frequent notifications and competing applications, the WOWCube offers a sandboxed ecosystem focused exclusively on puzzle and educational games. This design supports deep engagement with a single task and reduces the risk of cognitive fragmentation that has been linked to multitasking environments [8], [9]. In this sense, WOWCube aligns with pedagogical approaches that emphasize sustained focus as a prerequisite for higher-order cognitive skills.

Finally, the tangible design of the device contributes to the development of fine motor control and hand–eye coordination. Frequent twisting, tilting, and reorienting movements provide kinesthetic training rarely found in flat-screen applications. Comparable benefits have been observed in research on Rubik's Cube solving and speedcubing, where rapid manipulations improve manual dexterity and coordination [17]. WOWCube extends this advantage by embedding motor practice within a wider range of playful and adaptive digital contexts.

5.2 Comparison with Tradi'onal Puzzles and Smartphones

WOWCube vs. Rubik's Cube.

The Rubik's Cube remains a classic puzzle with proven cognitive benefits: perseverance, algorithmic reasoning, and spatial visualization [15], [18]. However, its single-objective design and steep learning curve can discourage learners who lack guidance or immediate reinforcement. The WOWCube, by contrast, supports a portfolio of puzzles and games that adapt to learner skill levels, provide interactive tutorials and hints, and deliver progressive feedback on performance. This adaptability ensures that tasks remain within a learner's zone of proximal development, maintaining motivation while avoiding frustration. Thus, WOWCube retains the cognitive rigor of the Rubik's Cube while introducing scalability, variety, and user-centered personalization.

WOWCube vs. Smartphones and Tablets.

Smartphones and tablets are versatile educational tools but are also burdened with significant distraction potential. Studies indicate that even the silent presence of a smartphone can reduce available cognitive capacity and task performance, a phenomenon sometimes called the "brain drain" effect [8], [9]. Furthermore, short-form video and notification-driven environments on such devices contribute to fragmented attention and reduced executive control [6], [7].

By design, WOWCube circumvents these issues. It is a dedicated, closed ecosystem, devoid of social media feeds, web browsers, or video streaming platforms. All available content is curated within its ecosystem, ensuring that learners engage with cognitively enriching activities rather than attention-fragmenting media. This focus positions WOWCube as a middle ground: it provides the rich interactivity and visual engagement of digital platforms without the negative externalities of general-purpose devices.

6 Extending WOWCube with AI: The "Digital Pet" Tutor Prototype

To expand the educational potential of tangible gamification, a proof-of-concept version of the WOWCube®—the WOWCube AI Edition—was developed. This prototype integrates additional hardware and software components that transform the device from a puzzle-based gaming console into an intelligent tutoring system.

The AI Edition consists of two major hardware extensions:

1. Pet Module. This specialized cube segment replaces one of the standard modules and is equipped with a miniature camera, microphone, and additional processing capacity. Its external display hosts an animated digital pet, codenamed "Oki", which functions as the learner's virtual companion. The Pet Module provides sensory input, enabling the device to recognize faces, track attention, and process voice commands.
2. Docking Station AI. This upgraded charging dock contains more powerful processors and serves as an edge-computing hub for tasks exceeding the cube's onboard capacity. It manages speech recognition, natural language understanding, and cloud-based queries to large language models (LLMs). The docking station maintains seamless wireless communication with the cube, balancing portability with advanced computational capabilities.

Together, these components enable multimodal interaction and lay the foundation for adaptive learning scenarios (see Figure 3). The main AI-driven functionalities include:

1. Personalization. The system identifies the learner through face or voice recognition, greets them by name, and maintains individual progress profiles.
2. Voice-Guided Onboarding and Gameplay. The digital pet explains device functions, narrates tutorials, and guides learners through cognitive exercises in real time.
3. Performance Analytics with Feedback. Gameplay data is logged and analyzed, allowing the AI to highlight improvements (e.g., faster reaction times, reduced errors) and encourage persistence through motivational feedback.
4. Adaptive Challenges. Based on user performance, the system adjusts game difficulty and recommends new challenges targeting weaker skill areas.

5. Educational Q&A. Via controlled integration with cloud-based LLMs, the AI companion can answer questions or provide contextual facts related to ongoing tasks, extending the device's role from puzzle console to conversational tutor.

This prototype reflects a convergence of gamification, tangible computing, and intelligent tutoring systems (ITS). By embedding adaptive AI into a playful environment, the WOWCube AI Edition moves beyond static puzzle-solving toward personalized cognitive training. Currently, the system remains in beta development, with a structured user study planned to measure its effectiveness in sustaining engagement, improving cognitive outcomes, and supporting learning transfer.

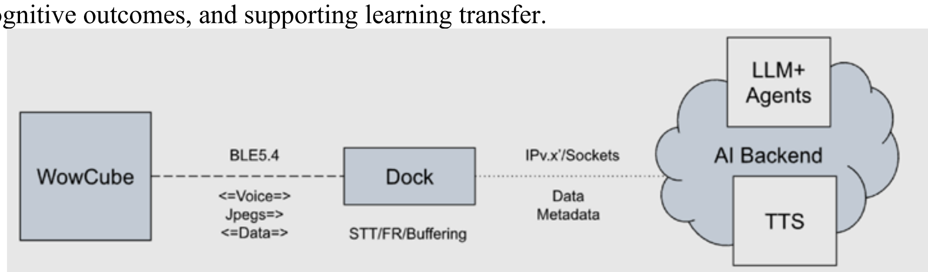

Fig. 3. WOWCube® AI Edition concept: Pet Module (camera/microphone, digital pet) + Docking Station for voice/vision and cloud LLM support.

7 Discussion and conclusion

The WOWCube® platform lies at the intersection of game-based learning, tangible computing, and adaptive AI tutoring, representing a novel direction for educational technology. Its benefits can be grouped into several domains:

1. Engagement. Hands-on, game-like interaction sustains learner motivation and curiosity, particularly for tasks that may otherwise feel abstract or repetitive [1], [2].
2. Personalization. The AI-augmented edition introduces individualized progress tracking and adaptive challenges, aligning with current research on intelligent tutoring systems [3], [4].
3. Safe Learning Environment. By restricting content to curated educational and puzzle games, the WOWCube avoids the distractions and potential harms associated with social media or short-form video platforms [5], [6].
4. Collaborative Potential. The tangible, visible nature of the device facilitates co-located learning, enabling small groups to share problem-solving experiences.
5. Curriculum Integration. Through its SDK and authoring tools, the platform has potential to support domain-specific content creation by educators, expanding applications from general cognitive training to targeted curricular topics [7].

At the same time, several limitations and challenges must be acknowledged. The cube's physical manipulation may present accessibility barriers for learners with motor impairments. Hardware durability and cost could constrain large-scale classroom deployment. Most importantly, the conceptual and design advantages outlined in this paper require empirical validation. Future studies should examine not only short-term engagement but also measurable gains in cognitive abilities (e.g., spatial reasoning, attention, problem-solving transfer) and learning outcomes across age groups.

The future research roadmap involves three priorities:

1. Usability of Authoring Tools. Simplifying content creation for non-programmer educators, possibly via visual programming or AI-assisted authoring.
2. Accessibility. Developing alternative input modes (e.g., voice-based interactions via the AI module) for learners with physical limitations.
3. Longitudinal Studies. Conducting controlled trials to evaluate long-term educational impact, including comparative studies with tablets, Rubik's Cubes, and other mixed-reality tools.

In conclusion, WOWCube® exemplifies how combining physical interaction with digital game-based learning can create an effective, focused, and engaging educational platform. It occupies a unique position: as engaging as a video game but without distracting feeds, and as cognitively enriching as a puzzle but without static limitations. The AI-augmented prototype suggests a future where conversational tutoring agents are integrated into tangible, play-based environments, providing adaptive and personalized support.

Finally, the work presented here aligns directly with the core tracks of the eLearning 2025 Conference:

1. Virtual Learning Environments (VLEs): WOWCube provides a sandboxed ecosystem for interactive education.
2. Authoring Tools: Its SDK enables the development of customized scenarios and learning modules.
3. Gamification and Interactive Learning: The device applies puzzle mechanics and feedback loops to foster engagement and persistence.
4. Augmented Reality in Learning: As a mixed-reality TUI, WOWCube bridges physical and digital experiences.

By situating WOWCube at this intersection, we argue for its potential as a next-generation educational technology that channels human curiosity, leverages embodied interaction, and integrates adaptive AI to promote meaningful and sustainable learning.

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