

Demonstrating Rūh: A Serious Mobile AR Game Exploring 3D Interactive Markers to Harmonise Physical and Virtual Realities

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Figure 1: From left to right: In the first image, a participant creates a cloud marker using foam blocks in the mobile AR game. In the second image, another participant expresses their emotions with a smiley face after completing the game. These images highlight the integration of tangible objects in enhancing the mobile AR gaming experience.

Abstract

Mobile augmented reality (AR) games have shown great potential in blending physical and digital experiences, yet the potential of 3D interactive markers remains understudied. We see this gap as an opportunity to investigate how these markers, including everyday objects, can redefine interactions in mobile AR games. To address this, we present Rūh, a serious mobile AR game that balances physical and virtual realities through 3D interactive markers. By transforming everyday objects into interactive markers, Rūh leverages their familiarity and tangibility to enhance user engagement and presence. Designed within the Double-Diamond Design process and guided by co-design practices, Rūh utilises interactive markers to create immersive and collaborative gameplay. Rūh demonstrates how 3D interactive markers can enhance user engagement and redefine gameplay mechanics by introducing a novel approach to tangible digital balance. Our work highlights the untapped potential of these markers and sets the stage for further exploration in mobile AR games.

CCS Concepts

• Human-centered computing → Interface design prototyping.

Keywords

Mobile Augmented Reality, Serious Games, Co-Design, Qualitative Study, Tangible Markers

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1 Introduction

Mobile Augmented Reality (AR) games represent a remarkable advancement in how players interact with both digital and physical environments, enabling seamless integration of the virtual into everyday life [1]. Marker-based AR, which uses visual markers such as images or QR codes to trigger digital content, has emerged as a particularly compelling feature [2]. These technologies foster interactions that are both contextual and dynamic, spanning indoor and outdoor spaces [4]. While extensively explored in various applications, the full potential of marker-based AR for fostering creativity and collaboration remains untapped. Tangible Play, which emphasises using physical objects in interactive experiences, could offer a promising avenue for deepening engagement in mobile

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AR games. By balancing the physical and virtual worlds, tangible play encourages sensory-rich, hands-on interactions that support both imaginative and collaborative gameplay [9, 10]. Although its potential has been noted in education and physical games [5], the role of tangible play in mobile AR game design, particularly regarding material selection and user interaction, has not been sufficiently addressed. This gap highlights the need for innovative approaches that leverage tangible play to enhance user experience and creativity, specifically in mobile AR games. To explore these opportunities, we developed Rūh, a serious mobile AR game that integrates interactive 3D markers to create a novel gameplay experience. Rūh incorporates everyday materials, including whiteboards, foam blocks, puzzle pieces, and LEGO® bricks, as interactive markers, inviting players to engage with their immediate environment and balance both worlds seamlessly (see Figure 1). Drawing on a multi-disciplinary co-design approach [7] and designed within the Double-Diamond Design process [8], the development of Rūh involved collaboration with teachers (N=3), school psychologists (N=2), designers (N=6), children (N=8), and developers (N=2). This participatory process not only shaped the game's design but also provided valuable insights into the usability and functionality of tangible markers in mobile AR games. Informed by these findings, we propose viewing tangible markers as a "design canvas" for mobile AR games, enabling the exploration of alternative approaches to engagement and interaction. By leveraging the material properties of everyday objects, Rūh highlights how ambiguity and modularity in marker design can foster hands-on learning, creativity, and collaboration. Inspired by the potential of tangible play, Rūh aims to balance the gap between physical and virtual interaction, paving the way for more inclusive, sustainable, and innovative applications of mobile AR in education and entertainment. Through this research, we emphasise the importance of multi-disciplinary collaboration in mobile AR game design and advocate for a deeper exploration of tangible play. By doing so, we aim to expand the possibilities of marker-based AR and contribute to the ongoing discourse on enhancing engagement, creativity, and presence in mobile AR games.

2 Overview of Rūh

Rūh is a serious mobile AR game that leverages interactive 3D markers to balance physical and virtual realities (see Figure 2). Players join Abby in a quest to find her missing friend, Alex, starting with a digitally augmented math book and a riddle solved using a whiteboard. The game spans four stages, where players create interactive markers using materials like whiteboards, foam blocks, puzzle pieces, and LEGO® bricks guided by riddles that blend physical and digital play (see Figure 3). Completing the final marker reunites Abby with Alex. Players reflect on their emotions through drawings before and after gameplay, with the conclusion delivering a reassuring message about seeking help and support.

We followed a design approach inspired by participatory [6] and co-design [7] practices, drawing on insights from educators, psychologists, designers, users (children) and developers. The primary design goals of Rūh are engagement, presence and interactivity. Additionally, we consider Rūh as both a tool for exploration and a

platform for eliciting players' meaningful emotional and social responses. To provoke alternative interpretations, another key design goal is to balance the physical and digital elements through interactive 3D markers, which are seamlessly integrated into the player's environment. These markers, made from everyday materials like whiteboards, foam blocks, LEGO® bricks, and puzzle pieces, create a unique fusion of tangible and virtual gameplay. The familiarity of the physical materials combined with the virtual world evokes a sense of curiosity and immersion, prompting players to reflect on their role in shaping both realities. This section presents the design process, features, and user flow of Rūh.

2.1 The Design Process

The design and development of Rūh follow a structured, multi-disciplinary approach to address educational and technical challenges. The design process integrated insights from educators, psychologists, designers, children, and software developers, collectively guiding the creation of a serious mobile AR game (see Figure 4). Rūh combines participatory [6] and co-design [7] practices using the Double Diamond Design process [8] to ensure an iterative and efficient workflow.

The Discovery Phase focused on identifying challenges and gathering key insights that established the game's foundation. Teachers (N=3) and the school psychologist (N=1) emphasised balancing digital and tangible interactions, fostering collaboration, and ensuring the gameplay mechanics were accessible. Their input influenced the selection of everyday materials, which became central to the game's design. Children's (N=8) feedback emerged as a crucial component in the Definition Phase. Their input on usability and engagement underscored the importance of tactile and customisable markers, shaping the game's interactive elements. Designers (N=6) complemented this feedback by prioritising using sustainable and versatile materials, aligning with the game's goals of hybrid interaction and environmental responsibility. During the Development Phase, these inputs were synthesised into a functional prototype. The school psychologist ensured that emotional safety and reflective gameplay were seamlessly integrated while software developers (N=2) addressed technical constraints, such as optimising AR marker recognition on Android devices. Designers refined tangible and virtual elements, creating a cohesive and seamless user experience prioritising accessibility, engagement, and narrative coherence.

According to the Masaryk University law, ethical approval is required only for research involving underage participants. The workshops with children were approved by the Research Ethics Committee of Masaryk University, and all volunteers agreed to participate, and their legal representatives signed an informed consent. The rest of the stakeholders signed a consent form to proceed with the study.

2.2 Crafting Play: Material Selection and Interactive Marker Design

The marker materials for Rūh were carefully selected and designed to enhance tangible play while supporting the game's narrative. Each material—whiteboards, foam blocks, LEGO® bricks, and puzzle pieces was chosen for its unique physical properties, emotional

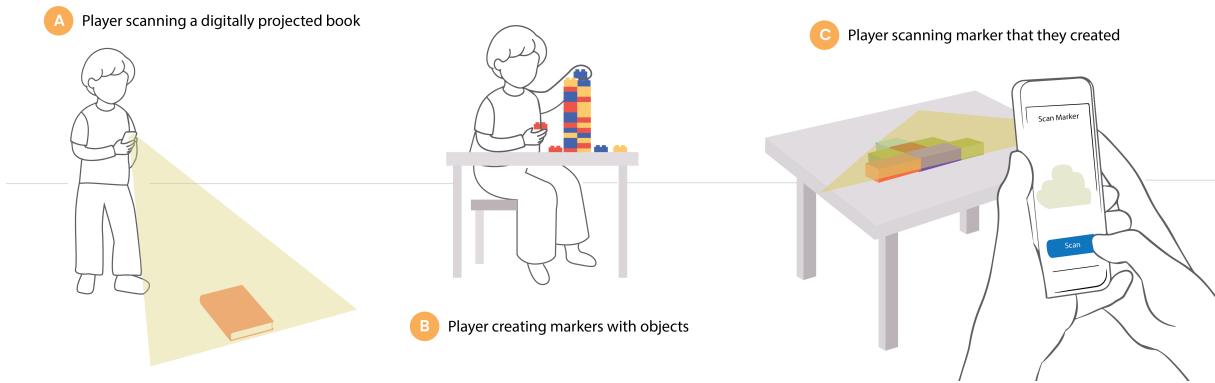


Figure 2: AR features in the game: A) Players explore virtual objects, like a book, projected into physical spaces via their phone. B) As interactive game components, The player creates custom markers using LEGO® bricks. C) The player scans the marker they created with foam blocks.



Figure 3: Screenshots showcasing key moments in Rūh—(A) the main screen introducing the game, (B) a riddle guiding marker creation, (C) a success screen upon completing a marker, and (D) a concluding message reinforcing the game's supportive theme.

engagement potential, and compatibility by co-designing with designers and children (see Figure 5). These materials provide distinct tactile experiences that align with the game's objectives and enrich the player experience.

Whiteboard. Whiteboards (see Figure 5, A) introduce the game, offering an intuitive and sensory-rich medium for players to engage in creative problem-solving. Their fluidity and erasable surfaces

make them ideal for iterative exploration. Players use these tools to solve an initial riddle embedded in a math book, marking the first instance of blending physical interaction with digital content.

Foam Blocks. Foam blocks (see Figure 5, B) add a new layer of engagement, emphasising texture and sensory responsiveness. These blocks offer a soft, stackable design that encourages experimentation with form and structure. Players are tasked with creating a

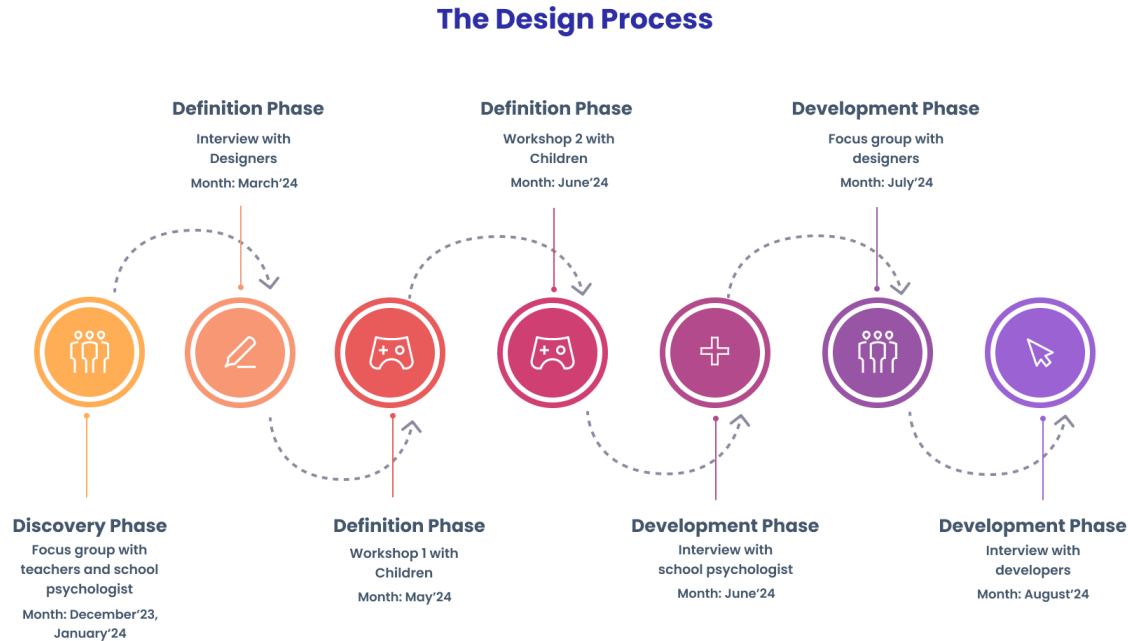


Figure 4: Diagram illustrating the step-by-step design process of Rūh, structured into three Double Diamond Design phases: The Discovery Phase involved two focus groups with teachers and school psychologists; the Definition Phase included an interview with designers and two workshops with children; and the Development Phase featured an interview with a school psychologist, along with focus groups involving designers and developers.



Figure 5: Markers created by children using different materials—whiteboards, foam blocks, LEGO® bricks, and puzzle pieces. (A) A participant draws their marker on a whiteboard. (B) A participant assembles a cloud marker using foam blocks. (C) To solve a riddle, a participant constructs a LEGO® bag marker. (D) A participant creates a marker by assembling puzzle pieces.

cloud marker, a tangible clue tied to the narrative theme of Alex's love for rain.

LEGO® Bricks. LEGO® bricks (see Figure 5, C) expand the gameplay by leveraging their familiarity and modularity. As players construct Alex's bag, they are challenged to build complex objects that reflect creativity and precision. The assortment of bricks in various sizes and vibrant colours allows for endless configurations, fostering a sense of accomplishment as physical creations merge seamlessly with AR elements.

Puzzle Pieces. Puzzle pieces (see Figure 5, D) bring the material selection full circle, introducing tasks that integrate tactile assembly with narrative discovery. Their interlocking design supports both 2D and 3D interactions, encouraging players to spell out the name of Alex's cat. This final activity links the act of assembly with the story's emotional resolution, offering a satisfying conclusion to the gameplay.

Each stage of Rūh introduces a new material that aligns with a specific interaction style, guiding players through a progression of tactile and cognitive challenges. The whiteboards encourage

creativity and communication [12], foam blocks promote sensory exploration [11], LEGO® bricks facilitate social interaction [5], and puzzle pieces promote active learning, and encourage peer-assisted learning [3]. Rüh demonstrates how tangible elements can deepen engagement, spark creativity, and seamlessly integrate with augmented reality by transforming everyday materials into dynamic tools for immersive play. This material-driven approach enriches the game's design and provides a replicable model for future mobile AR experiences.

3 Conclusion

We present Rüh, a serious mobile AR game that leverages interactive 3D markers to balance physical and digital play. By transforming everyday materials into tangible markers, Rüh explores the potential of sensory-rich interactions to foster creativity, collaboration, and engagement. Designed using participatory and co-design practices within the Double Diamond Design process, Rüh demonstrates how multi-disciplinary insights can address educational and technical challenges in mobile AR games.

To enhance the interplay between the physical and virtual worlds, we employ familiar materials like whiteboards, foam blocks, LEGO® bricks, and puzzle pieces as interactive markers. These markers are crafted with simplicity and functionality, encouraging imaginative exploration and reflective gameplay. Through iterative design and collaboration with educators, psychologists, children, designers and developers, Rüh creates a blend of tangible and digital elements that provoke curiosity and alternative interactions. We demonstrate Rüh to highlight how interactive 3D markers can expand the design space for mobile AR games, offering new opportunities for creative engagement, hands-on learning, and hybrid interaction.

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References

- [1] Huixiang Chen, Xiangming Wen, and Weidong An. 2018. Understanding the Characteristics of Mobile Augmented Reality Applications. In *2018 IEEE International Symposium on Performance Analysis of Systems and Software*. IEEE, IEEE, 128–138. <https://doi.org/10.1109/ISPASS.2018.00026>
- [2] Vicente Ferrer, Alex Perdomo, Hazem Rashed-Ali, Carmen Fies, and John Quarles. 2013. How Does Usability Impact Motivation in Augmented Reality Serious Games for Education?. In *2013 5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)*. IEEE, Poole, 1–8. <https://doi.org/10.1109/VS-GAMES.2013.6624233>
- [3] Sue Franklin, Mary Peat, and Alison Lewis. 2003. Non-traditional interventions to stimulate discussion: the use of games and puzzles. *Journal of Biological Education* 37, 2 (March 2003), 79–84. <https://doi.org/10.1080/00219266.2003.9655856>
- [4] Kai Kuikkaniemi, Marko Turpeinen, Antti Salovaara, Timo Saari, and Janne Vuorenmaa. 2006. Toolkit for user-created augmented reality games. In *Proceedings of the 5th international conference on Mobile and ubiquitous multimedia*. ACM, Stanford California USA, 6. <https://doi.org/10.1145/1186655.1186661>
- [5] Daniel B. LeGoff. 2004. Use of LEGO® as a Therapeutic Medium for Improving Social Competence. *Journal of Autism and Developmental Disorders* 34, 5 (Oct. 2004), 557–571. <https://doi.org/10.1007/s10803-004-2550-0>
- [6] Michael J. Muller, Daniel M. Wildman, and Ellen A. White. 1993. Taxonomy of PD practices: A brief practitioner's guide. *Commun. ACM* 36, 6 (1993), 26–28.
- [7] Glenn G Page, Russell M Wise, Laura Lindenfeld, Peter Moug, Anthony Hodgson, Carina Wyborn, and Ioan Fazey. 2016. Co-designing transformation research: lessons learned from research on deliberate practices for transformation. *Current Opinion in Environmental Sustainability* 20 (June 2016), 86–92. <https://doi.org/10.1016/j.cosust.2016.09.001>
- [8] Alan M Rugman and Joseph R D'cruz. 1993. The "double diamond" model of international competitiveness: The Canadian experience. *MIR: Management International Review* (1993), 17–39.
- [9] Eric Schweikardt and Mark D. Gross. 2008. Learning about Complexity with Modular Robots. In *2008 Second IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning*. IEEE, Banff, AB, Canada, 116–123. <https://doi.org/10.1109/DIGITEL.2008.49>
- [10] Brian Vandenberg. 1980. Play, problem-solving, and creativity. *New Directions for Child and Adolescent Development* 1980, 9 (1980), 49–68. <https://doi.org/10.1002/cd.23219800906>
- [11] Hengfeng Zuo, Mark Jones, Tony Hope, and Robin Jones. 2016. Sensory Perception of Material Texture in Consumer Products. *The Design Journal* 19, 3 (May 2016), 405–427. <https://doi.org/10.1080/14606925.2016.1149318>
- [12] Zeynep Çetin and Nimet Güneş. 2021. Drawing as a means of self-expression: a case study. *Early Child Development and Care* 191, 1 (Jan. 2021), 136–147. <https://doi.org/10.1080/03004430.2019.1608195>