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A serious game to increase children's awareness about the vital role of sharks in marine ecosystems

Maria Costa*, Diana Boaventura[§¶], Isabel Alexandre Manchado*, Pedro Santana[†‡]
*Instituto de Telecomunicações, Instituto Universitário de Lisboa (ISCTE-IUL), Lisboa, Portugal
[†]Instituto Universitário de Lisboa (ISCTE-IUL), Lisboa, Portugal
[‡]ISTAR-Information Sciences and Technologies and Architecture Research Center, Lisboa, Portugal
[§]Centro de Investigação e Estudos, Escola Superior de Educação João de Deus, Lisboa, Portugal
[¶]MARE – Marine and Environmental Sciences Center /ARNET – Aquatic Research Network,
Faculdade de Ciências, Universidade de Lisboa, Portugal
Emails: mqgca@iscte-iul.pt, d.boaventura@escolasjoaodeus.pt, isabel.alexandre@iscte-iul.pt, pedro.santana@iscte-iul.pt

***Abstract*—The alarming decline in populations of many shark species requires an increase in education on this critical environmental issue. Overexploitation and indiscriminate fishing have pushed many shark species to the brink of extinction, threatening marine ecosystem biodiversity and trophic structure. This paper describes the development of a serious game, comprising two mini-games, designed to positively influence children's perceptions and raise awareness about the crucial roles sharks play in marine ecosystems. Additionally, the study aims to establish a link between player types and performance metrics collected during gameplay. The game was developed using a participatory design method, involving children throughout different phases of the project. It underwent four versions, with a total of 52 children participating. Out of these, 38 tested the final prototype, providing promising and interesting results both in the knowledge gain and in perception, which positively changes pos-game.**

***Index Terms*—Serious games, Environmental education, Shark conservation, Participatory design, Player types, Overfishing**

I. Introduction

Many shark species, occupying the apex predator roles in marine food webs, have a pivotal function in maintaining marine ecosystems globally. Their adaptability goes through diverse habitats, ranging from tropical seas to polar regions, highlighting their significance in regulating marine populations [1]. With a vast amount of over 500 species, sharks exhibit remarkable diversity in morphology, behavior, and ecological functions. This diversity enables them to manage prey populations effectively, preventing overpopulation and ensuring a balanced food web. Moreover, by targeting weaker individuals, sharks enhance the overall resilience and health of marine communities [2].

Despite their ecological importance, sharks are faced with multiple threats from human activities. The demand for shark fins, driven by the lucrative shark fin trade, has led to severe population declines across numerous species. Each year, millions of sharks are caught primarily for their fins, which are used in traditional Asian cuisine, particularly shark fin soup, initially produced in China. However, the popularity of this dish is spreading to other countries. This practice has decimated populations, with estimates suggesting that up to 100 million sharks are killed annually solely for their fins. This unsustainable exploitation not only disrupts marine ecosystems but also disrupts the balance that sharks maintain within them [3]. Habitat destruction further amplifies these challenges. Coastal development, pollution, and climate change degrade essential shark habitats such as coral reefs, reducing their availability and quality. Additionally, sharks face accidental capture in fishing nets that originally targeted other species, known as bycatch, which further threatens their survival. These cumulative pressures have pushed many shark species to the brink of extinction, requiring urgent conservation efforts [4] [5].

In response to these threats, innovative educational strategies are crucial to raise awareness and foster conservation actions. Serious games, which combine entertainment with educational content, represent a promising tool for engaging audiences [6], particularly children since this is when the predisposition to behavior change is stronger [7], in complex environmental issues like shark conservation.

This paper introduces a digital serious game designed to enhance children's understanding and appreciation of sharks [8]. By targeting young audiences, the game aims to instill early awareness and positive attitudes toward shark conservation by increasing children's knowledge and changing any negative misconceptions they might have on these animals. Through interactive gameplay, children are immersed in learning experiences that challenge misconceptions about sharks and teaches about their critical roles in marine ecosystems. The game unfolds across multiple stages, each one crafted to educate players about shark biology, behavior, and conservation challenges.

The initial stage of the experiment involved a baseline questionnaire to assess players' knowledge and perceptions of sharks. The following stages feature interactive activities, such as tracking virtual sharks to monitor their movements and behaviors, and engage in scenarios where players aid injured sharks by answering conservation-related questions.

These activities not only reinforce learning but also aim to nurture empathy and a deeper connection with sharks as vulnerable cartilaginous fish deserving of protection. To evaluate the game's efficacy, multiple assessments employed both quantitative and qualitative methods. Pre- and post-game surveys measured changes in players' knowledge and perceptions, providing important insights into the game's educational impact. Participants also expressed three words they associate with sharks before and after gameplay, offering qualitative perspectives on shifts in perception and attitudes.

The structure of the paper is organized to provide a thorough exploration of the game's development, mechanics, and educational objectives. Firstly, a brief introduction to the topic is made (Section I). The paper then reviews pertinent literature on serious games in environmental education and conservation efforts (Section II). Following this, it examines the game design and development, including the prototype evaluation (Section III) and testing phases (Section IV). The outcomes are discussed (Section V), and finally, the paper concludes with reflections on future directions to broaden the game's reach and enhance its effectiveness in fostering awareness and conservation of sharks (Section VI).

II. Related work

This section is specifically dedicated to exploring a spectrum of articles and projects that hold relevance to the development of the present study. The literature lacks a focus on the utilization of serious games to alter children's perceptions or enhance their knowledge about sharks. Despite this, it is worth acknowledging certain studies, that dive into the broader topic of marine conservation, educating children on sustainability and changing their perception on sharks. While not explicitly centered on serious games and sharks, these investigations contribute valuable insights into the context of environmental awareness and conservation efforts.

A. Study about changing children perception about sharks

Nicole Warren and Rachel Yoho conducted a study [9] to determine if personal connection text and questions within storybooks could change children's negative perceptions of sharks. They used a pre-test/post-test design where children were asked to draw sharks and list three words that came to mind before and after reading a book about Sand Tiger Sharks [10].

The study found that children who read the book with personal connection text used more positive words like "helpers" and "boss of the ocean" in their post-reading descriptions and drawings. These children described sharks as top predators without the same fear and hostility as before. In contrast, the group that read the book with only factual information showed less pronounced changes. From this study, despite the small sample size, valuable insights were gained into evaluating children's perceptions and emphasizing the pivotal role of creating a personal connection to influence their attitudes [11]. Designing a game that immerses children in active engagement has the potential to foster this connection, aiming to create a sense of care and empathy towards the subject matter, in this case sharks. Additionally, the use of three-word assessments provided a straightforward and accessible method to get access to children's views on sharks.

B. Study about using serious games to educate on Marine Conservation

The study [12] conducted by Rossano et al. introduces a serious game designed for primary school pupils to educate them about marine litter and four endangered species in the Mediterranean Sea. The research mentions the effectiveness of game-based learning and video games as valuable tools in both formal and informal educational settings.

The serious game aims to cultivate ecological skills and foster positive environmental attitudes among students. Initial findings from a pilot study indicated strong appreciation from both students and teachers for this innovative approach. Preliminary data also showed that students perceived the game as useful and satisfying, highlighting its potential as an engaging educational tool.

C. Study about promoting sustainability behavior using serious games

In 2020, Veronica and Calvano [13] introduced a serious game and an explainer video aiming to address the pressing issue of marine litter, which is currently a significant threat to marine species. Specifically centered on the biodiversity of the Apulian and Mediterranean seas, these educational tools aim to heighten children's awareness of the critical need for marine life conservation. The evaluation of their effectiveness revealed that children acquired substantial knowledge through these innovative educational technologies, showcasing the success of game-based learning approaches.

Research emphasizes that integrating sustainability experiences into school environments through game-based learning enhances comprehension of complex sustainability challenges. Games not only stimulate engagement and motivation but also encourage proper behavioral practices among students. Importantly, evaluations confirmed that students retained and applied their newfound knowledge, with noticeable improvements in waste disposal habits observed in classroom settings.

Furthermore, the positive reception of both the video and the serious game among students highlights their effectiveness in engaging learners and fostering interest in interdisciplinary learning. This illustrates the potential of game-based approaches to create meaningful educational experiences and instill sustainable behaviors among young audiences. Such initiatives are beneficial to reach an ambitious general end-goal of our study, which aims to empower children to actively participate in shark conservation efforts and contribute to sustaining ocean ecosystems on a broader scale.

In summary, while the direct application of serious games to alter perceptions about sharks remains an emerging area of study, the limited exploration in this field highlights the significance of our contribution. The broader literature on

environmental education through interactive technologies provides a robust foundation for this innovative approach. Moving forward, using these insights and methodologies can create a generation of environmentally conscious citizens who actively contribute to shark conservation and sustainable practices, helping to save endangered shark species crucial for ocean health and balance.

III. Ethics

The participation in this study was entirely voluntary, with informed consent obtained from both the schools and the children's tutors. The study received approval from the ISCTE Ethics Committee, confirming compliance with ethical standards. Additionally, all collected data were anonymized, ensuring that no individual child could be identified, thereby safeguarding the participants' confidentiality and privacy.

IV. Game Design and Development

A. Brainstorming Phase

The serious game was designed with active participation from a group of 20 children, comprising 12 girls and 8 boys with ages between 8 and 10, ($AVG = 9.1$, $STD = 0.64$, where AVG stands for average and STD for standard deviation of the ages). Four children were from foreign countries, with the majority being Portuguese. The participatory design approach [14] was used during this phase, taking place in their school, ensuring the game's engagement and effectiveness for the target audience [15]. The process began with a brainstorming session aimed at understanding children's perceptions of sharks and gathering their ideas for a game that could help change negative perceptions and increase some previously not obtained knowledge.

During the initial brainstorming session, which took around 1h30m, the children were asked their opinions about sharks. They were questioned about their views on sharks, estimated how many sharks they think die in an hour, and identified some of the biggest threats sharks face today. This approach was designed to surprise the children, increasing their curiosity and awareness of the importance of sharks in marine ecosystems, while addressing common misconceptions about their danger to humans. This discussion aimed to inform and inspire the children, setting the stage for their creative input. The children were then encouraged to share their ideas for a game that would educate other kids about sharks and promote a more positive image.

Numerous ideas were proposed, with some particularly interesting and viable ones emerging from the session. Notable suggestions included tracking sharks and monitoring their behavior through players placing trackers on them, arresting illegal fisheries by taking on the role of marine protectors, and removing plastic from the ocean to raise awareness about marine pollution and directly link environmental conservation with shark protection. In addition to gameplay ideas, feedback was sought on the initial game environment. The children suggested various enhancements to make the game world more immersive and engaging. They recommended adding assets such as whales, large ships, more turtles, a greater variety of fish, and diverse species to enrich the game setting. An example of the final game environment, incorporating these suggestions, is depicted in Figure 1.

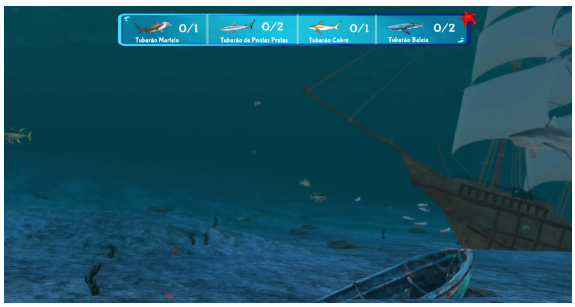


Fig. 1. Game environment

B. Game Development Phase

All the suggestions made by the children were carefully considered, and modifications were made to the initial game scene accordingly. Following this collaborative design phase, development focused on creating two mini-games that encapsulated the most promising ideas, the initial design took around two months to be completed and then it was refined, until reaching the final version, during the iterations phase. The first mini-game *Tracking Sharks* involves players placing tracking devices on different shark species as depicted in Figure 2. Players can monitor the sharks' movements and behaviors and check their health level depending on the light that the tracker emits (Red for injured, green for healthy as shown in Figure 3). This activity aims to demystify sharks and emphasize their importance in marine ecosystems.

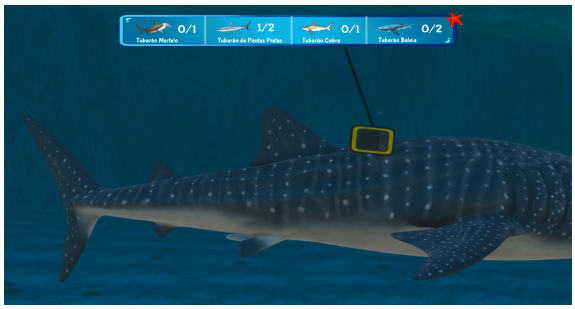


Fig. 2. Task 1: Tracking sharks

Tracking Sharks is followed by the task *Removing Trash* from sharks, in this mini-game, players help clean up the ocean by removing trash that harms sharks, to remove it the players needs to answer 3 shark-related questions correctly. This interactive task highlights the impact of pollution on marine life and increases the environmental education, it is possible to see the player answering the questions as well as the radar in the right upper corner of Figure 4.

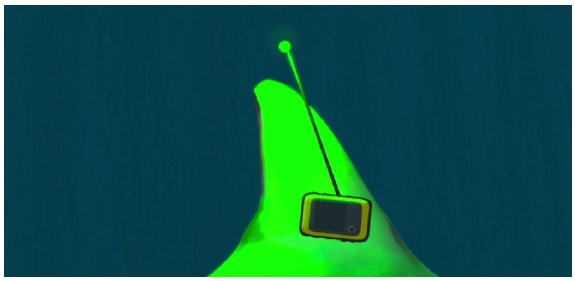


Fig. 3. Tracker showing green light meaning the shark is in a healthy state



Fig. 4. Task 2: Saving sharks by answering to questions about them

These mini-games were developed with intermediate testing and feedback sessions involving the children. This iterative process ensured that the game remained aligned with the interests and educational needs of the target audience. Along with this mini games an initial, depicted in Figure 5, and ending scene, in Figure 6, were designed to introduce a questionnaire that evaluated the knowledge and perception of children pre- and post-game.



Fig. 5. Initial scene with an embedded questionnaire - A diver explains how the initial scene will proceed and asks the player if they are ready

Overall, the participatory design approach not only made the game development process more inclusive but also enriched the game's content, making it both educational and engaging. The active involvement of children in brainstorming and testing phases ensured that the final product was well-suited to foster positive perceptions of sharks among young players.

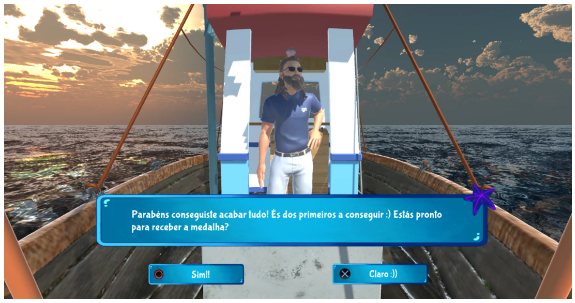


Fig. 6. End scene that has a questionnaire embedded into it - Diver congratulates the player on finishing the tasks and asks if they are ready to recieve a medal

C. Technical Details

The game was developed in Unity and is played using a DualShock 2 controller. It consists of three distinct scenes with different tasks and purposes.

The initial scene includes a shark knowledge and perception questionnaire.In this scene a diver character explains the process and asks the player if they are ready to proceed. The initial and final scenes utilize a water shader to create an ocean-like appearance, and a skybox to enhance the realism of the sky. A boat in these scenes simulates wave motion through a script that replicates up-and-down movement, adding to the immersive experience. The diver character was created using "Ready Player Me" and combined with multiple animations from "Mixamo." When dialogue text changes, a random animation from a predefined set is displayed to add dynamism and engagement, making the interactions more lifelike.

The main scene involves tracking sharks and rescuing injured ones. All models and animations were imported from Sketchfab using a Unity plugin. The shark tracker was modified to include an antenna and a health status light.

Throughout the first task, the game checks if the player is close enough to an untracked shark. If so, a canvas prompts the player to click on the circle, presented in the DualShock 2 button set, to approach the shark, activating another camera that follows the side view of the shark and displays the tracker. The tracker moves towards the shark as soon as the player presses the button, if it hits the fin, a collider detects this collision and maintains the tracker stuck to the fin. If the player fails the tracker eventually hits another collider, displays a motivational message to keep the player engaged and the tracker goes back to the original position. In case of success the camera is switched back to the diver's original view. To complete the first task, the player needs to track at least two blacktip sharks, two whale sharks, one copper shark, and one hammerhead shark.

After completing the initial shark tracking, the player retrieves a radar from the boat. This radar displays the position of each tracked shark on a canvas centered on the player's position. Sharks are randomly selected from the already tracked list, and previously hidden objects, such as hooks and fishnets, are revealed. The tracker color for the selected sharks turns red,

indicating they are injured and need assistance. This adds an element of urgency and reinforces the conservation message.

The player must then locate these injured sharks. When close enough, a canvas is displayed, prompting the player to answer questions. These questions are selected from a predefined list verified by an expert in the field, ensuring the educational content is accurate and relevant. If an answer is wrong then motivational audios are played to keep the player as motivated as possible even if the questions were incorrectly answered. Correctly answering three questions sequentially removes the nets or hooks, changing the tracker color back to green on both the physical tracker and the radar. Once the player rescues all three injured sharks, a congratulatory message appears, and the final scene begins.

The final scene features a follow-up questionnaire, after which the player receives a medal and a pamphlet, reinforcing the educational experience and providing a sense of accomplishment. The main scene is designed with boundaries made of four planes that form a box, ensuring the player remains within the play area. If the player reaches these boundaries, they are redirected to the center of the game with a warning, maintaining a seamless and focused gameplay experience. To preserve the immersive aspect, players can swim to the surface, but a transparent plane limits how high they can go. Additionally, when the player reaches the surface, the audio changes to simulate the sounds heard outside of the water. Upon returning to the depths, the game transitions to deep ocean audio, enhancing the realism and immersion of the underwater environment.

Each element of the game is meticulously crafted to provide both an enjoyable and educational experience. The realistic models, dynamic animations, and interactive tasks promote awareness and positive attitudes towards shark conservation.

D. Development Iterations Phase

The development iterations phase was initiated, where the game was tested to detect any bugs or usability problems. There were four versions of the game tested during its development and in total took one month to be completed.

The initial version, taking 2 hours to test, had several bugs including issues with game borders that prevented player rotation and difficulties with tracker placement on hammerhead sharks, resulting in tracker loss. These bugs were addressed in subsequent versions.

The second version was tested with 6 children and was tested in the course of a morning. Feedback indicated that children were becoming frustrated with the second task. To improve engagement, the third prototype introduced different audio cues and reassurances that players would have another chance to answer correctly if they failed. Motivational messages were also added to keep players encouraged. Additionally, some questions were revised to better assess children's perceptions and knowledge about sharks, which were validated by an expert in education and marine science.

The third version, tested with 4 children taking around 2 hours of testing, highlighted an issue with the question "I do not like sharks," which caused confusion due to its negative phrasing. Respondents were unsure whether agreeing or disagreeing indicated a positive perception of sharks.

In the fourth version, taking 2 hours to test, changes were made to the questions in the second task to emphasize the ecological importance of sharks. This version was also tested with 4 children and marked the final iteration before moving to the results phase. Improvements were noted in children's knowledge and perceptions about sharks.

By the end of this process, the final version of the game was refined not only to educate but also to engage young players in an entertaining manner. This comprehensive approach ensured that the game promoted positive attitudes towards shark conservation while maintaining a high level of player interest and enjoyment.

V. Evaluation

A. Experiment design

The study included 38 Portuguese children, different than the ones that participated in the prototype validation and brainstorming phase, comprising 23 boys and 15 girls, with ages ranging from 9 to 11 ($AVG = 9.4$, $STD = 0.55$), each doing this experiment in a classroom. This experiment took two visits to the school each day 8 hours, making this in total 16 hours of experiments. It began with each child completing an initial questionnaire aimed at gathering demographic information. This questionnaire included questions about the child's age and gender for statistical analysis purposes. To understand the child's initial mindset and preconceived notions about sharks, the questionnaire also included a section where children were asked to list three words that come to mind when they think of sharks. Additionally, the child's player type was determined using the questions in Table 1, which enabled the investigation of correlations between their preferred aspects of the game, retrieved parameters, and their user type according to the Hexad model—a framework categorizing users into distinct types based on their motivations and preferences in gamified systems[16].

TABLE I
Questions to assess user's Hexad player type

ID	Question
Q.1	It is important to me to follow my own path
Q.2	Being independent is important to me
Q.3	I enjoy emerging victorious out of difficult circumstances
Q.4	I enjoy group activities
Q.5	It makes me happy if I am able to help others
Q.6	I like being part of a team
Q.7	Rewards are a great way to motivate me
Q.8	I see myself as a rebel
Q.9	If the reward is sufficient, I will put in the effort
Q.10	I dislike following rules
Q.11	I like mastering difficult tasks
Q.12	The well-being of others is important to me

Following the initial questionnaire, the child participated in an in-game survey. This in-game survey, shown in Table 2, was

tailored to assess the child's existing perceptions and knowledge about sharks. This survey was validated by a specialist in the area of education and marine science. The questionnaire included questions designed to evaluate children's awareness of sharks' roles in marine ecosystems, their understanding of the threats sharks face, and any misconceptions they might hold about these animals. The responses were evaluated on a scale from -2 to 2, based on the Likert Scale ranging from totally agree to totally disagree. For example, if a child answered "totally agree" to the statement "all sharks are dangerous to humans," the response would be assigned a value of -2, indicating a negative perception. This approach differs from the usual 0 to 5 classification, emphasizing whether the perception is negative or positive, as well as if the knowledge acquired is factually wrong or right by using the negative or positive signal with this intent. Additionally, the neutral option was removed to encourage children to make a definitive choice rather than opting for a neutral response.

TABLE II
QUESTIONNAIRE TO ASSESS CHILDREN'S CURRENT PERCEPTION AND KNOWLEDGE OF SHARKS

ID	Question
SQ.1	All sharks are dangerous to humans
SQ.2	Sharks are important to maintain the ocean's health
SQ.3	If I come across a shark I will always be attacked
SQ.4	It is necessary to protect sharks
SQ.5	Humans are shark's favourite food
SQ.6	I hate sharks and I am scared of them
SQ.7	The ocean's health stays fine without sharks
SQ.8	I want to know more about sharks
SQ.9	Sharks are bad animals and we should kill them all
SQ.10	Many sharks are captured for the value of their fins

Once the initial data collection was completed, the child was introduced to the game environment. The introduction included a brief oral explanation on the basic movement and rotation commands necessary to navigate the game.

The primary task for the child was to locate and place trackers on at least six different sharks: two blacktip sharks, two whale sharks, one hammerhead shark, and one copper shark. This activity familiarizes the child with different shark species and creates a sense of care for them.

After successfully placing the trackers, the child navigates to a boat positioned on the surface of the water. As soon as the child was close enough to the boat it was possible retrieve a radar device that displayed the status of all the tracked sharks. Each tracked shark's health status is shown on the radar. This feature was shows the importance of monitoring and protecting marine life.

The next phase of the game involved a rescue mission. The child needs to find each injured shark and answer three consecutive questions correctly to free a shark that was entangled in a hook or a fishnet. The child's learning was reinforced through trial and error about a constant list of questions that appear in a random order. The questions were about the child's knowledge about sharks, their ecological importance, and possible threats to their existence.

Upon completing the game, the child was prompted to retake the initial perception and knowledge questionnaire. This post-game survey was conducted within the game environment and aimed to measure any changes in the child's perceptions and knowledge about sharks. The results from this questionnaire provided quantitative data on the educational impact of the game.

Figure 7 illustrates the workflow of the game, highlighting each distinct stage. It clearly separates the different activities performed within the game environment, providing a comprehensive overview. This detailed depiction helps to understand the sequence of actions in-game activities.

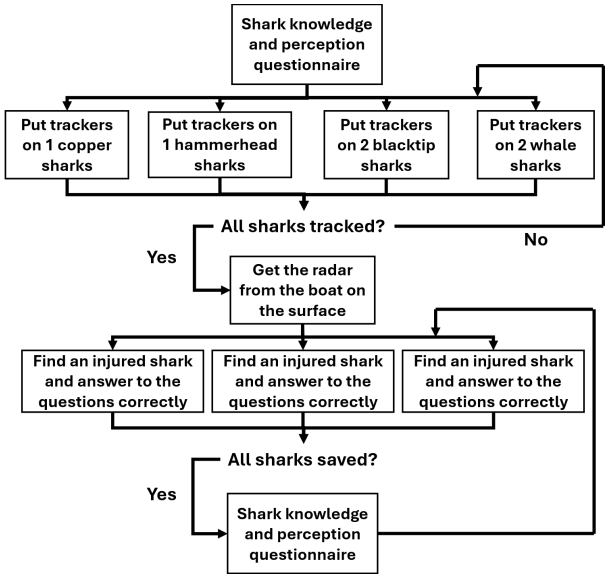


Fig. 7. Workflow of the game

In addition to the post-game survey, the child was presented with a pamphlet containing practical tips on how to contribute to shark conservation in their daily life. This pamphlet served as an educational tool to extend the learning experience beyond the game. To recognize their efforts, the child received a certificate naming them an official guardian of sharks, encouraging continued interest in shark conservation.

Finally, the child was asked to reflect on their game experience by writing three words that now come to mind when they think of sharks. This repetition aimed to capture any shifts in perception. They were also asked to draw their favorite and least favorite parts of the game. This activity provided qualitative insights into what aspects of the game were most engaging or challenging, helping to inform future game design improvements, in Figure 8 it is possible to see the workflow throughout the whole experiment, providing a visual guide to the sequential steps and activities children engage in, not only in the game but before and after as well.

B. Results

In order to evaluate the impact of the educational game on children's knowledge and perception of sharks, both question-

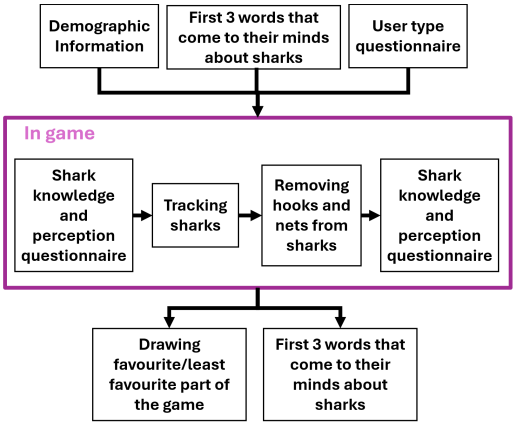


Fig. 8. Workflow of the experiment

naire responses and the three words children associated with sharks before and after playing the game were analyzed. This comprehensive approach allowed for a thorough assessment of changes in their understanding and attitudes towards sharks.

Table 3 presents the means and standard deviations calculated in the subsequent paragraphs. This is done to provide a clearer understanding of the impact of the results.

The knowledge and perception scores ranged from -10 to 10, allowing for the quantification of changes in these areas. The differences in knowledge scores before and after for each child were calculated, and then the mean difference across all children was determined. The results show a significant increase in knowledge ($AVG = 4.03$, $STD = 2.56$), a detailed statistical analysis of these results is made in the following pages.

Changes in perception were assessed by calculating the mean difference in perception scores. The analysis revealed the following results ($AVG = 1.61$, $STD = 2.47$), indicating a more positive view of sharks after the game.

The words asked of the children before and after gameplay were categorized as positive, negative, or neutral. Neutral words carried no positive or negative connotation and were simply descriptive (represented in gray in Figures 9 and 10).

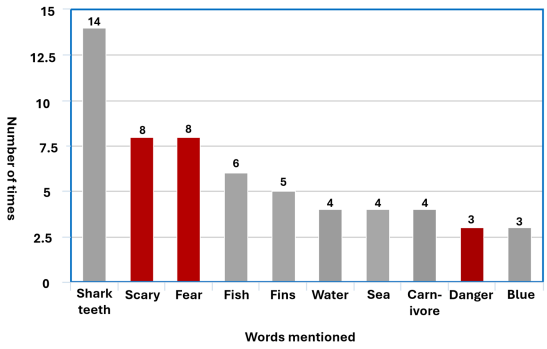


Fig. 9. Top 10 words before game

The most popular negative words were "scary" and "fear"

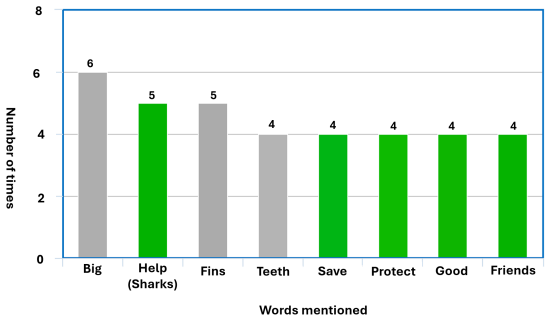


Fig. 10. Top 10 words after game

(shown in red in Figures 9 and 10), while the positive word "help", conveying the idea that sharks need assistance, was used frequently (words with positive connotations are represented in green in Figures 9 and 10). Figures 9 and 10 display the top ten words before and after gameplay, respectively.

The difference in the number of positive and negative words was then calculated before and after gameplay. The results of the difference between before and after the child played the game were ($AVG = 1.34$, $STD = 1.12$) for positive words and for negative words ($AVG = 0.87$, $STD = 0.93$).

This data shows the educational game's effectiveness in enhancing children's knowledge about sharks and fostering more positive perceptions of these important marine creatures.

TABLE III
AVG AND STD OF THE DIFFERENCES BETWEEN DIFFERENT PARAMETERS BEFORE AND AFTER PLAYING THE GAME

Parameters	Scale	AVG	STD
Knowledge questions	[-10,10]	3.92	3.03
Perception questions	[-10,10]	1.60	2.47
Positive words	[-3,3]	1.34	1.12
Negative words	[-3,3]	-0.87	0.93

These results suggest that the educational game was effective in enhancing children's knowledge about sharks and positively influencing their perceptions. Additionally, the study explored the relationship between player types and game performance and parameters, but no significant correlation was found at this stage. These data provides valuable insights to be utilized in future iterations of the game to potentially tailor game play experiences based on different player profiles.

To determine the statistical significance of these results, the Shapiro-Wilk Test was used to assess whether the perception data followed a Gaussian distribution, given its effectiveness for smaller to moderately sized samples (up to around 50). The data followed a Gaussian distribution since $p > 0.05$ ($p = 0.0519, n = 38$). This was further confirmed visually with a Q-Q plot, as shown in Figure 11.

A paired t-test was performed to compare perception scores before and after the game, and Confidence Intervals (CI) were calculated accordingly. The results showed statistically significant changes with more than 99% confidence as $p < 0.05$ ($p < 0.01$, $CI = [0.74, 2.36]$, $n = 38$).

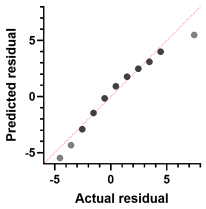


Fig. 11. Q-Q plot illustrating the distribution of perception differences: Dots represent the predicted residual and the line is the line of identity

The knowledge results did follow a Gaussian distribution as well according to the Shapiro-Wilk test since $p > 0.05$ ($p = 0.497, n = 38$), with help of the Figure 12 it is possible to see the dots follow the line meaning the data passes the normality test. A paired *t-test* was then performed and indicated the output is statistically significant with a confidence level of more than 99% ($p < 0.01$, , $CI = [2.93, 4.92]$, $n = 38$). Both statistical tests confirmed the significance of the differences.

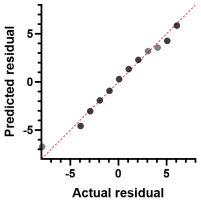


Fig. 12. Q-Q plot illustrating the distribution of knowledge differences

For practical significance, Cohen's d was calculated for both knowledge and perception differences. The knowledge data had a Cohen's $d = 1.33$, indicating a large effect size (Cohen's $d \geqslant 0.8$), while the perception data had a Cohen's $d = 0.64$, indicating a medium effect size ($0.5 \leqslant$ Cohen's $d \leqslant 0.8$) [17] [18].

These results suggest that the educational game was effective in significantly enhancing children's knowledge about sharks (with a large practical impact) and positively influencing their perceptions (medium practical impact).

VI. Conclusion

The global decline of many shark species indicates the need for new educational strategies to enhance conservation awareness and promote sustainability. This study aimed to develop and evaluate a serious game to improve children's understanding and perceptions of sharks. Featuring two mini-games, this tool was designed to demystify sharks and highlight their crucial role in marine ecosystems.

Using a participatory design approach in initial phases such as brainstorming and early game design ensured diverse perspectives. The final iteration, showed significant improvements in knowledge and perceptions about sharks. Participants demonstrated an increase in knowledge scores positive perception scores post-gameplay, with qualitative insights revealing increased positive word associations and decreased negative perceptions. While correlations between player characteristics and game performance metrics showed no statistically significant relationships yet, these initial insights provide a foundational dataset for future adaptations. This serious game stands as a valuable educational tool with beneficial implications for environmental education and conservation.

Future research should explore gender disparities in shark perceptions and gameplay moments, as well as, the link between player types and game parameters. Investigating the longevity of the findings and testing with a broader diversity of participants could further validate this experiment as an educational tool about sharks.

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