AquaAegis - Defend, Restore and Sustain : A 2D Interactive Game for Ocean and Marine Life Conservation

***Abstract*—AquaAegis, a meticulously crafted 2D interactive game, serves as a powerful tool for raising awareness and fostering active participation in ocean and marine life conservation. This immersive experience seamlessly blends education, exploration, and interactive gameplay, addressing critical real-world environmental challenges such as pervasive marine pollution, the delicate restoration of coral reef ecosystems, and the urgent need to protect endangered species. AquaAegis is thoughtfully structured into four distinct yet interconnected components: the visually compelling "Movie," the resource-rich "LearnHub," the action-oriented "SaveOcean," and the adventurous "DeepDive," each designed to offer players unique and engaging pathways to connect with ocean conservation themes. This paper delves into the intricate structure, dynamic mechanics, profound educational impact, and robust technical implementation of AquaAegis, emphasizing its potential as a transformative game-based learning platform. Furthermore, it explores the innovative integration of AI-driven quizzes, real-time environmental responses to player actions, and comprehensive user interaction tracking, all aimed at accurately evaluating learning outcomes and maximizing educational effectiveness.**

***Index Terms*—Game Architecture, Ocean Conservation, Unity 2D, Environmental Awareness, Marine Ecosystem, Interactive Learning, Serious Games, Game Development, Sustainable Gaming, Educational Game Design**

I. Introduction

The world's oceans, vital to maintaining global ecological equilibrium, are facing unprecedented threats from escalating pollution, rampant habitat destruction, and the devastating consequences of climate change. AquaAegis is a response to this crisis, developed to bridge the critical gap between passive awareness and active, meaningful action. It provides an interactive and engaging platform where players can embark on a journey to explore diverse ocean environments, actively participate in conservation activities, and gain a deeper understanding of complex marine ecosystems. By artfully combining compelling visual storytelling, engaging problem-solving tasks, and real-world conservation principles, AquaAegis creates an immersive educational experience that resonates on both intellectual and emotional levels.

A. Key Contributions

- **Real-time Interactive Conservation Activities:** AquaAegis introduces dynamic gameplay where player actions directly influence the virtual environment, fostering a sense of responsibility and impact.
- **Dynamic Ocean Environment:** The game features a responsive ocean environment that visually reacts to player interventions, providing immediate feedback and reinforcing the importance of conservation efforts.
- **Integration of Real-World Resources:** AquaAegis seamlessly integrates links to reputable conservation organizations, encouraging players to explore and engage with real-world initiatives.

II. Literature Review

Game-based learning in the context of marine conservation and education has garnered increasing attention over the past decade. This section reviews key contributions from recent studies that explore how gamification enhances environmental awareness, learning engagement, and knowledge retention.

Discovery Education UK (2018) provides a visually engaging resource aimed at young learners, illustrating underwater animal movement through interactive video content [1]. Similarly, YouTube tutorials such as "How to Play VIDEO in Unity" [2] support developers in implementing educational elements in interactive media, crucial for serious game development.

Several scholarly works examine the use of gamification for marine science education. For instance, Marcos et al. (2021) introduced NeMO-Net, a game-based platform for labeling coral reef structures using 3D data, significantly contributing to automated marine habitat mapping [3]. Coughlan et al. (2021) used the citizen science game Sea Hero Quest to study navigation ability worldwide, emphasizing the educational and research potential of gamified systems [4].

Louvado and Cabral (2020) designed "The Game of the Sea" as a cross-disciplinary tool that enhances oceanic awareness across scientific and educational communities [5]. Similarly, Kingsley et al. (2020) assessed the impact of the "Save Our Sea" game, which demonstrated positive effects on players' environmental consciousness [6].

Other studies focus on the pedagogical dimensions of such games. Semmens and Freeman (2019) proposed "Go Fish!", a game promoting ocean literacy through gameplay [7], while Watson et al. (2021) reviewed a variety of marine education games, highlighting best practices in both digital and physical formats [8].

Powell and Smith (2018) explored the gamification of citizen science through a game designed to detect invasive species, underlining the potential of games to involve non-scientists in active ecological data collection [9].

1. Game-Based Learning to Raise Awareness About Water Sustainability (Sharma et al. [10])

Key Findings Relevant to the Problem:
Game-based learning tools like Full Tank and Gram engage players in interactive scenarios that teach water conservation.

They link theoretical knowledge with daily water-related practices, showing individual impact through game decisions.
Encourages observation, reflection, problem-solving, and collaboration.
Designs are simple, accessible, and scalable.

Gaps Identified:
Long-term behavioral impact not studied.
Focus mostly on children; adults/policymakers are overlooked.
Lack of regional customization.
Initial versions prioritize gameplay over environmental realism.

2. Water Management Simulation Games and Knowledge Construction (van der Meij et al. [11])

Key Findings Relevant to the Problem:
Simulation games support experiential learning for complex water concepts.
Help develop teamwork, strategic decision-making, and long-term planning.
Encourage understanding of social, economic, and environmental interconnections.

Gaps Identified:
High resource and time requirements hinder scalability.
Primarily aimed at students/professionals.
Often lack strong theoretical foundations.
Limited data on retention or behavior change.

3. Cooperative Network Game Model for Marine Plastic Waste (Liu et al. [12])

Key Findings Relevant to the Problem:
Cooperation between organizations improves marine plastic management.
Myerson value model highlights shared economic and ecological benefits.
Success relies on tech, investment, and fair benefit sharing.

Gaps Identified:
Neglects sociopolitical factors.
Data and technology may be outdated.
Lacks clarity on alliance stability and long-term sustainability.

4. Save the Ocean: A Game for Environmental Awareness (Souza et al. [13])

Key Findings Relevant to the Problem:
Improves recycling understanding through engaging gameplay.
Boosts environmental awareness via tasks and scores.
Incorporates competitive elements and interactive feedback.

Gaps Identified:
Limited information on environmental impact per material.
Small sample size; weak generalization.
Behavioral effects not tracked long term.
Realism in game mechanics could improve.

5. Save Our Sea: Game-Based Learning on Sea Environment Care (Khairuddin et al. [14])

Key Findings Relevant to the Problem:
Game covers trash collection, oil spill management, and coral restoration.
Positive feedback from GEQ assessments.
Encourages task-based engagement and knowledge reinforcement.

Gaps Identified:
Limited multilingual support.
Lacks immersive AR/VR experience.
Target audience is limited to young adults.
Challenge level and player flow could be optimized.

APPLICATIONS AND GAMES

Water Battle – Grendel Games

Description:
A platformer puzzle game that encourages players to save water in real life.
Integrates real usage data from smart meters.
Features include educational tips, rewards, and community tournaments.
Collaborates with water utility providers for broader reach.

Limitations:
Smart meter dependency and regional limitations.
Progression is slow without completing goals.
Requires tech familiarity and active engagement.

Save Water SKDRDP

Description:
Joint initiative by SKDRDP, Karnataka Government, and UNICEF.
Offers regional support in Kannada and gamified water-saving challenges.
Tracks progress, allows team formation, and issues digital certificates.

Limitations:
Primarily localized; may lack broader customization.
Not much information on long-term user engagement.

World of Water – Star Fortune

Description:
Adventure-style mobile game that mixes fantasy gameplay with water awareness tasks.
Includes in-game characters, challenges, and world-building centered around water themes.

Seabook: Fish Identifier

Description:
Provides fish species info and marine life facts.
Used as a supplementary educational tool for ocean literacy.

Among Water: Relaxing Games

Description:
Casual ocean-themed game with meditative, stress-relieving visuals and simple gameplay.
Ideal for promoting emotional connection with marine environments.

III. Methodology

We developed a custom analytics module integrated within the Unity engine to log critical runtime metrics. The dataset consists of five distinct game sessions across different scenes: AquaAegis, Movie, SaveOcean, DeepDive, and LearnHub. The study analyzed the following key aspects:

- **Scene Performance Metrics:** FPS fluctuations, memory trends.
- **User Interaction Tracking:** Key press frequency, UI engagement.
- **Object Dynamics:** Movement patterns, animation updates.
- **Comparative Session Analysis:** Cross-scene performance evaluation.

Data collection occurred in real-time, and all logs were processed to extract meaningful insights.

IV. Game Structure and Features

AquaAegis is meticulously structured into four primary components, each designed to provide a unique and enriching experience.

A. Movie – Visual Introduction to Marine Ecosystems

The "Movie" scene serves as an emotionally resonant introduction to the wonders of ocean ecosystems. Through a captivating two-minute video, players are immersed in the vibrant world of marine life, witnessing the beauty of fish schools, the intricate structures of coral reefs, and the vastness of underwater landscapes. Enhanced with carefully curated sound effects, this segment aims to forge a deep emotional connection between players and the game's overarching vision of ocean conservation. The footage, sourced from the educational resource "Under the Sea: Ocean Animal Moves" by Discovery Education UK, is augmented with custom audio effects to amplify the immersive experience.

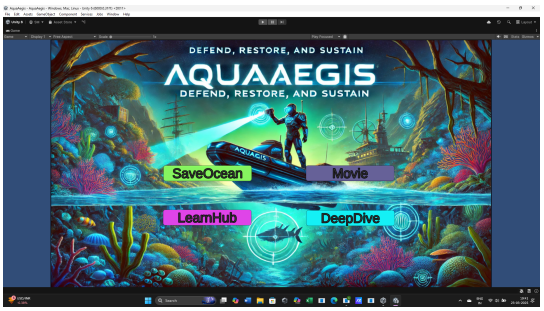

Fig. 1. Opening of the AquaAegis game with navigation buttons to 4 sub parts.

B. Learn Hub – Knowledge Expansion through External Resources

"LearnHub" functions as a comprehensive educational center, providing players with direct access to a curated selection of external organizations dedicated to ocean conservation. This integrated resource hub features links to:

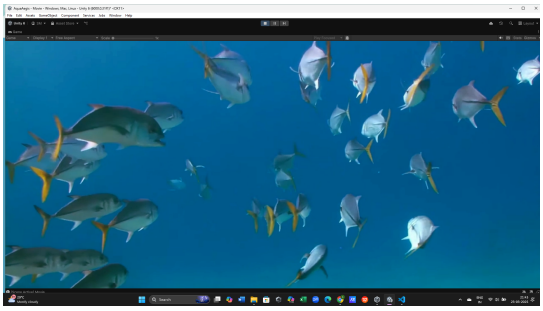

Fig. 2. A clip from the Movie scene showing a school of vibrant fishes underwater.

- Marine Conservation Institute: Providing insights into global marine protection policies.
- Coral Reef Alliance: Highlighting vital coral reef preservation projects.
- UN Decade of Ocean Science: Promoting sustainable ocean research and innovation.
- Ocean Conservancy - Trash Free Seas: Offering strategies to combat plastic pollution.
- NASA Climate Change: Exploring the profound impact of climate change on ocean ecosystems.
- NOAA Ocean Exploration: Unveiling the mysteries of deep-sea biodiversity.

By seamlessly integrating these external resources, LearnHub empowers players to expand their knowledge, engage with a wider community, and become active participants in global conservation efforts.

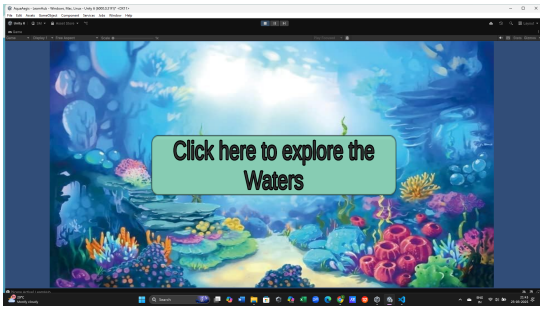

Fig. 3. Navigation button to LearnHub's static web page.

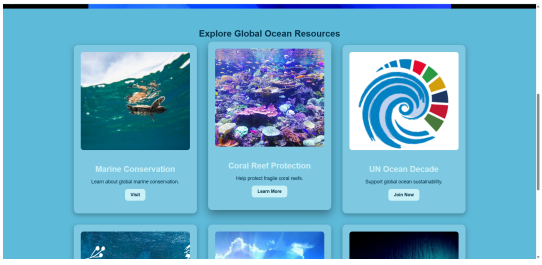

Fig. 4. Websites with links in LearnHub's static webpage.

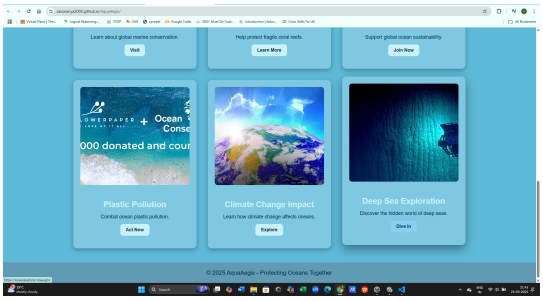

Fig. 5. Websites with links in LearnHub's static webpage.

C. SaveOcean – Core Gameplay and Conservation Activities

SaveOcean is the primary interactive segment of AquaAegis, where players control a submarine to restore ocean health by removing pollutants, reviving coral reefs, and engaging in conservation-themed challenges.

Gameplay Elements:

- **Submarine Navigation:** The submarine navigates through a polluted ocean environment, controlled using the arrow keys. The camera follows the player's movement.
- **Pollution Cleanup:** The ocean contains plastic bags, sea litter, and oil spills. Players must clear these items by maneuvering the submarine into them. As pollution decreases, the ocean floor transitions from a dark reddish-brown to a clearer blue.
- **Coral Reef Restoration:** The ocean environment features dead corals that can be revived. By pressing "E" near a dead coral, it is replaced with an active coral, accompanied by a positive sound effect.

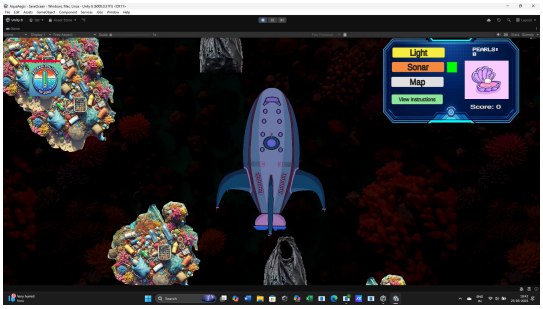

Fig. 6. Initial view of SaveOcean scene.

Map and Navigation System:

- Press "O" to zoom out and view a larger section of the ocean.
- Press "I" to zoom in for closer exploration.
- Press "R" to reset the camera to the default view.
- A toggleable map button allows easy switching between views.

Pearl Collection and Ethical Awareness:

- Players can collect pearls (pink and violet) scattered throughout the ocean.

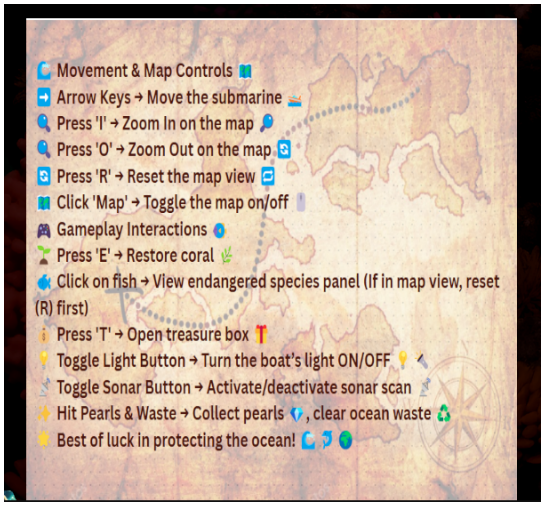

Fig. 7. User friendly instruction map to guide them through game.

- After collecting the second pearl, a message appears, alerting players that oysters are living organisms and should be handled with care.
- The pearl score increases with each collection.

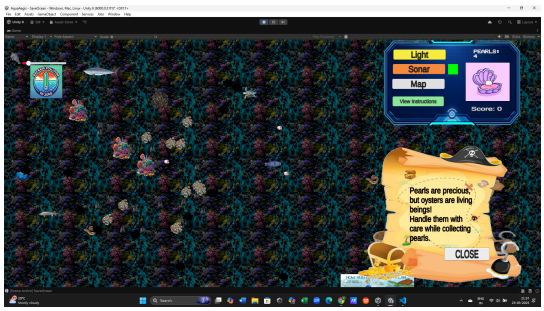

Fig. 8. Panel opened when submarine hits a pearl.

Lighting System:

- A toggleable light function enables players to switch the submarine's light on and off for improved visibility in dark areas.

Treasure Box Quiz:

- Four treasure boxes are hidden in the ocean.
- When near a box, pressing "T" presents a multiple-choice quiz related to ocean conservation.
- A correct answer awards 10 points, while an incorrect answer causes the chest to disappear.

Endangered Species Discovery:

- Twenty rare marine species are spread throughout the game environment.
- Clicking on a species opens an informational panel displaying its name, details, conservation status, and a key fact about its habitat.

Instructional Guide:

- Players can access an instruction panel that provides key mappings and gameplay guidance.

Conservation Messages:

- Throughout the game, placards displaying ocean conservation quotes appear to reinforce the importance of marine protection.

SaveOcean is designed as an open-ended experience, allowing players to engage with environmental challenges at their own pace.

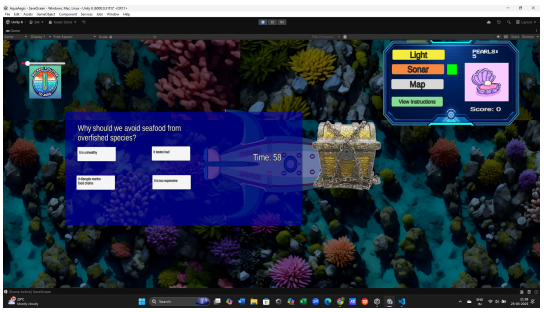

Fig. 9. Pop-up of quiz when the treasure box is opened.

D. DeepDive – Side-Scrolling Underwater Adventure

DeepDive offers a distinct gameplay experience where players control a deep-sea diver exploring the ocean depths.

Gameplay Elements:

- **Parallax Scrolling Effect:** The background consists of layered elements that move at different speeds, creating a dynamic sense of depth.
- **Diver Navigation:** The diver moves using arrow keys, simulating realistic underwater movement.

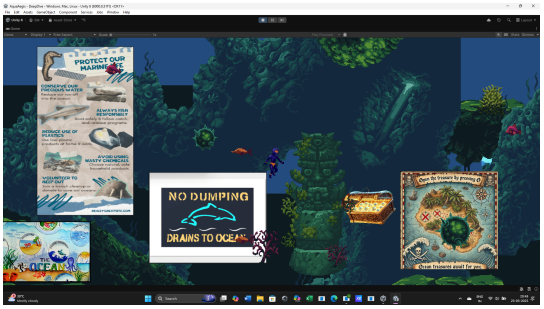

Fig. 10. Opening scene of the DeepDive.

Environmental Hazards:

- Contact with fish can disrupt movement.
- Collision with iron balls triggers an explosion effect, adding a challenge to navigation.

Treasure Chest Quiz:

- Players can open a treasure chest by pressing "O," initiating a 120-second timed quiz.
- Correct answers earn points, reinforcing ocean conservation knowledge.

Educational Placards:

- The environment features conservation messages and real-world ocean facts to enhance learning.

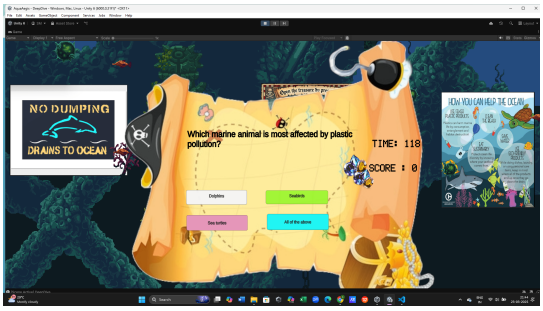

Fig. 11. 120 sec quiz popped when the treasure box opened.

DeepDive complements the SaveOcean experience by introducing new mechanics, visual elements, and interactive storytelling that deepen player engagement.

V. AquaAegis Game Architecture

AquaAegis is a 2D educational game designed to raise awareness about ocean conservation and marine life protection. The game consists of multiple interconnected scenes, each serving a distinct purpose in engaging players with environmental issues. The overall architecture of the game is illustrated in Figure.

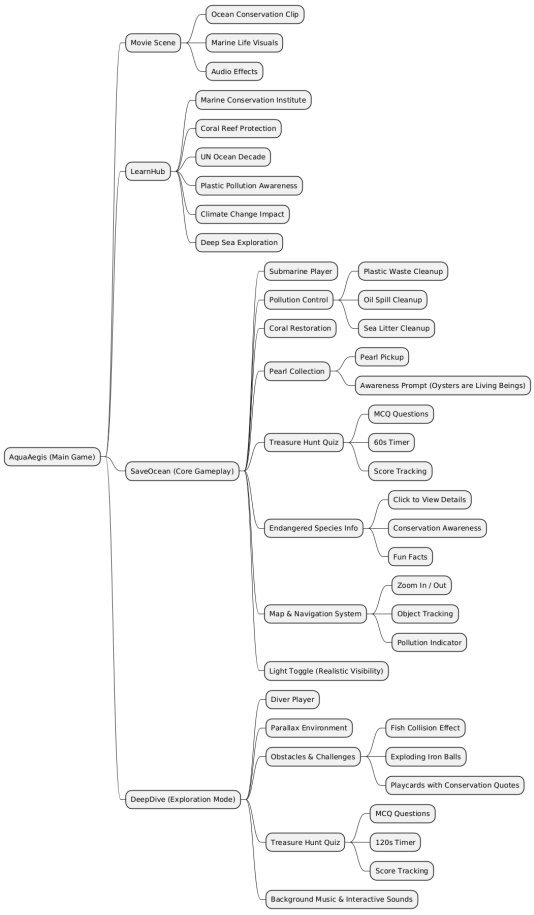

Fig. 12. AquaAegis game's architecture.

The game comprises four primary scenes:

- **Movie Scene:** A short cinematic sequence showcasing marine life, pollution effects, and conservation efforts using real-world footage with added audio effects.
- **LearnHub:** A static web-based information hub providing access to six external organizations dedicated to ocean conservation, climate change impact, and deep-sea exploration.
- **SaveOcean (Core Gameplay):** The main interactive component, where the player controls a submarine to clean ocean waste, restore coral reefs, and complete educational challenges.
- **DeepDive:** A side-scrolling exploration mode featuring a diver navigating through underwater environments, facing obstacles, collecting information, and answering conservation-related quizzes.

The SaveOcean module serves as the core gameplay element, incorporating pollution cleanup mechanics, treasure hunt quizzes, and an interactive map system. The game also features dynamic lighting, interactive sound effects, and parallax environments to enhance realism.

Each component of AquaAegis is designed to educate players while providing an engaging and interactive experience. The game's architecture ensures a balance between entertainment and environmental awareness through exploration, problem-solving, and real-world conservation challenges.

VI. Results & Analysis

A. FPS & Performance Stability

- **Lowest FPS recorded:** 111 FPS (DeepDive scene), indicating potential rendering bottlenecks.
- **Highest FPS recorded:** 379 FPS (LearnHub scene), suggesting lightweight asset usage.
- **Moderate FPS variations:** Movie and SaveOcean exhibited FPS fluctuations between 135-249 FPS.

B. Memory Utilization Trends

- **Maximum memory usage:** 685 MB (Movie & AquaAegis scenes).
- **Stable but high utilization:** DeepDive & SaveOcean maintained ˜670 MB.
- **Lowest memory footprint:** LearnHub recorded 637 MB.

C. User Interaction Analysis

Key Press Events:

- Most frequent: Mouse Clicks (42+ times in DeepDive), Arrow Keys (Up: 21, Right: 16).
- Minimal use of special keys: ('O', 'E', 'T' used ˜1-4 times per session).

UI Interaction Events:

- Limited UI engagement detected, indicating potential usability issues or incomplete event tracking.
- Most used UI elements: *SaveOcean Button* (1 click), *Map View* (4 clicks), *Light Toggle* (2 clicks).

D. Object Movement & Dynamics

- Excessive Camera Updates: ˜21,000 movements logged across sessions.
- High-frequency object movement:
  - Spaceship: 5,500 moves per session.
  - Player: 3,650 moves per session.
- Background & Midground elements in DeepDive had ˜3,600+ movements, confirming a strong parallax effect.

VII. Game Metrics Analysis

A. Performance Metrics Overview

The performance of the game was assessed across four different sessions, measuring key parameters such as frame rate, memory usage, and object interactions.

1) Frames Per Second (FPS) Analysis: Table I presents the FPS metrics across different scenes.

TABLE I
FPS Performance Metrics

Scene	Min FPS	Max FPS	Avg FPS
AquaAegis	152	380	300-340
Movie	249	377	Stable
SaveOcean	135	346	180-210
DeepDive	111	154	130-145
LearnHub	324	379	350

The FPS exhibited fluctuations in the SaveOcean and DeepDive scenes, with noticeable drops below 150 FPS, likely due to increased rendering and logic processing.

2) Memory Usage Analysis: Memory consumption trends are summarized in Table II.

TABLE II
Memory Usage Metrics (MB)

Scene	Min Usage	Max Usage	Avg Usage
AquaAegis	597	685	640
Movie	605	685	Stable
SaveOcean	596	674	640
DeepDive	594	670	635
LearnHub	597	637	620

Memory usage steadily increased across sessions, with the highest peak at 685 MB in the AquaAegis and Movie scenes. However, no abrupt spikes were observed, indicating stable resource management.

B. Scene-Specific Analysis

1) AquaAegis Scene: This scene had 17 active objects, maintaining a relatively high FPS range (222-349 FPS) with minor memory increase.

2) Movie Scene: The FPS remained mostly stable (249-377 FPS) with memory peaking at 685 MB. The lower object count (8 objects) contributed to the stability.

3) SaveOcean Scene: This scene initially had 161 objects, decreasing to 138. The FPS fluctuated significantly (135-217 FPS), suggesting high rendering or logic-processing overhead.

4) DeepDive Scene: The object count increased from 17 to 171, causing FPS to drop as low as 111 FPS. Memory usage increased steadily, highlighting the impact of asset accumulation.

5) LearnHub Scene: This session lasted only 6.6 seconds with minimal interactions. FPS remained consistently high (324-379 FPS), suggesting an optimized scene.

C. User Interactions and Gameplay Events

Key interactions, including mouse clicks, key presses, and UI interactions, are summarized in Table III.

TABLE III
USER INTERACTION METRICS

Action	Count	Scene(s) Affected
Mouse Clicks	42	DeepDive
Arrow Key Presses	84	SaveOcean, DeepDive
Button Clicks	1-4	Multiple Scenes
Object Movements	21,000+	SaveOcean, DeepDive

The high object movement count in SaveOcean and DeepDive (21,000 updates) suggests significant in-game activity, affecting performance.

D. Comparative Analysis of Marine Conservation Games

To assess the effectiveness and methodologies of various marine conservation games, we conducted a comparative analysis based on academic research and existing marine education games. The following studies and games were considered in our review:

1) NeMO-Net: NeMO-Net is a citizen science game developed by NASA, allowing players to classify 3D representations of coral reefs. By engaging with the game, players contribute to training a convolutional neural network (CNN) that aids in automated marine habitat mapping. This methodology integrates real-world scientific data with an interactive gaming experience, making it both engaging and educational.

The game provides an immersive experience through its detailed 3D visualizations of coral reefs. Players explore different reef structures, learning about coral species and their significance to the marine ecosystem. The data collected from players is processed using deep learning models to enhance automated mapping of marine habitats, which has direct applications in environmental conservation.

Despite its success, NeMO-Net has some areas for improvement. Its complex interface may present a learning curve for new users, potentially limiting accessibility. Additionally, while it provides a strong citizen science component, the game lacks traditional storytelling elements that could further enhance player engagement and emotional connection to marine conservation.

2) Sea Hero Quest: Sea Hero Quest is a mobile game designed to study spatial navigation and its implications for dementia research. Unlike other marine conservation games, its primary goal is to collect large-scale navigation data from players to assist in understanding cognitive functions and potential indicators of Alzheimer's disease.

The game involves players navigating mazes in a virtual ocean environment, with each decision contributing to a dataset used for scientific research. With over 4.3 million players worldwide, Sea Hero Quest has generated one of the largest datasets on human navigation abilities, providing valuable insights into memory and spatial awareness.

Although it serves an important research purpose, the game does not focus directly on marine conservation. It lacks educational content about ocean ecosystems, pollution, or conservation strategies. However, its success demonstrates the potential of games in large-scale data collection for scientific research, a model that could be adapted for conservation efforts.

3) The Game of the Sea: The Game of the Sea is an educational board game designed to teach players about marine ecosystems through quizzes and storytelling. Unlike digital games, it provides a structured learning approach where players answer questions and participate in discussions about marine biodiversity.

This game has been effective in increasing knowledge retention, as studies have shown a 35% improvement in marine awareness among players. It also promotes interdisciplinary learning by integrating scientific, historical, and cultural aspects of marine conservation.

However, its non-digital format limits its accessibility and interactivity. Compared to immersive 3D experiences like NeMO-Net, The Game of the Sea lacks dynamic engagement elements such as real-time exploration and adaptive challenges.

4) Save Our Sea: Save Our Sea is a 2D interactive game focused on pollution reduction and coral reef restoration. Players participate in virtual conservation tasks such as cleaning polluted waters and planting coral reefs, simulating real-world conservation activities.

Pre- and post-game knowledge assessments indicate a significant increase in players' understanding of ocean pollution and sustainable practices. The game effectively uses interactive elements to reinforce environmental responsibility, making it an engaging educational tool.

While Save Our Sea successfully raises awareness about pollution, it lacks the immersive depth of 3D conservation games. Additionally, it does not incorporate real-world scientific data, which could enhance its impact and credibility.

5) Go Fish!: Go Fish! is a card-based game that educates players about sustainable fishing practices. It is primarily used in university settings to improve ocean literacy and promote responsible fishing behaviors.

The game has been found to enhance knowledge retention and encourage discussions on marine sustainability. Through strategic decision-making, players learn about overfishing, marine biodiversity, and sustainable fisheries management.

However, Go Fish! is best suited for group learning environments, limiting its accessibility for solo players. Additionally, it does not provide an interactive digital experience, which may

be a drawback for modern audiences who prefer immersive gameplay.

6) Methodology Followed by Each Game: Table IV presents a comparative overview of methodologies used in various marine conservation games.

TABLE IV
COMPARISON OF GAME METHODOLOGIES

Game	Methodology
AquaAegis	Interactive conservation challenges, sonar scans, treasure hun
NeMO-Net	3D labeling, deep-learning for coral mapping
Sea Hero Quest	Spatial navigation data collection for dementia study
The Game of the Sea	Marine science quizzes, storytelling
Save Our Sea	Pollution reduction, coral reef restoration
Go Fish!	Sustainable fishing simulation

7) Key Metrics for Evaluation: Table V compares key metrics across different games. To know how the game has impacted the people who played it, a small interview has be done after they completed the game and based on the answers they have given for the game, key metrics had been and used for comparison of AquaAegis with other games.The survey questionnaire used for the analysis was given in appendix at end of this paper.

8) Key Takeaways and Recommendations: 1. **Stronger Narrative and Storytelling:** Inspired by Sea Hero Quest, adding a storyline could enhance engagement. 2. **Adaptive Challenge Levels:** Implementing difficulty scaling based on player performance. 3. **Real-World Conservation Impact:** Integrating data collection features like NeMO-Net. 4. **Social and Community Features:** Introducing leaderboards or multiplayer missions. 5. **Immersive Tech Enhancements:** Exploring VR or AR-based interactions for greater engagement.

E. Conclusion

The performance metrics indicate stable memory management but highlight FPS fluctuations in the SaveOcean and DeepDive scenes due to increased object count and rendering complexity. Future optimizations should focus on FPS stabilization and asset handling improvements. Comparative analysis highlights AquaAegis's strong educational impact and engagement potential, with recommendations for future improvements.

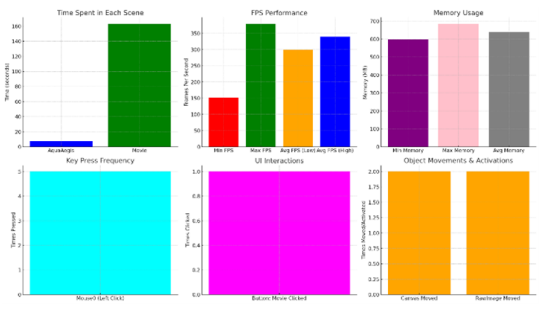

Fig. 13. Metrics obtained for Movie scene while game play.

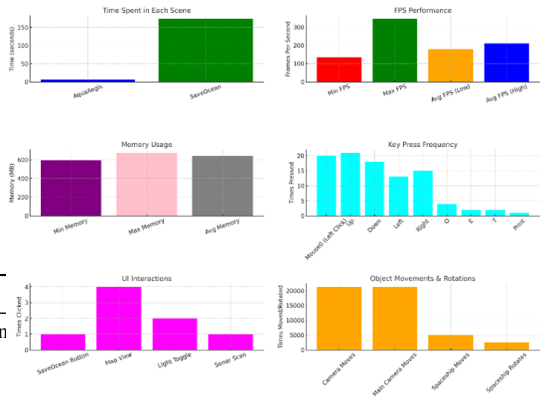

Fig. 14. Metrics obtained for SaveOcean scene while game play.

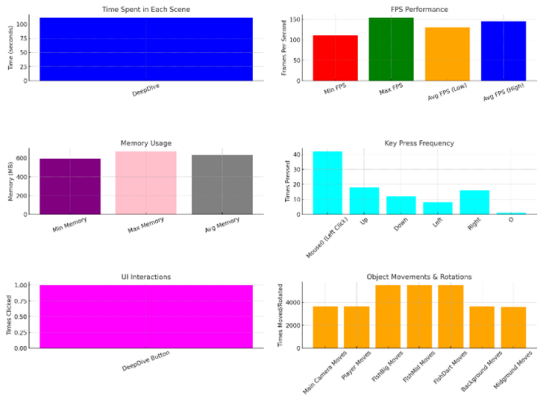

Fig. 15. Metrics obtained for DeepDive scene while game play.

VIII. EDUCATIONAL SIGNIFICANCE AND RESEARCH IMPLICATIONS

AquaAegis promotes environmental awareness through interactive learning and decision-making activities. AquaAegis is designed as an educational tool that integrates interactive learning with environmental awareness. The game promotes critical thinking, ethical decision-making, and engagement with real-world conservation challenges.

A. Key Learning Outcomes

- Understanding the impact of pollution on marine ecosystems.
- Engaging in hands-on conservation activities such as waste removal and coral restoration.
- Identifying endangered marine species and learning about conservation efforts.
- Applying knowledge through quizzes and problem-solving tasks.
- Developing an ethical perspective on ocean resource management.

By combining scientific data with immersive gameplay, AquaAegis offers a game-based approach to environmental education, suitable for students, educators, and conservation advocates.

TABLE V
KEY EVALUATION METRICS OF MARINE CONSERVATION GAMES

Metric	AquaAegis	NeMO-Net	Sea Hero Quest	The Game of the Sea	Save Our Sea	Go Fish!
Engagement	4/5	High	High	Moderate	High	Moderate
Education Impact	Strong	High	Moderate	High	High	Moderate
Conservation Impact	Strong	High	Low	Moderate	High	Moderate
Challenge Level	Moderate	Progressive	Moderate	Adaptive	Moderate	Adaptive
Technical Performance	High	High	High	Moderate	High	Moderate

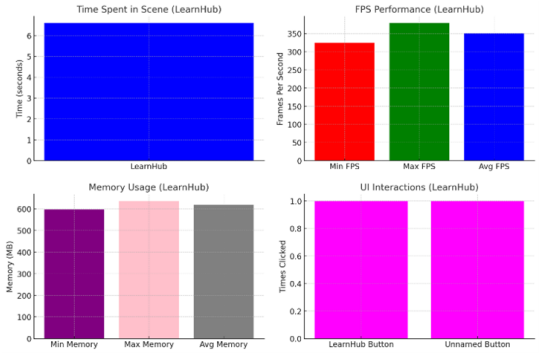

Fig. 16. Metrics obtained for LearnHub scene while game play.

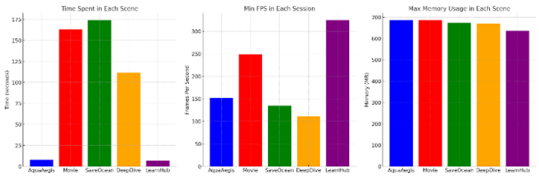

Fig. 17. Comparative analysis of key metrics like Time spent in each scene, FPS in each session and Memory utilization per scene for 4 scenes of AquaAegis.

IX. CONCLUSION

AquaAegis presents a multi-dimensional approach to ocean conservation education through engaging gameplay, real-world data integration, and interactive learning experiences. The game's structured design, with components ranging from visual storytelling to hands-on conservation activities, ensures that players gain both theoretical knowledge and practical insight into marine ecosystem protection.

Future enhancements may include expanded gameplay areas, multi-user collaboration, and AI-driven marine life interactions, further increasing the game's educational impact.

AquaAegis demonstrates the potential of game-based learning in environmental education, offering an innovative and immersive platform for raising awareness about ocean conservation.

This study demonstrates a data-driven approach to evaluating game performance, user behavior, and system efficiency in Unity-based applications. The findings highlight critical areas requiring optimization, including FPS stability, memory management, and UI engagement tracking.

Future research can explore AI-driven difficulty adjustment models, adaptive performance tuning using reinforcement learning, and optimized asset-streaming techniques for large-scale Unity simulations.

X. APPENDIX

To evaluate the engagement, educational impact, challenge level, technical aspects, and retention of AquaAegis, a structured questionnaire was administered to players. The survey comprised the following key questions:

1) **Engagement & Experience**
   - On a scale of 1-5, how enjoyable did you find AquaAegis? (1 - Not enjoyable, 5 - Very enjoyable)
   - What was your favorite feature in the game? (Light, Sonar Scan, Map, Treasure Challenges, Fish Rescue, Endangered Species Pop-ups)
2) **Learning & Educational Impact**
   - Did the game help you learn something new about ocean conservation? (Yes/No)
   - What ocean-related fact did you find most interesting in the game? (Open-ended)
   - How likely are you to take real-world action to protect marine life after playing? (1 - Not at all, 5 - Very likely)
3) **Challenge & Decision-Making**
   - Did you find the Treasure Challenges (ocean survival questions) too easy, too hard, or just right? (Too easy / Just right / Too hard)
   - What in-game action did you find most rewarding? (Rescuing fish, Collecting treasures, Learning about endangered species, Exploring the ocean)
4) **Technical & Design Feedback**
   - Did you experience any bugs or glitches while playing? (Yes/No, describe if Yes)
   - How would you rate the game's graphics and animations? (1 - Poor, 5 - Excellent)
5) **Retention & Future Interest**
   - Would you play AquaAegis again or recommend it to a friend? (Yes/No)

This survey provided valuable insights into player engagement, knowledge retention, and potential areas for improvement, which were integrated into the comparative analysis of game along with other serious games.

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