Exploring Marine Biodiversity through Playful Interaction Design

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ABSTRACT

This research paper presents a critical analysis of a physical computing project that combines exploration and playfulness within an interactive marine environment. The space is designed to increase user engagement through physical interactions using a trident and lamp to control the fish and seaweed models. Significantly improving the overall educational experience by creating a noval and gamified environment. The aim of this project is to enhance user awareness of marine biodiversity, promoting conservation efforts. By examining user interaction, feedback and technical implementations, this study highlights the project's contributions to interaction design within the domain of augmented technology to foster a hands-on learning experience.

KEYWORDS

Interaction Design; Embodied-Interaction; Augmented Technology, Physical Activity; Marine Conservation; Educational

INTRODUCTION

In the evolving field of interaction design, the importance of creating an engaging and enjoyable experience is paramount when fostering user engagement and learning. This paper critically examines a physical computing project called Aqualumia which leverages playful interactions to offer users an immersive, explorative and informative experience within an ocean-themed interactive space. With the use of tridents and lamps to controls various sea creature models, Aqualumia facilitates an environment to enhance the user's understandings of marine biodiversity and support conservation efforts. The significance of this project is to highlights its ability to integrate physicality and playfulness with educational content to provide a hands-on learning experience.

Leading to the main concept this paper focuses on - the importance of physical interaction in fostering an efficient, engaging and effective learning experience. This paper first discusses the reasons digital learning methods needs to improve due to our progressively deteriorating cognitive ability to pay attention. It then provides references to the current systems using noval interaction paradigms for learning and identifying the under-explored opportunities in the field. The paper then explores how the methods, process and outcomes from Aqualumia presents insights into this broader field of interaction design.

BACKGROUND

Informational and educational technologies are rapidly evolving the way we experience the world. As Malinverni discourses [1], there exists an unparalleled disconnect between the 'previous generation' and the 'digitally grown generation' in the way we think, learn, process information and manage our leisure, which is directly reflected in the challenges faced within the educational community.

One of the unintended risks associated with the popularization of the digital age is the constant influx of information available to us, which has proven to have persistent detrimental impact on the brain. A study conducted by Lodge and Harrison [2] indicate that

through the use of digital learning technologies, our attention as a cognitive function has been significantly impacted. In 2004, the average person's attention span while using a digital device was recorded at two and a half minutes. By 2024, this had decreased by 66% to forty-seven seconds [3]. This effect on attention can impact engagement, long-term memory, and the ability to 'connect disparate ideas into cohesive understanding' [3].

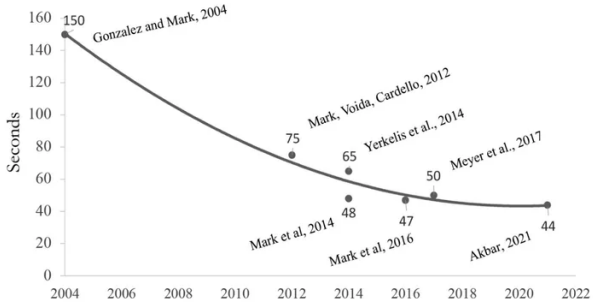

Figure 1: **Average attention span duration, 2004-2021 [4].**

As Resnick [5] states, "learning is an active process in which people construct new understanding in the world around them using active exploration, experimentation, discussion and reflection.". From this, it can be deduced that the importance of physical interactive designs is to provide an effective learning strategy in the digital era, encouraging users to take an active role in their learning process. Allowing them to transform information into knowledge through exploration, assimilation and collaboration with the system [1].

The technical descriptions provided in the next section delve into the specifics of how this project undertakes the task of designing such a system to keep users engaged and informed. This research contributes to the field of interaction design by analyzing and discussing the outcomes of user interaction, feedback, and technical implementations in this project.

PROJECT TECHNICAL DESCRIPTION

The interactive marine environment designed for this project comprises four key components:

- Fish models
- Seaweed
- Coral
- Lamp and Trident

Firstly, each component is incorporated with sensors and motors controlled by Arduino microcontrollers, creating a dynamic and engaging experience for users. The seaweed and fish models were designed to replicate the natural ecosystem of the ocean. Each model uses servo motors for motion; however, the integrated LDR sensors play the vital role in noval interactivity. These components were designed to be controlled using light, specifically by the sensors placed around the fish which would detect light and turn towards the corresponding direction thereby allowing the user to manipulate its motion. Similarly, the detection of light by the seaweed would stop its motion in the environment.

The trident and hand lamp serve as the main interaction tools for users within the environment. Each of these elements features an LED light at the top, allowing users to trigger the sensors on the fish and seaweed models.

Lastly, the intended educational aspect would be experienced by the user when they direct the fish models towards the various coral features placed around the space. Each coral has a corresponding color which would be detected by the fish, halting its movement. When the fish detects a specific coral, an auditory track is played with the relating information. The combination of these components fosters an active learning environment that requires users to explore the system, assimilate to the environment and collaborate with others.

Related Works

Several other learning environments that feature physically interaction have been explored to enhance the effectiveness of the learning process. Research into this space indicate that embodied interactions influences thought and learning. Highlighting that gestures and body movement reveal aspects of the learning process and promote 'learning in a special way' [6].

The first system that encompasses such an environment is called 'Sorter'. Sharing similarities to Tetris, this game requires its players to user their shadows, which is projected onto a board to physically move objects 'falling' from the top of the screen into the

correlating base. These objects are categorized based on geometrical shapes. The results recorded from this environment suggested that 41.6% of participants 'evoked' their actions after the interaction and 58.3% of participants evoked the concept incorporated within this game [6].

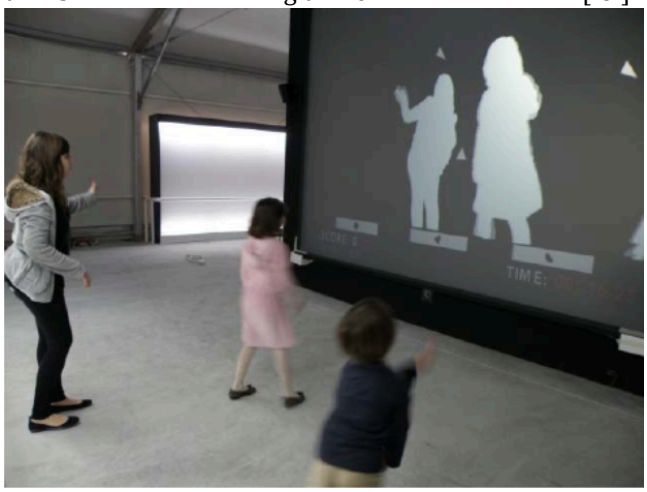

Figure 2: **Participants engaging with the 'Sorter' game [6].**

The second system that explores full-bodied interaction is called 'Mediate'. Mediate is designed to foster creative expression among people on the autistic spectrum (PAS). This infrastructure surrounds the participant with planar screens and tactile interface walls. Multiple interactive methods such as audio input, visual 'silhouette' and tactile interactions can be utilized by the user to interact with the dynamic visual field on screen [7].

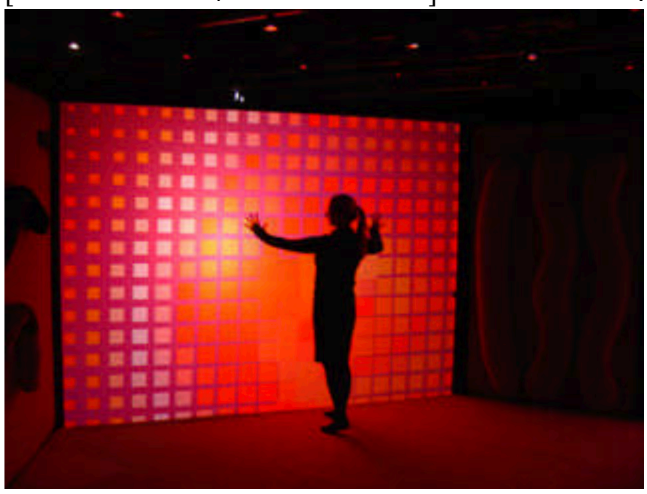

Figure 3: **Participants engaging with the 'Mediate' [8].**

PROJECT RESULTS AND ANALYSIS

The results for Aqualumia from users were overall positive, users expressed excitement and satisfaction from using the designed models to experiencing the environment. Subsequently accomplishing the intended experience of informing users about marine biodiversity and raising conservation efforts. The recorded feedback indicates that:

- One user found the experience "fun", indicating an interest to "learn how sea creatures live".
- Another user found themselves "reminiscing childhood memories". Indicating engagement through playfulness.
- One participant expressed the importance of stopping to "think about marine life". Raising awareness through experience

There are a few insights that could be identified by analyzing this feedback. The variety of experiences recorded indicate Aqualumia's effectiveness in appealing to a diverse demographic. On one hand, young participants were drawn to the playfulness offered by the interaction. Specifically, users enjoyed the gamification of a marine environment that encouraged them to explore by controlling the fish and seaweed, which kept them entertained while subtly imparting knowledge about marine biodiversity and conservation. As discussed by Kynigos et al., this aspect of playfulness aligns with the theories that emphasis the use of engaging, full-body games to improve understanding and retention [6].

On the other hand, older participants revealed a nostalgic connection to their childhood, reminiscing their memories evoked by the interaction with Aqualumia. This emotional connection is significant for fostering a deeper connection with the incorporated concept, leading to a lasting impact and awareness of marine conservation. As cited by Birchfield et al., designing an immersive and multimodal learning environment can vastly improve the user experience and learning outcomes [7].

Incorporating the technical information gained from the interactive elements also play a curial role in improving user satisfaction and experience. The fish and seaweed models controlled with light sensors and Arduino microcontrollers were praised by the participants. However, some challenged were noted

such as the lighting conditions in the testing environment varying constantly. The bright background light during the day interfered with the LDR sensors, disabling it from detecting the LED lights attached to the lamp and trident. Addressing this issue by carefully calibrating the sensors and its parameters would further enhance the systems responsiveness and user experience. Table 1 provides a summary of the user feedback categorized based on engagement, educational value and technical performance. This table helps to systematically present the diverse and summative feedback received and identify areas for improvement.

Table 1. Summary of the user feedback for Aqualumia.

Category	Responses	Areas for Improvement
Engagement	"Fun", "reminiscing childhood memories",	Difficulties in bright light conditions
Education Value	"learn how sea creatures live", "think about marine life"	Enhance and implement educational content
Technical Performance	Responsive and playful models	Sensor and parameter calibration for varied lighting

DISCUSSION

The outcomes of the Aqualumia project highlight significant advancements in the field of interaction design, particularly concerning the integration of playfulness and physical interaction to enhance learning experiences. The project's success in engaging users and promoting marine biodiversity awareness highlights the potential of combining interactive technology with educational content.

Firstly, the positive feedback from users indicates that the playful nature of the Aqualumia environment effectively captured their interest and sustained their engagement. This aligns with Resnick's assertion that learning is an active process that thrives on exploration, experimentation, and reflection [5]. By allowing users to manipulate the fish and seaweed models using tridents and lamps, Aqualumia fostered an environment of active exploration, mirroring Resnick's principles of effective learning in the digital age.

The project's reliance on physical interaction, as opposed to purely digital interfaces, addresses the critical issue of declining attention spans in the digital era. Studies indicate that digital learning technologies can negatively impact cognitive functions such as attention and memory [2]. Aqualumia's design mitigates these effects by encouraging users to engage physically with the environment, thereby promoting sustained attention and deeper cognitive processing.

The comparison with other physically interactive learning environments, such as the 'Sorter' and 'Mediate' systems, further contextualizes Aqualumia's contributions. Both of these systems emphasize the role of embodied interaction in enhancing learning outcomes. The 'Sorter' game demonstrated that physical movement and gesture-based interaction can significantly enhance conceptual understanding and recall. Similarly, the 'Mediate' system showcased the potential of multimodal interactions to support creative expression and learning among people with autism. Aqualumia builds on these insights by integrating sensor-based physical interactions within a marine-themed educational setting, thereby extending the application of embodied interaction to environmental education.

Moreover, the use of sensors and Arduino microcontrollers to create responsive and dynamic models of sea creatures and seaweed in Aqualumia exemplifies the potential of augmented technology in educational contexts. The real-time feedback and interactive elements of the project provided users with an immersive learning experience that was both informative and enjoyable. This approach aligns with the broader trends in interaction design that emphasize the importance of user engagement and interactive feedback in educational technologies.

In conclusion, the Aqualumia project demonstrates how playful, physically interactive environments can enhance educational experiences and promote environmental awareness. By addressing the cognitive challenges associated with digital learning technologies and leveraging the principles of embodied interaction, the project provides valuable insights into the design of effective educational tools.

Future work could explore the scalability of such environments and their application in diverse educational settings to further validate and expand upon these findings. The project's success suggests that integrating physicality and playfulness into educational design can lead to more engaging and effective learning experiences, contributing to a better understanding of both interaction design and marine conservation.

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