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Maritopia: A VR-Based Underwater Learning Experience Evaluated Through HEART Metric and Design Thinking Methodology

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Abstract

Maritopia is a Virtual Reality application that delivers immersive underwater exploration through interactive missions and a dynamic fish. Developed using the Design Thinking, the application integrates user-centered design principles through iterative prototyping and testing. User experience was evaluated using the HEART metrics: Happiness (87%), Engagement (80%), Adoption (73%), Retention (74%), and Task Success (81%). Involving 20 participants. Results indicate high levels of enjoyment, usability, and task completion. This study demonstrates the effectiveness of Design Thinking in VR educational development and highlights HEART as a robust empirical framework for assessing emotional and behavioral dimensions of user experience in immersive learning environments.

Keywords: Virtual Reality; Design Thinking; HEART Metric; User Experience; Maritopia

1. Introduction

The ocean is a vast, complex ecosystem that plays a critical role in sustaining life on Earth. Despite its significance, public understanding and awareness of marine environments remain limited, particularly among students and young learners. Traditional educational methods—such as textbooks, static illustrations, or classroom lectures—often fail to convey the spatial, sensory, and emotional dimensions of the underwater world [1]. As a result, learners may struggle to develop meaningful connections with marine life and ecological systems. Recent advancements in Virtual Reality (VR) have opened new opportunities for immersive and experiential learning. VR enables users to interact with

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simulated environments in three dimensions, offering a sense of presence that can enhance memory retention, engagement, and emotional involvement [2]. Within environmental and science education, VR has shown promising outcomes in fostering curiosity, empathy toward ecosystems, and a deeper understanding of complex phenomena [3]. However, for VR to be effective in education, its design must balance immersion with usability, comfort, and pedagogical relevance. This study introduces *Maritopia*, a VR-based learning application that simulates underwater exploration through a locally contextualized and emotionally supportive interface. Maritopia features mission-based learning, a visual 3D fish album, and naturalistic ocean soundscapes that together aim to enhance both cognitive understanding and emotional resonance. It was developed using a Design Thinking methodology, an iterative, human-centered approach to problem-solving that emphasizes empathy, ideation, and continuous testing with users [4]. To ensure that Maritopia delivers not only effective learning but also a comfortable and engaging user experience, the application was evaluated using the HEART framework developed by Google. This framework assesses five key dimensions of user experience: Happiness, Engagement, Adoption, Retention, and Task Success. By applying HEART metrics in the context of VR learning, the study provides an empirical basis for understanding how design decisions affect emotional satisfaction, cognitive outcomes, and long-term usability.

The aim of this research is twofold: (1) to present the design and development process of Maritopia as a model for immersive educational applications, and (2) to evaluate its effectiveness and emotional impact through structured UX analysis. This study introduces a novel integration of Design Thinking and the HEART metric to guide and evaluate the development of a VR-based educational application. It offers a replicable framework for designing user-centered immersive learning experiences, while also validating HEART as a tool for measuring both emotional and behavioral engagement in educational VR. By applying this approach to marine exploration, the study bridges interactive learning and environmental awareness, providing new insights into how VR can enhance both learning outcomes and user experience. In the process of designing and creating the VR Maritopia application using software namely: Unity Engine, C #, Unity Asset Store, Unity Editor, Sketchfab, Oculus SDK and XR Integration Toolkit. While the hardware is Meta Quest 2 with Qualcomm Snapdragon XR2 CPU specifications, Adreno 650 GPU, 6Gb / 128GB Internal Ram with 2 Touch Controller gen-3 with finger-tracking & haptics and Wi-Fi version 6

2. Methodology

The development of the Maritopia VR application was guided by the principles of Design Thinking, a human-centered, iterative method aimed at understanding users, redefining problems, and creating innovative solutions [4], [5]. This methodology is particularly suitable for immersive educational technology, as it balances empathy, creativity, and user testing [6]. Maritopia was designed not merely as a technological product, but as a learning environment tailored to users' cognitive and emotional needs.

2.1. The Evolution of Design Thinking Models

The evolution of Design Thinking has resulted in various institutional adaptations, as summarized below [7], and further detailed in Table 1.

Table 1. Different phases and activities of DT approaches.

Model Provider	Phases
Stanford d. school	Empathize – Define – Ideate – Prototype – Test
Hasso Plattner Institute	Understand – Observe – POV – Ideate – Prototype – Test
Nielsen Norman Group	Discover – Define – Develop – Deliver
IBM Design Thinking	Hills – Playbacks – Sponsor Users – Principles – Loops

2.2. Maritopia Research Stages

The application development followed a structured design thinking process as outlined below. These adaptations are illustrated in Table 2. To measure the emotional and behavioral dimensions of user experience, this study adopted the HEART Framework, introduced by Google [8]. It includes five domains: Happiness – user satisfaction and emotional response, Engagement – time spent and depth of interaction, Adoption – initial user success with new features, Retention – returning usage or repeat engagement and Task Success – effectiveness in completing intended tasks. HEART was chosen because: It provides a quantitative structure for measuring UX without neglecting emotional impact [9]. It is well-suited to interactive, exploratory applications such as VR learning [10]. And, It enables clear, comparative evaluation between iterations [11]. The integration of HEART into the testing phase offers a robust empirical basis for assessing how well Maritopia fosters enjoyable, meaningful, and repeatable learning experiences in a virtual underwater.

Table 2. The research stages are in accordance with the Design Thinking (DT) method.

Phase	Activity Description	Output	Target Object
Empathize	Interviews and observations with students, teachers, and educational designers	Identified user needs and exploration barriers	Potential users
Define	Problem synthesis focusing on underwater learning challenges	Well-structured design problem statement	Empathy insights
Ideate	Brainstorming ideas such as interactive missions and 3D fish album	VR learning concept and feature roadmap	Design team
Prototype	Developing the first version of Maritopia with interactive scenes and ocean ambiance	Alpha version of Maritopia VR application	Designers & developers
Test	User testing using HEART metrics and observation-based UX evaluation	User feedback and quantitative HEART metric data	Pilot participants

3. Model Description

3.1. Use Case

According to the terms, use cases are activities or interrelated interactions between actors and systems. In general, it can be interpreted as a technique used for software development, to determine the functional requirements of the system. The meaning of the use case diagram itself is the depiction process carried out to show the relationship between the user and the designed system [12]. Based on the diagrams shown in Fig.1 and Fig.2, the use case of the Maritopia VR application can be described; The Maritopia application is a virtual reality-based underwater exploration game that allows users to interact with marine environments and game elements in real-time. The use case diagrams present the core functionalities, user interactions, and object-based mechanics divided into three main categories: visual feedback, player input, and gameplay responses. In this diagram, the central actor is the player who interacts with the virtual marine world. The player is able to: View Environmental Elements: View Sea Environment, View Tunnel, View Outside Tunnel, View Inside Tunnel, View Inside Submarine, View Game Metrics: View Time Limit, View Score, View Oxygen, View Depth Bomb and Experience Core Learning Content: View Fish, Description Display, Optional Choice Display.These use cases represent the immersive learning features and sensory feedback offered during gameplay. They also reflect how visual information is integrated into the player's field of view to support exploration and marine literacy. In Fig. 2 (a): Detailed Use Cases with Player Input Interaction. The first sub-diagram illustrates the player's movement and navigation capabilities: Move Forward, Move Backward, Move Left, Move Right, Move Up, Move Down and Optional Choice – refers to decision-making during missions or tasks. These use cases reflect intuitive navigation controls, crucial for a smooth VR experience and exploration freedom. In Fig. 2 (b): Game Object Interaction. The second part depicts interactions with in-game objects: Take Fish – educational interaction representing species collection or identification, Hit Oxygen Tanks, Hit Depth Bomb – collision-based events tied to the player's success/failure, Terrain Collision – spatial awareness and boundary response. These interactions simulate realistic constraints and challenges within the VR ocean setting, adding gameplay depth with (3) Miscellaneous Effects As shown in Fig. 2 (c). The third part represents automated system responses: Receive Extra Time, Receive Point, Play Sound. These actions are triggered by player success or milestones, reinforcing reward-based learning and emotional engagement.

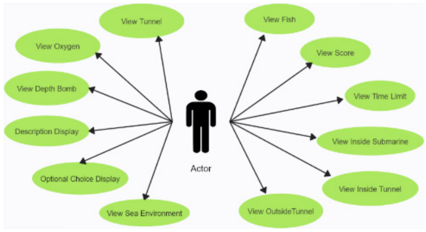

Fig. 1. Use Case Diagram for Maritopia

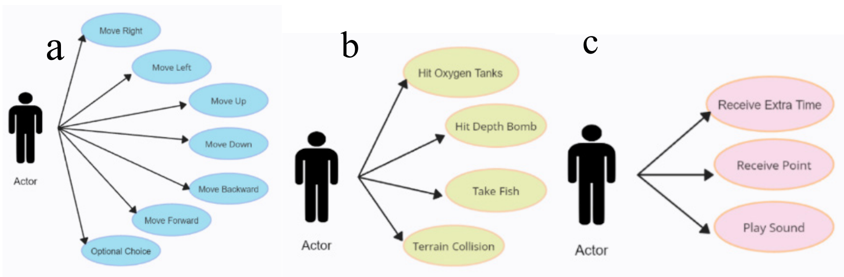

Fig. 2. Detail Use Case for (a) Player Input, (b) Game Object Interaction and (c) Miscellaneous

3.2. Gameplay

Gameplay refers to the specific way in which players interact with a game, encompassing the rules, challenges, and actions that define the player's experience and Fig. 3 highlights this process. In virtual reality applications, gameplay design must consider immersive interactions, spatial navigation, and user engagement to create compelling experiences.[13]

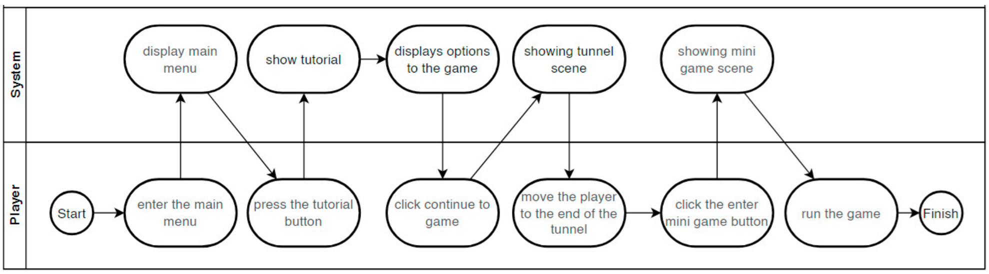

Fig. 3. Gameplay of Maritopia VR

The gameplay experience in *Maritopia* begins with the user donning the Meta Quest 2 headset and launching the application by selecting the Maritopia icon from the main VR interface. Upon entry, the user is directed to the main menu, where an optional tutorial is available. Most users are encouraged to engage with this tutorial, which provides guided instructions on navigation, object interaction, and the overall learning objectives of the game. After completing the tutorial, the player initiates the core gameplay by selecting the start button. The game environment transitions into an immersive underwater tunnel, where the player is surrounded by a variety of 3D-rendered fish species. Each fish is interactable and accompanied by a short description, allowing players to gain marine biological knowledge in an exploratory and visually engaging manner. At the end of the tunnel, the player is presented with a decision point. By selecting a designated button, the player can choose to enter a time-limited mini-game phase. In this segment, the player is challenged to locate specific types of fish within a given timeframe. To extend gameplay and avoid failure, the player may also search for oxygen tanks scattered throughout the virtual environment, thereby increasing the sense of urgency and strategy. This structured flow—from tutorial to guided observation and then to active problem-solving—supports a layered pedagogical model that combines passive learning with interactive reinforcement. The sequence not only enhances cognitive retention but also allows for adaptive pacing and exploratory autonomy within a gamified learning ecosystem.

3.3. UI UX

User Interface (UI) refers to the graphical layout and interactive elements of an application, including buttons, icons, and menus that users interact with directly [14]. UI design refers to the visual and interactive elements of a system, while UX (User Experience) focuses on the user's overall interaction and emotional response to the system [15]. In the Maritopia project, the development workflow prioritized a user-centered design approach beginning with the formulation of the UI/UX concept by the 3D designer. Prior to implementation in Unity, the design team created structured interaction flows and layout mockups to ensure usability and coherence with immersive VR interaction principles. Simultaneously, the 3D artist produced scene sketches to visualize the spatial and narrative progression of the virtual environment, establishing the aesthetic direction of each scene.

Fig. 4. Main Menu

The project includes three main scenes, starting with the Main Menu Scene at Fig. 4, which displays the application title and user options: Guide, Start, and Settings. Set against an immersive beachfront theme with tropical assets, this scene enhances emotional engagement and sets the maritime context. Selecting Start leads to the second scene at Fig. 5, an interactive underwater tunnel tour where users explore a 3D virtual aquarium featuring marine life and educational content for immersive learning.

Fig. 5. Tunnel aquarium

As illustrated in Fig.6, upon selecting the *Play* button, the player is transported into the core exploratory environment—a fully navigable underwater tunnel. Within this scene, users have the freedom to move throughout the space at their own pace, observing the variety of marine life presented outside the transparent tunnel walls. This segment is designed to simulate a naturalistic aquarium experience while supporting informal learning through visual exploration. Each visible marine species is accompanied by an interactive description panel, which provides the player with contextual information and taxonomical insights. By approaching these panels, players can read brief descriptions of each fish species, enabling cognitive engagement through environmental storytelling and situated learning. At the end of the tunnel, the player encounters a decision point in the form of a doorway equipped with a button-triggered pop-up interface. When activated, the pop-up overlays the screen and presents the player with two distinct choices: (1) to proceed into a mini-game challenge, or (2) to continue exploring the tunnel environment at their own leisure. This branching interaction model reinforces user autonomy and maintains immersion, allowing players to either pursue a goal-oriented game scenario or extend their observational journey. It also introduces adaptive pacing, a critical factor in maintaining comfort and engagement in virtual reality learning environments.

3.4. Mini Game

A mini game in virtual reality refers to a short, self-contained interactive challenge embedded within a larger VR experience. Mini-games are often used to promote focused learning, skill-building, or to enhance engagement by breaking up longer immersive sessions [16]. As can be seen in Fig.6, the system shows the user a menu for playing the mini game. Upon entering the mini-game phase, players are immediately presented with a mission pop-up interface detailing their objectives. The primary goal in this segment is to locate and identify several specific fish species within the allotted time.

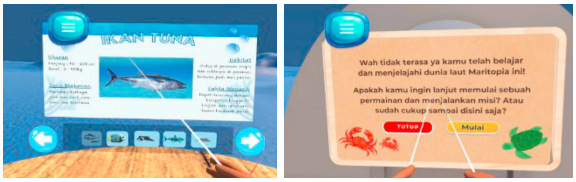

Fig. 6. Fish descriptions and mini-game menu

Simultaneously, players receive environmental hazard warnings, such as the appearance of underwater explosives ("sea bombs") and the need to find oxygen tanks scattered throughout the virtual seascape. These elements are designed to introduce time pressure and survival-based decision-making, thereby increasing player engagement and cognitive alertness. To navigate the underwater mission area, players control a virtual submarine using the dual analog joysticks on the VR controller right and left for directional input. Additional system functions and user preferences, such as movement speed or orientation calibration, can be accessed and adjusted via the Oculus menu button, enabling real-time interaction refinement. The integration of tactile navigation, spatial hazards, and educational search tasks exemplifies a layered game design strategy that supports both motor engagement and cognitive learning. As shown in Fig.7, the mini-game balances urgency and exploration, reinforcing attention, memory, and coordination—key components of active learning in immersive environments.

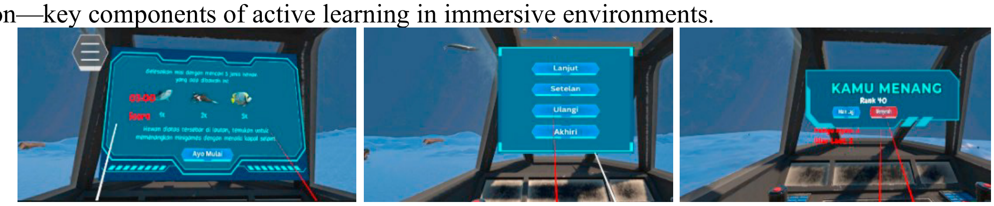

Fig. 7. Minigame

3.5. Testing Implementation

As demonstrated in Fig. 8, to assess the usability and user experience of the Maritopia application, a structured questionnaire was developed based on the HEART framework, which includes five key dimensions: Happiness, Engagement, Adoption, Retention, and Task Success. The questionnaire was administered immediately after users completed a guided interaction session with the application, under the observation and facilitation of the researcher. According to Fig. 8, this approach ensured that the responses captured immediate impressions and minimized recall bias [17].

Fig. 8. Testing Implementation

4. Questionnaire Development and Testing

The questionnaire design followed a goal-oriented evaluation strategy, aligning each item with a specific aspect of the HEART framework. First, the research team defined the goal of the usability evaluation—to measure the effectiveness, satisfaction, and user engagement resulting from the use of Maritopia in a controlled environment. This method aligns with user-centered design principles, where measurement is tightly coupled with real user interaction contexts [18]. A questionnaire is a set of common questions laid out in a standard and logical form to record data from respondents [19]. Based on the defined goal, relevant metrics were identified and translated into a series of Likert-scale questions mapped to each HEART variable in table 3. The structured administration of the questionnaire immediately after usage ensured the contextual relevance of user feedback. This method provided both quantitative and qualitative insights into the effectiveness of Maritopia in delivering an engaging and intuitive learning experience.[20]. A total of 20 participants took part in the user testing, including 5 university students, 6 IT professionals, 5 individuals from the general population, and 4 regular VR users. All participants were within the age range of 17 to 35 years.

Table 3. Variable, Goal and Questions.

Variable	Goal	Code	Question
H – Happiness	Users feel emotionally satisfied and enjoy the underwater VR experience	H1	How enjoyable was your overall experience in Maritopia?
		H2	How satisfied are you with the visual and audio quality of the app?
		H3	Did Maritopia make you feel curious or inspired during the exploration?
		H4	Would you describe your experience as relaxing or pleasant?
E – Engagement	Users actively interact with marine content and explore the environment fully	E1	How often did you interact with objects (e.g., fish, buttons)?
		E2	Did you feel immersed and focused throughout your time in the app?
		E3	Did you explore all areas available to you in the experience?
		E4	Did you voluntarily spend more time than required in Maritopia?
A – Adoption	First-time users can easily understand how to use the application and complete the tutorial.	A1	Was the tutorial easy to follow and understand?
		A2	Did you feel confident using the controls after the first few minutes?
		A3	Did you encounter any obstacles when starting the experience?
		A4	Was it clear how to begin each activity or mission in the app?
R – Retention	Users are motivated to return and re-engage with the application voluntarily	R1	Would you like to use Maritopia again in the future?
		R2	Do you feel the application has more to explore beyond one session?
		R3	Would you recommend Maritopia to your friends or peers?
		R4	Would you be interested in trying future updates or new levels?
T – Task Success	Users are able to complete missions successfully and learn about marine species effectively	TS1	Were you able to complete the fish-finding mission in the mini-game?
		TS2	How many times did you retry the mission before succeeding?
		TS3	Did you understand the mission objectives clearly from the beginning?
		TS4	Did you find the oxygen and avoid sea bombs effectively?

Table 4. The Results of the Calculation"

Question	SA (5)	A (4)	N (3)	D (2)	SD (1)	Score	Total (%)
H1	10	8	2	0	0	88	87%
H2	10	8	2	0	0	88	
H3	5	13	2	0	0	83	
H4	13	3	4	0	0	89	
E1	4	12	4	0	0	80	80%
E2	8	5	6	0	1	79	
E3	5	7	6	2	0	75	
E4	10	7	2	1	0	86	
A1	3	7	9	1	0	72	73%
A2	7	10	3	0	0	84	
A3	3	5	4	7	1	62	
A4	1	12	7	0	0	74	
R1	3	11	6	0	0	77	74%
R2	3	13	4	0	0	79	
R3	3	6	10	0	1	70	
R4	3	6	10	0	1	70	
T1	3	10	7	0	0	76	81%
T2	4	13	3	0	0	81	
T3	5	12	3	0	0	82	
T4	8	9	3	0	0	85	

The calculation of each variable value involves several stages, as described below: Calculating the maximum possible value (Nmax), which is obtained by multiplying the number of respondents, the maximum expected score per item, and the number of questions in each criterion:

$$Nmax = NQmax \times \sum Q \times R \tag{1}$$

Nmax: Maximum expected score for each question criterion, NQmax: Maximum score for each question item, ∑Q: Total number of question items in each criterion, R: Total number of respondents for that criterion. The results of the HEART evaluation will indicate the usability level based on the total score, as presented in table 4.

6. Conclusion

The HEART metric evaluation of the *Maritopia* VR shows a generally positive user experience across all dimensions. Happiness 87%, Engagement 80%, and Task Success 81%—all within the Excellent category—indicating that users found the experience enjoyable, immersive, and effective in completing tasks. However, Adoption (73%) and Retention (74%) were slightly lower, suggesting room for improvement. These scores reflect minor barriers such as the absence of onboarding guidance and limited tutorial scaffolding, which may have caused initial confusion. Additionally, the lack of progression systems or reward mechanisms may have reduced users' motivation to return. To enhance usability and long-term engagement, several improvements are recommended: introducing guided tutorials with visual prompts, implementing unlockable content to incentivize re-engagement, adding quick tutorial recap options, and gathering qualitative feedback from users with lower adoption or retention. Overall, *Maritopia* is a functional and well-received educational VR tool. This study contributes by demonstrating a practical integration of the Design Thinking methodology in the structured development of VR learning applications, alongside the use of the HEART framework for empirical UX evaluation. Together, these approaches offer a replicable model for developing emotionally engaging, user-centered immersive learning experiences.

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