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Redesigning Digital Habits in Early Adolescents through Gamification

Vibhasha R[1], Jeni Cyndrella Yazhini R[2], Lakshika Mangai S[3], Sherlyn Samuel[4], Dr. D. Nithya[5]
[1,2,3,4] UG Scholar, Computer Science and Engineering, Avinashilingam Institute for Home Science & Higher Education for Women, Coimbatore, Tamil Nadu, India
[5] Associate Professor, Computer Science and Engineering, Avinashilingam Institute for Home Science & Higher Education for Women, Coimbatore, Tamil Nadu, India
Emails: *vibhasharg@gmail.com[1] , jenicyndrella04@gmail.com[2] , lakshikamangai09@gmail.com[3] , sherlyn.samuel@gmail.com[4] , nithya_cse@avinuty.ac.in[5]*

Abstract

The recent technological era has completely transformed the digital habits of young adolescents by shortening their attention span with rapid-scroll content. There has been an active proliferation of educational applications aimed at a younger demographic of students. However, there is a hesitation in tackling subjects that are deemed difficult to supplement outside of a sterile classroom, like mathematics. Regionally-confined practices like Indian Sign Language (ISL) are difficult to access, and discussed with a lack of ease. In response to this need, Menta-Ray focuses on addressing the lack of engagement from students with level-based gamified learning, thus providing a platform for young adolescents to engage with these subjects. Gamification is a modern concept that embodies the integration of traditional learning methods of repetitive recall and memorization combined with digital elements of entertainment and bright visual imagery. Additionally, it fosters growth-oriented learning by providing a safe space for failure. Furthermore, learning ISL at a young age helps bridge the disconnect between visual & non visual communicators, as well as reduce their exclusion in social settings. The final objective of Menta-Ray is to help mitigate the negative effects of rapid-scroll content by fostering a meaningful learning environment that an early adolescent needs.

Keywords: *Gamification, Indian Sign Language, Mathematics, Young Adolescents, Menta-Ray*

1. Introduction

Digital technologies have changed the direction of contemporary education significantly in the past decades, making interactive platforms a cornerstone tool for teaching practical and hands-on learning. There have been many advancements in technology that have greatly aided educators in their didactic duty. Many fields utilize a simulated 3D world to familiarize students with real world situations, primarily in the medical and automobile industries. Despite these steps forward, most current tools are not necessarily tailored for younger minds who struggle to hold their attention. Young students need an environment that is designed to engage and stimulate their cognitive understanding, and gamification is one such process that has seen success in this regard. Menta-Ray is an interactive, quiz-based learning environment for middle school students that aims to address this challenge. It is designed as an integrated platform that combines pedagogy with gamification.. At its core, curricular concepts in mathematics are decomposed into granular concepts, each associated with a bank of questions. The quiz engine presents questions in short quizzing sessions of varying difficulty levels. The system also includes a basic ISL learning component, centred on basic alphabet and fingerspelling. This module is not designed as a full sign language course, but as an introductory layer that familiarises hearing learners with fundamental ISL signs. Menta-Ray adopts an age-appropriate gamification strategy. The user interface incorporates a mascot character and a game-like underwater world, where subjects, levels, and learner progress are embedded into a visually coherent experience. The platform is designed for children below the age of twelve, with emphasis on middle-school curriculum, and focuses on two key domains: mathematics and introductory Indian Sign Language. In this sense, Menta-Ray is not simply a quiz application, but a broader attempt to model how gamified, inclusive, and offline-capable educational technology can be designed for young learners. This document outlines the design, implementation, and testing of Menta-Ray, detailing the hardware and software components involved. Our goal is to contribute to transform idle screen time into an actively engaging learning experience, and to provoke conversation about how gamification can be used to inspire conversation about assistive technology for children. [1-5]

1.1.Significance of Gamification

Gamification refers to the borrowing of game design elements such as points, badges, levels, progress bars, and leader-boards in environments that are not inherently intended for gaming. In the avenue of education, this is reflected by utilizing game mechanics to incur motivation, to encourage participation, and to build persistence in the learner's mind-set. Gamified learning offers a response to the current techno-social zeitgeist that has resulted in declining attention spans and gratification-seeking behavior. When designed well, gamified learning can ease the user into engaging and complex concepts, as well as establish them in their knowledge bank. To achieve this, it depicts various aspects of education in a fun and visually exciting way. Progress reports and feedback are given in a gamified score board, making it easier for educators and users to target and improve upon their weaker topics. The user gets to choose their own pace of learning and repeat modules whenever they feel the need to solidify or test their progress. Gamification in education is built upon several aspects that work together to present a more jovial learning experience.

Reward: Rewards lay at the root of gamification, serving as an in-game motivator for replayability and improvement. Rewards are usually represented in the form of points, coins, levels, cosmetics or other signs of achievement. These elements provide the user with an immediate acknowledgment of their efforts.

Progression: The applications can be organized into levels, areas, or checkpoints. They can separate difficulty, topics, and story. This allows the student to break down large subjects into manageable, modular concepts that are largely standalone and revisitable.

Challenge: Gamified systems often include tasks of increasing difficulty to create a sense of challenge. Challenge is what compels a user to replay a level or module, as it can prompt students to improve their performance. Leaderboards are often used to enkindle friendly competition between users. When implemented right, it can encourage growth and sociability. [6-10]

Feedback: Immediately feedback for topics can help the user to quickly solidify the correct version of any concept. Moreover, auditory and somatic feedback such as verifying tones, vibrations, visuals, progress bars, and alerts can greatly ameliorate the user experience.

Storytelling: While it is not an essential component, gamification uses storytelling and conceptual fidelity to make the learning environment feel robust and meaningful. This can be achieved through forging an emotional connection with characters, mascots, narratives and quests.

Autonomy: Learners are free to choose their own path through the features of the application, providing them with a sense of control. This is especially effective with children, who can pick their own pace and become personally invested in their progress.

2. Methods

2.1.System Architecture

Menta-Ray is composed of several modular layers that function interdependently. A user device layer, a game processing layer, a backend layer, LLM-supported API services, and a database layer are the primary distinctions in the architecture. The user device serves as the point of interaction, handling touch input and audio-visual output. The Flame engine acts as the processing unit, managing game logic and map rendering while coordinating functions in the background. The backend is responsible for authentication, authorization, and application logic. It manages secure communication, validates requests, and also involves integrating Gemini API to support LLM-based question generation. Persistent user data and progression data are stored in a MySQL database, which also manages login credentials, player state and player progress.

2.2.Hardware and software requirements

The software requirements of Menta-Ray include Java, Dart, and Python for backend development, frontend design, and LLM-supported functions, along with frameworks and tools such as Flame for

2D game development, Visual Studio Code and IntelliJ IDEA for coding, and Aseprite for creating visual assets. The hardware requirements include an Intel Core i5 processor, 8 GB RAM, any integrated graphics card, at least 10 GB of free storage, and Windows 10 or 11 as the operating system. Together, these requirements provide the necessary environment for developing, testing, and running the application smoothly Figure 1.

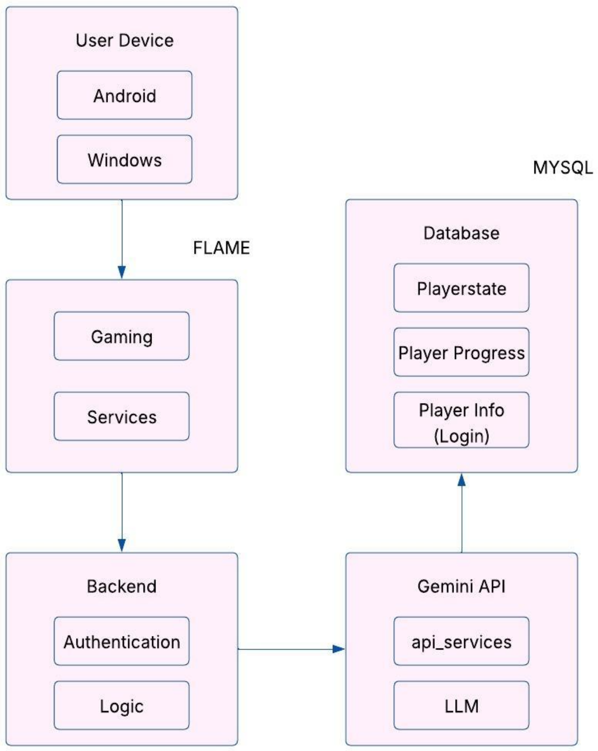

Figure 1 Software Architecture of Menta-Ray

Table 1 Hardware and Software Requirements of Menta-Ray

Software Or Function	Language	Environment
Backend Logic	Java	VS Code, IntelliJ Idea
Flutter	Dart, Python	Flame Engine
LLM Integration	JSON Format	Gemini API
UI Development	JPEG	Aesprite, Blender

2.3.Module 1: User Interface

The user interface of Menta-Ray is designed to be visually stimulating for children while still adhering to it's didactic principles. The interface does not follow the style of a conventional quiz app; it adopts a game-like underwater world where navigation, subject selection, and learning progress are presented as part of an interactive experience. This design choice helps reduce the rigidity often associated with educational platforms and allows children to approach learning with a sense of curiosity and exploration. A major feature of the Menta-Ray user interface is its underwater visual theme, which provides the platform with a distinct identity. The use of ocean-inspired colors and pixel-art styling creates a calm yet adventurous atmosphere that is appealing to children. Menta-Ray includes an appealing mascot and player character that helps bridge the gap between education and play. The progression map functions like a navigable underwater zone, where students move through different locations or levels as they advance in learning. The pixel-art style also contributes to the playful tone of the system while keeping visual assets lightweight and suitable for most hardware. The login screen and sign-up interface are designed as simple elements that ensure that children can move naturally through the application without being overwhelmed by unnecessary complexity. Table 1. The Level Map UI is one of the most distinctive components of the user interface. It serves as the central lobby of the game, allowing the learner to select subjects, enter modules, and choose difficulty levels through a visually connected environment rather than a disconnected set of screens.. Overall, the user interface of Menta-Ray is a core strength of the platform because it brings together visual storytelling, gamified interaction, accessibility, and educational structure in harmony. [11-15]

2.4.Module 2: Backend and Integration

The backend integration module forms the operational backbone of Menta-Ray by connecting the Flutter-based frontend with the server-side infrastructure. It's functions include authentication, data handling, and persistent progress management., The module establishes communication between the application interface and the backend services developed using RESTful APIs, which serves as the

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link through which the frontend requests and accepts responses related to user login, registration, gameplay progress, and other application states. Figure 2. [16]

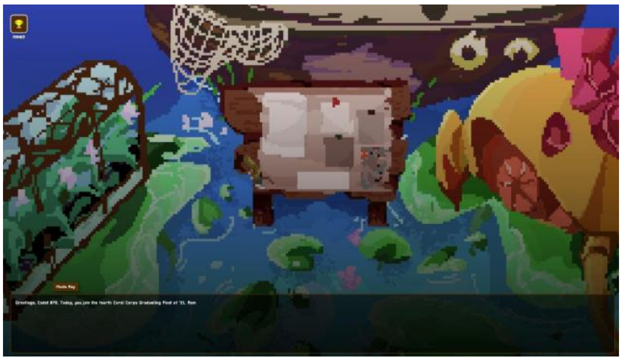

Figure 2 User Tutorial

A central technical concern in this module is the integration of two different development environments: Flutter on the client side and Spring Boot on the server side. To make this communication reliable during development, we Cross-Origin Resource Sharing (CORS) was configured. This setup allowed the application to securely exchange data over localhost while preserving request validation and structured response handling. Another major function of this module is user authentication and role-based access control. The backend uses Spring Boot along with JWT-based authentication to support secure login and control access. User credentials are verified on the backend and secure tokens are used to manage authenticated sessions. The backend integration module also handles progress tracking and persistent user data management in the form of endpoints, allowing data such as completed levels, scores, achievements, and gameplay state to be maintained over time. Finally, the backend integration module strengthens the scalability and maintainability of the platform. Because frontend actions are separated from server-side logic, the system can more easily support future additions such as more subjects, analytics dashboards, personalized recommendations, and expanded teacher or parent views. In this way, the module supports both continuity of user experience and the broader educational goal of tracking learning development. Figure 3. [17]

Figure 3 Leaderboard

2.5.Module 3: Math Module

The MathDirective serves as an interactive game lobby where players are greeted by the character Menta Ray through an immersive, typewriter-style dialogue system. The game naturally guides you from a story-driven introduction to a personalized name entry, eventually opening up a multi-layered quest board for you to explore. To keep things polished, the layout automatically adjusts to fit any screen size and carefully controls the flow of information, ensuring you finish reading the story before moving on to the next adventure. The user interface was designed based on an underwater restaurant, with the player character's 'quest' involving them to help the restaurant with their mathematical skills. The UI was designed to support a horizontal quizzing format, featuring the question, the user's life system and the choice-based answers. A tutorial UI is integrated to guide new users navigate the level. Figure 4.

Figure 4. Math Level

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2.6.Module 4: ISL Module

The user interface for the ISL level was designed based on a medical camp, where the player character is meant to communicate with patients underwater. The application entry point is defined in the main function, which initializes the Flutter engine and restricts the interface to a landscape orientation to ensure a consistent user experience. This horizontal game screen focuses on matching ISL gesture images with their corresponding letter bubbles. The interface features a top status bar that tracks your score, remaining time, and health shown through a classic heart-based system. To keep the focus on the visuals, the screen is split into two sections: the top displays the target images, while the bottom offers a row of letters for you to choose from. As you play, the game provides clear feedback, highlighting your selections and making matched pairs transparent to show your progress. Everything is built to be responsive, ensuring the pixel-art style and interactive elements stay perfectly aligned on any device. When the round ends or time runs out, a simple alert pops up to summarize your results. Figure 5.

Figure 5 Math Level

3. Results and Discussion

3.1.Results

The outcomes explain why the Menta-Ray system was built and to report on it's workings. It is designed to turn uninspired screen time into active learning sessions. Tests were run to gather input about user experience and the impact of the application to their pre-existing knowledge. The large language model was able to contribute dynamic questions of varying complexity. The application was also tested with a small sample group of varying characteristics such as age, gender and educational background. The User Experience was easily navigable and intuitive to the users. In addition, the system was developed in combination of integrated components including a Flutter-based frontend, the Flame game engine that deals with the immediacy of interactions, a backend system for authentication and control logic, a MySQL database for data storage and LLM integrations through API support for the adaptive content generation. Their combined operation was observed to work reliably during system implementation. They were able to provide consistent and optimized features. Integration of these technologies further aids in meeting the consolidated goal of the system's provision of the digital learning environment in an engaging manner.

3.2.Discussion

The results of Menta-Ray present a focus on how the integration of gamification and adaptive learning leads to enhanced educational outcomes. This proves that reward-based mechanisms combined with an interactive interface are effective in retaining the attention of the users. The adaptive flexibility of the questions indicate that personalization is vital in maintaining a level of challenge without risking disengagement or cognitive overload. The inclusion of offline accessibility and progress tracking further adds to the system's practicality in difficult learning environments. They conclude that the amalgamation of intelligent quiz generation through LLMs could be harnessed to improve digital learning tools. The system also serves as a baseline for opening conversations around the gamification of assistive technology.

Conclusion

The study tackles the sharp rise in passive screen use by children. It presents Menta Ray, a learning platform that turns every minute on the screen into an active lesson. Game rules, adaptive quizzes guided by a large language model and an interface that responds to touch all work together. Children stay motivated, keep attention longer plus remember more of the material. Lessons load and run without an internet connection but also every step of progress is saved in order. Those two features allow the same platform to operate in cities and in villages with poor connectivity. A separate module teaches through

Indian Sign Language - deaf as well as hard-of-hearing pupils receive the same content. The design reaches its stated goals - children receive education instead of passive entertainment and the same software scales to many schools or homes.

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