

Development and evaluation of a gamified application for environmental education: coralQuest

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Abstract. Environmental education plays a critical role in addressing current environmental challenges. However, it is challenging to effectively engage and motivate students to learn more and have a critical view about it. Therefore to enhance students learning experience in environmental education, this paper presents the development of a gamified app named coralQuest that aims to boost motivation, enjoyment and improve learning outcomes. To evaluate the interaction and user experience of coralQuest, data was collected from log data, questionnaires, and interviews, from 41 children aged 12-14 years old. The results indicate the positive effects of various game elements, like the leaderboard, while highlight that other, like the pedagogical agent, needs more attention for their appropriate inclusion. Further research is necessary on the development of gamified learning environments that effectively engage learners and cultivate positive attitudes in environmental education while catering different demands.

Keywords: gamification, environmental education, application.

1 Introduction

Given the pressing environmental challenges our world is facing, it is imperative to acquire knowledge about the environment and adopt sustainable lifestyle. Environmental education plays a vital role in raising awareness and enhancing understanding of environmental issues, serving as a stepping stone towards achieving the UN Sustainable Development Goals. It focuses on creating awareness about environmental concerns, sustainability, and the intricate interconnections between humans and their surroundings [1]. Environmental education is now considered as a fundamental component of numerous school curricula worldwide. However, there are difficulties in motivating and engaging students. Consequently, there is a necessity to introduce novel and innovative approaches to enrich student learning experiences.

Studies have demonstrated that gamification holds great promise as a tool to accomplish this [2]. By integrating game elements into educational contexts, educators can establish a more engaging learning environment that increases student motivation and improves their learning outcomes. Gamification has been shown to enhance self-efficacy, empower students to take control of their learning, and make the learning process

more enjoyable [3]. Nevertheless, gamification does come with its own set of challenges that need to be considered. While it can be an effective approach it can also serve as a distraction from the actual learning process [4,5]. Furthermore, gamification has the potential to foster a competitive classroom culture where students prioritize winning over actual learning [4]. Hence, it is crucial to thoroughly contemplate the potential negative consequences prior to implementing gamification in educational settings.

Due to a lack of research on how gamification can be used in environmental education for K-12 students, in this study, a gamified web app named coralQuest is developed and tested with students to investigate the topic further with the research question: *How did students evaluate their experience with the coralQuest app?*

2 Gamification and environmental education

Using game elements in various domains to enhance engagement has garnered increasing attention. This approach, known as gamification, involves integrating game elements such as points, badges, and leaderboards into non-game contexts [6]. Gamification has been successfully employed in diverse industries such as e-commerce, finance, healthcare, and fitness [3]. This growing trend of gamification extends to the field of education as well [3, 6]. Multiple studies have highlighted the advantages of implementing gamification in educational environments for students across various age groups. When game elements are integrated effectively, it can lead to numerous advantages, including heightened motivation, engagement, and enjoyment among students [3, 5, 7]. Research has indicated that primary school children exhibit a preference for gamified learning activities when it comes to subconscious learning [8].

Additional evidence suggests that gamification elements have the potential to enhance children's academic performance [9], enhance their motivation to learn science [10], and increase their satisfaction with homework [11]. However, it is important to note that poorly implemented game elements could have adverse effects on children's learning experiences [12]. Hence, it is vital to meticulously design gamification applications to ensure they align with the learning objectives and meet the needs of the users [12].

Regarding environmental education, it is characterized as a process where people investigate environmental issues and participate in activities that learn about them, have critical thinking and understand how they can be more aware and responsible doing actions that can be beneficial for the environment. An emerging issue in this context is the concept of climate anxiety, which denotes the emotional distress and fear individuals experience as a result of the daunting nature of climate change [13]. Embracing a compassionate and empathetic approach, educators have the ability to empower students, enabling them to become proactive change-makers. By equipping them with the essential tools and knowledge to address environmental challenges, educators can foster a sense of agency in students [14, 15].

In this study, through the integration of gamification and the use of mobile learning environments we can leverage the inherent inclination of younger students to interact with technology and educate them about the environment through an engaging learning

activity. This can direct them towards knowing more and potentially act towards tackling urgent global issues, such as climate change.

3 Development of the coralQuest

3.1 Designing the coralQuest

The development of the coralQuest web app followed an iterative approach with the development of low and high-fidelity sketches. Design decisions were made based on review of relevant literature, the GameFlow model developed by Sweetser and Wyeth [16] and the Octalysis framework created by Chou [12]. The GameFlow model, emphasizes enjoyment as the single most important goal of digital games and reports findings on elements that make games enjoyable [16]. The Octalysis framework is used for creating gamified activities and concentrates on the eight primary player motivations for effective gamification. It uses a human-centered approach, focusing on inner drives that have been demonstrated to be useful in producing an enjoyable gaming experience. The primary motivators include, among other things, social influence, unpredictability, ownership, and accomplishment [12]. During the design process, sessions with 4 researchers informed the design of the app involving also the responsible staff from the planetarium section of the *The Science Center* in Norway. The app is inspired by one of the movies shown in the planetarium named *Expedition reef* at the Science Center. This documentary highlights the coral reefs' beauty and richness as well as the scientists working to repair them [17].

3.2 coralQuest app final prototype

Below the final interfaces and functionalities of the coralQuest app are presented.

Landing page, log in and avatar view: A description of the project and the goal of the application were given on the landing page. Users can proceed by clicking the bottom-of-the-page button, which takes them to the log in and then the avatar view. There, they can choose and name their avatar (figure 1a and b).

Home view: The users get a summary of all the activities taking place in the app. After the log in, the Crab (pedagogical agent), (figure 1c) welcomes them and prompts them to check out all the tasks that are offered. The view shows the user's personalized coral reef, which may be replenished with corals by gaining experience points and sand dollars. The user's avatar, username, and progress bar are all displayed in the navbar on the left side, that offers links to various views. The user's level is displayed within a starfish on the progress bar, along with their current XP and the quantity of XP required to advance to the next level. After the user has completed the third and last level and purchased every coral that is available, the coral reef is inhabited by animated fish, seahorses, and a turtle if appropriate corals are purchased (figure 1d).

Quiz and Scuba dive view: The Quiz is the initial quest in the app and has three degrees of difficulty that players can unlock as they advance (figure 1e). Each quiz there are five questions (inspired by the movie *Expedition Reef*) with answers to choose. If the user answers correctly, it is displayed in green color, if not, the chosen answer

becomes red and the correct one is shown as green. The Crab responds to the user with feedback and additional information (figure 1f). Users receive sand dollars and XP for each accurate response, with the amount increasing in accordance with the quiz's degree of difficulty. The header at the top of the page allows users to keep track of their virtual currency, or sand dollar, balance and shows the current question's position among the five total questions. At the Scuba Dive quest, users get the chance to explore numerous coral reefs utilising the Google Earth API (figure 1g). They receive educational material and are given a free-text question where they can enter their observations at each coral reef website. Between each stop, the Crab gives the user feedback and further information.

Coral shop view and Leaderboard view: The Coral shop view, is a pop-up modal that is accessed from the Home view. It gives users the option to buy corals, which helps their coral reef by introducing corals with brilliant colours (figure 1h). Three more corals are made available to the user when they complete each level. Each coral has a different cost, and users may only buy them if they have collected enough sand dollars through successfully completing quests. The Leaderboard is the application's last screen and enables visitors to see the top five users with the most XP. It also allows users to view their own position. The scoreboard has two tabs, one of which shows the overall rankings of all app users, and the other shows rankings especially for the user's class or group. To avoid creating resentment among students who rank lower, the leaderboard will only display the top five users (figure 1i).

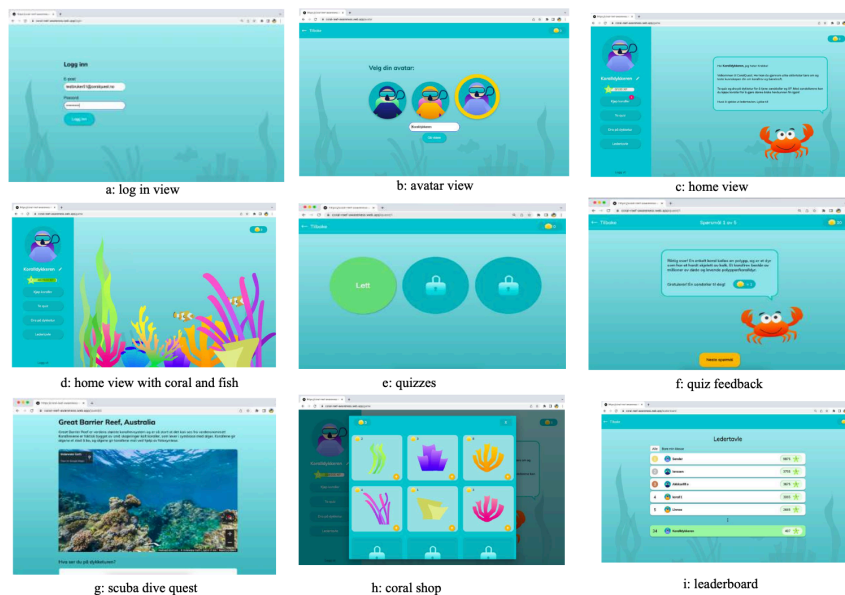


Fig. 1: coralQuest prototype views

4 Methodology

4.1 Participants, procedure and data collection

Participants in the study were 41 students from two different schools in Norway who visited the Science Center with their class in two groups. The sample consisted of 24 boys (58.5%) and 17 girls (41.5%), all were between the ages of 12 and 14 ($M=13$, $SD=.775$, $min=12$, $max=14$). Students' participation has gotten an approval from the Norwegian Agency for Shared Services in Education and Research; legal guardians were informed through a letter and have signed the consent form for their child's participation in the study. Before the students tried the coralQuest app, they watched the movie *Expedition Reef* in the Science Center's planetarium through which they were introduced to the coral reef topic. Then, they went to specially designed rooms for educational purposes at the Center. Each student sit in-front of a laptop and started interacting with the app. First, participants filled in a pre-questionnaire (embedded in the app), and then they were asked to play as long as they wanted having an average interacting time of 20 mins. If they had any questions during the process they could ask help from to the two researchers who were in the room. Finally, when a student finished interacting with the app, was directed to answer a post-questionnaire (embedded in the app). Apart from the demographics, the pre and post questionnaires included questions appropriately adapted for the purpose of the study, related to students interest [18], motivation [19] attitudes [20] enjoyment and the System Usability Scale (SUS) assessment [21, 22], using a 5-point Likert scale and a smileyometer [23]. From the usage data during the interaction, the app collects data regarding the number of the total sand dollars earned, the sand dollars spent, the XP, the corals bought, the achieved level, the unlocked quizzes and the student's responses in the free text answers in the app. At the end, 12 students were interviewed (7 boys and 5 girls); each interview lasted for approximately 12 mins and the questions were related to how they experienced the interaction with the app, its functionalities, the gamification elements, their perceptions and learning about the environment and if/how the use of the app affected them.

4.2 Data analysis

The focus and analysis of the data in this paper, is on the qualitative data collected through interviews, showing what they found interesting interacting with the app, and what they think about it together with what they learned. After transcribing the interviews, a thematic analysis was conducted based on Braun and Clarke [24]. First the an open source web-based tool was used to assign codes, that were then grouped in themes. Iteratively, the analysis was carried out, with codes and themes revisited and modified until a comprehensive list was produced. Prior to comparison, the first iteration was carried out independently by the two researchers. A high Cohen's kappa score for this initial iteration indicated great inter-rater reliability.

5 Results

First, the descriptive statistics on the most relevant to the context of this paper quantitative data include the “Motivation for Environmental Education” (mean = 2.89, SD = 0.952) “Interest in Environmental Education” (mean = 3.22, SD = 0.866) “Importance of Environmental Education” (mean = 4.10, SD = 0.800), SUS scale score (mean = 66.40, SD = 14.546). The mean experience points (XP) obtained were 1573.41. However, the substantial standard deviation of 1597.285 indicates a significant variation in the actual amount of XP earned among the users. This pattern extends to the sand dollars, with some students earning as little as 18 and others as many as 950, resulting in an average of approximately 35 sand dollars. Except for two participants, all others managed to reach the highest level in the application, which is level 3.

From the interviews, *environmental education* and *learning through the use of the app* are themes that emerged from the qualitative analysis. Most of the students expressed that environmental education is important and interesting for them. One of the students said *"It is important because you can become smart and know a lot about the climate and things like that"*. However some of the students experienced that learning about the environment can be a bit boring. For example, *"I think it is a bit exciting, but for me, but it may not be the most enjoyable thing I know"*.

When it comes to the *interaction with coralQuest and learning through the app*, most of the students said that it was a good learning experience. Specifically they mention that they learned new things such as *"I have learned about what happens when the coral loses its color"* and *"it was a very good app, an educational app. Kind of fun to be challenged with questions"*. Several students expressed that they would like to play the game again, while some wanted to play it at school and at their spare time but for other it was not something that they would like to be in their free time *"I could play the game again at school or somewhere similar, but maybe not during my spare time"* or *"I think I would like to play the game when I have time off from school, maybe at home"*.

Regarding the gamification elements and design decisions students overall liked the app and suggested further improvements. One student said *"The colors and animations create a vivid image which makes me want to continue playing the game"*. The scuba diving quest and the competition feature (leaderboard) appeared to be the ones the students enjoyed most *"I thought the quiz was fun. But the most fun was the diving and stuff because you could still move forward even if you answered correctly or not"* or *"It gave a bit of a competitive spirit, and it was cool to be able to see what others were doing"*. Also, the leaderboard gave some motivation to the students to answer more quizzes and engage in the app due to the competition with their peers and them wanting to score better than others or simply share their success with them and see it like a fun thing to do. Regarding the students' motivation to answer the quiz correctly, many mentioned that they wanted more corals and also that they liked the different difficulty levels. One student said *"Yes, I wanted more of those corals"* *"I liked the intermediate one the best"*

The students' expressions about the crab (pedagogical agent) in the app were diverse. Some students found it entertaining while others found it annoying. *"I just skipped it, I was just trying to collect points"* or *"It was cool. I read what it said because I was not*

quite sure what to do in the beginning, and it helped me figure out what was possible in the application"

When it comes to ideas for further improving the app the students mentioned that they liked it and they wanted more educational context in the form of quizzes and quests or other content that can engage them for longer time. Moreover other suggested clearer instruction for the use of the app and the game elements. One student said *"Maybe adding something more to learn" or "I would use it more, if there were more quizzes and questions and stuff" or "...when you have gone through all of it, maybe it gets a bit boring when you do the same a few more times". In addition, some students wanted the option to personalize their avatars and purchase extra items. "You should include an upgrade feature where you can upgrade the corals by building them bigger. I have a lot of money but cannot do anything or buy anything".*

6 Discussion

This paper presents the coralQuest, an app that aims to engage and motivate students in playful learning for environmental education with content specifically about life in the ocean and coral reefs. Teaching children about the environment can motivate them and lead to actions that will have an effect and support a sustainable future. Therefore, finding ways to engage them through mobile learning apps that have the appropriate content with attention to the users' needs is at most importance.

Based on the results from the thematic analysis of the interviews, we can conclude that in general the students liked their interaction with the app, they learned a lot and want to use the app in the future. On the other hand the overall SUS scores indicated a moderate level of usability, indicating the potential for improvement. The valuable feedback received from participants highlighted specific issues that should be addressed to enhance the usability of coralQuest and elevate the overall user experience.

More specifically, for the different gamification elements offered in the app in relation to their learning experience, many students mentioned the leaderboard as their favorite element. The students expressed enjoyment in observing the highest-ranking players on the leaderboard, which motivated them to strive to surpass their competitors. This is consistent with previous research that has demonstrated the effectiveness of leaderboards in enhancing student motivation, enjoyment, and engagement [4, 25, 26, 27]. Most of the students showed a preference to track the leaderboard that was specific to their own class rather than the one with all the all users of coralQuest. The alignment with the Self-Determination Theory (SDT) and the notion of relatedness is reflected in this preference, as the class-specific leaderboard promotes a feeling of team spirit and connection among students while engaging in gameplay [28]. The Octalysis framework recognizes the significance of social dynamics, affirming that social influence and a feeling of connectedness can elevate an individual's performance beyond what they would attain without social interaction [12]. Therefore, this suggests that the existence of social influence in an educational app can act as a motivating element, prompting the student to persevere with the application, thereby potentially resulting in enhanced learning outcomes.

An interesting finding from the interviews with the students, is the different opinions of the students regarding the pedagogical agent. From some students, it was characterized as both entertaining and beneficial in terms of comprehending how to navigate the application. This corresponds with similar findings from studies conducted by Ying et al. [29] and Priyadarshini et al. [30], indicating that the presence of a pedagogical agent can be advantageous for specific students, as it enhances their learning experience by offering feedback, increasing enjoyment, and facilitating the learning process. Nevertheless, other students indicated that they occasionally overlooked the information presented by the pedagogical agent in coralQuest. This, implies that the pedagogical agent may have delivered an excessive amount of information or appeared too frequently within the app and that its presence has caused disruptions in the flow. Therefore, it is crucial to minimize these disruptions and maintain a flow that is beneficial [12, 16] and ensure a seamless interaction with the pedagogical agents into game environments, avoiding any disruptions to the flow. Further research in this aspect can investigate the levels of interactions appropriate to each app and context.

Autonomy and freedom of choice are fundamental aspects of the Self-Determination Theory (SDT) [28]. In the context of gamification, these principles are incorporated into coralQuest by providing players with a range of activities and coral options to select from. By offering students the opportunity to make choices and granting them a sense of freedom within the app, their motivation can be enhanced. The students liked the scuba diving quest and the quizzes. Allowing students to choose the activities they enjoyed the most and spend less time on those they did not find as appealing, the application facilitated their ability to exercise freedom of choice and engage in preferred activities. Furthermore, the scuba diving quest in coralQuest fostered exploration and facilitated subconscious learning, which, as suggested by Mee et al. [8], is a gamified learning activity that is frequently favored by primary education students. Given this discovery, it would be intriguing to explore additional methods of integrating subconscious learning into gamified applications.

Nearly all the students expressed that it is very likely to continue using the app at home or at school if there were additional activities offered. Since the coralQuest application was created as a prototype, it only included few quests, which were found to be sufficient for this testing, but in a future version of the application, the existing quests could be expanded by incorporating more tasks, and new types of environmental education topics can be introduced. Furthermore, based on the free text answers in the app students acquired knowledge about coral reefs, environmental issues and reef conservation. Knowledge among students holds great value as it has the potential to foster positive attitudes toward the ocean and the environment [31]. Further research can focus on the possible long-term effect of such gamified apps on attitudes and behavior towards the environment and different contexts like science learning [32].

This study has some limitations. First, the fact that the study was in relation to the students watching a movie before trying the app may have influenced their experience. Also, more data analysis is needed to give a more general view of the students' experience with the app.

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