BEAT ODYSSEY: A RHYTHM GAME FOR EDUCATION AND ENGAGEMENT

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ABSTRACT

The rapid expansion of the Internet of Things (IoT) has created a need for educational tools that extend beyond simple data collection to encompass real-time, interactive user experiences. A significant gap exists in foundational IoT education, which often overlooks the design of engaging, self-contained interactive devices. This study addresses this gap through the design, development, and evaluation of an Arduino-based rhythm game. The primary objective was to create a functional prototype using core IoT components including an Arduino Uno R3, an LCD display, push-buttons, and a buzzer to serve as a practical model for teaching embedded systems and enhancing cognitive skills through gamification.Using a descriptive research design, the prototype was tested through researcher-led play sessions. Results demonstrated that the system performed reliably, successfully meeting its functional objectives by providing clear auditory feedback and visually stable transitions. The findings confirm that the game effectively delivers real-time user interaction, reinforcing principles of input-output processing, system feedback, and gamification. Furthermore, engagement with the rhythm game supports the development of cognitive skills such as timing, reflexes, and hand-eye coordination. This project serves as an effective case study, demonstrating that gamified IoT applications can be valuable educational tools for teaching fundamental principles of human-computer interaction while fostering cognitive skills such as timing, reflexes, and coordination.

Keywords: *Rhythm Game, Internet of Things (IoT), Arduino, Real-time Interaction, Gamification, Cognitive Skill Development*

INTRODUCTION

The Internet of Things (IoT) has rapidly expanded beyond simple data collection, evolving into a rich ecosystem of interconnected devices that enable real-time, interactive human experiences. The global IoT market's substantial growth underscores a technological shift towards embedding intelligence and connectivity into everyday objects, from smart home assistants to wearable fitness trackers (Mordor Intelligence, 2025). While commonly applied with industries such as healthcare, business, and automation, IoT extends to entertainment, where interactivity and engagement play a crucial role. At the same time, video games, particularly rhythm-based games, are powerful tools in this space, serving as platforms that entertain while sharpening reflexes, focus, and coordination. By combining IoT technologies with the immersive qualities of rhythm games, this project aims to create an educational device that merges fun with practical learning in embedded systems and cognitive skill development.

The history of interactive electronic entertainment provides a valuable parallel for this educational endeavor. According to a systematic review by Xiao, Wu, and Hamari (2021), integrating principles of gamification categorized as system factors such as Intrinsic Incentives which include goals, challenges, and achievements and Interactability which includes feedback and contextual awareness is an emerging and promising approach linked to increased user engagement in technological systems, including IoT-enabled systems. This concept is exemplified by games like Dance Dance Revolution (1998), which perfected a core loop of sensory input (visual and auditory cues), precise user action, and immediate system feedback. This same interactive loop forms the basis of many modern IoT applications, where a device must sense a user's command, process it, and actuate a response. The Arduino platform, launched in 2005, has become a cornerstone for learning these principles, allowing students and developers to build and test such interactive systems efficiently.

However, a noticeable gap exists in foundational IoT education. Many introductory projects focus heavily on sensor-based data transmission to the cloud (e.g., weather stations, soil moisture monitors) but often overlook the design of engaging, real-time user interfaces at the device level. While data collection is a key function of IoT, the ability to create a responsive, self-contained interactive experience is equally critical. Projects that fail to integrate core mechanics like dynamic difficulty, scoring, and synchronized audiovisual feedback miss an opportunity to teach the complete cycle of interaction design essential for the field.

This study proposes Rhythm Game, an interactive device built with core IoT components on the Arduino Uno R3. Integrating an LCD display, push-buttons, and a buzzer to create a cohesive and challenging game. This project serves as a practical case study in designing for real-time user interaction, exploring principles of feedback, system state management, and escalating complexity. It provides a learning model for the fundamental skills required to build the intuitive, responsive devices that comprise the Internet of Things.

Objectives of the Study

The study aims to design and develop a rhythm-based game using Arduino and other IoT components that enhances user engagement through interactive hardware and real-time feedback.

Specific Objectives:

1. To design a functional rhythm game that utilizes an LCD display, push buttons, buzzer, and microcontroller to simulate timing-based gameplay.
2. To develop the core game mechanics by programming the Arduino to generate falling block sequences and accurately process real-time player inputs.
3. To implement key gamification features, including a dynamic scoring system, progressively increasing difficulty levels, and synchronized audio-visual feedback for correct and incorrect actions.
4. To evaluate the final prototype's functionality and its effectiveness in demonstrating how IoT can be used to create interactive applications for skill-based learning and human-computer interaction.

Statement of the Problem

The major problem of the study is to design and develop an Arduino-based rhythm game that demonstrates the integration of IoT components in creating an interactive, real-time, and educational entertainment system. Specifically, it seeks to answer the following:

1. What are the technical requirements for developing the rhythm game in terms of:
   1.1 Hardware (Arduino Uno R3, LCD display, push-buttons, buzzer)
   1.2 Software (Arduino IDE programming and game logic)
   1.3 Game Design (scoring system, difficulty levels, audio-visual feedback)
2. How can the Arduino-based rhythm game simulate real-time interaction between player inputs and system feedback?
3. What gamification features can be implemented to increase user engagement and skill development?
4. What challenges may be encountered in developing the prototype in terms of responsiveness, accuracy, and usability?
5. How effective is the developed rhythm game in demonstrating IoT applications for interactive learning and cognitive skill enhancement?

METHODOLOGY

Research Design

This study used as descriptive research design because it focuses on presenting how Arduino-based Rhythm Game functions as an interactive entertainment system via Tinkercad. The descriptive approach is appropriate since the study highlights the actual features of the prototype such as the scoring system, increasing levels of difficulty, and real time interaction between the player and the device. In addition, the descriptive design provides a way to emphasize the unique characteristics of the Rhythm Game and show how it stands out compared to other simple Arduino projects by integrating entertainment value with technical application.

The design makes it possible to observe how players interact with the game and to describe the effectiveness of its components including the LCD display, push buttons, and buzzer. The study is concerned with documenting what happens when the game is played, such as how the falling blocks displays, how the buttons respond to inputs, and how the player makes correct or incorrect actions based on the set instructions. The study also notes what happens during error, such as when the buzzer emits an error tone and the game ends, leaving the final score displayed on the LCD.

Through this research design, the study was able to assess the accuracy, responsiveness, and playability of the Rhythm Game prototype. It also supported the following objectives of showing how IoT components can be applied in developing an engaging entertainment device to the players that helps them to improve their reflexes, focus and determination. Furthermore, the design enabled the researchers to evaluate how the players reacted to the progressive difficulty of the game, how well the system handled repeated inputs, and how the gameplay process overall contributed to both entertainment value and their engagement with the game.

Instrumentation

The project will be initially designed and developed using Tinkercad, a web-based application for creating electronic circuit designs and simulating their functionality through code. By utilizing Tinkercad, the group can effectively simulate and verify the intended operation of the system before physical assembly. The Arduino components required for the system are enumerated below, with their specific functions detailed in Table 1. Furthermore, Figure 1 provides a visual representation of the circuit diagram, showing the practical application and connection of these components as designed in Tinkercad.

Component	Purpose / Function	Quantity
Arduino Uno R3	A microcontroller board that acts as the brain of the system. It serves as the main controller to run the game and handle inputs, outputs, and timing functions needed for the rhythm mechanics.	1
20x4 LCD screen	A flat-panel screen that will serve as the main visual interface, displaying falling blocks, score, and player instructions.	1
Tactile Push Buttons	An input device that will act as the player's primary controls. It will allow the user to start or restart the game, pressed in time with the rhythm during gameplay to score points.	2
23mm Piezo Buzzer	An audio output device that will generate the game's music, and provides audio feedback with tones for correct inputs and error sounds for mistakes.	1
Potentiometer	A rotational device connected to the LCD's contrast pin, allowing the user to adjust the screen's text for optimal visibility under different lighting conditions.	1
220Ω Resistors	An electric component that will serve as regulators to limit current to protect components from damage	1
Breadboard	A tool that organizes the circuit and maintains a stable, solder-free setup for prototyping.	1

Table 1. Arduino Components and Their Purpose and Function in the Rhythm Game.

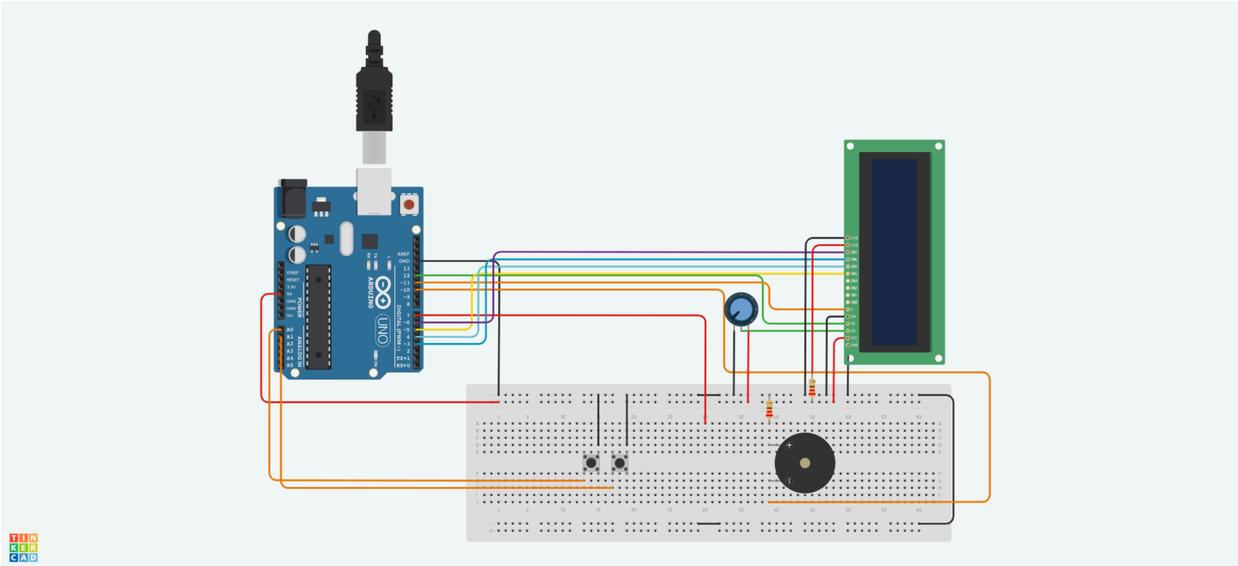

Figure 1. Application of Rhythm Game Arduino Components in Tinkercad.

Game Algorithm

The game operates on a precise timing schedule. When a song is selected, the game doesn't rely on random chance, it calculates a fixed timeline for the entire song. It determines the exact millisecond each note should appear on the far right of the screen (spawnMs) and the exact moment it should align with the target "P" marker on the left (startMs).

During gameplay, the main loop constantly checks the current time against this pre-calculated schedule. When the time matches a note's spawn time, a "note block" is created as a digital object. This object holds all the important information for that note: which row it's on, its position, and whether it has been hit by the player.

The game then updates the screen in frames. In each frame, it calculates how far every active note block should have traveled based on the time elapsed since it was spawned and the current difficulty setting, which acts as a speed multiplier. A note's visual position is simply a function of (time_elapsed / total_travel_time). This ensures smooth movement regardless of the simulation's speed.

When a note reaches the target column (column 0), the game opens a brief "hit window" of 180 milliseconds. It constantly scans for a button press on the correct row during this window. If a correct press is detected, the note is marked as "hit," a rewarding sound is played, and the player's score increases. If the window closes without a press, the note is marked as a "miss," a buzzer sound plays, and an "X" briefly appears on the screen. Once a note is either hit or missed, it is removed from the active list to keep the game running efficiently. This entire cycle of spawning, updating, and resolving notes continues until the timeline for the last note has passed.

Game Flow

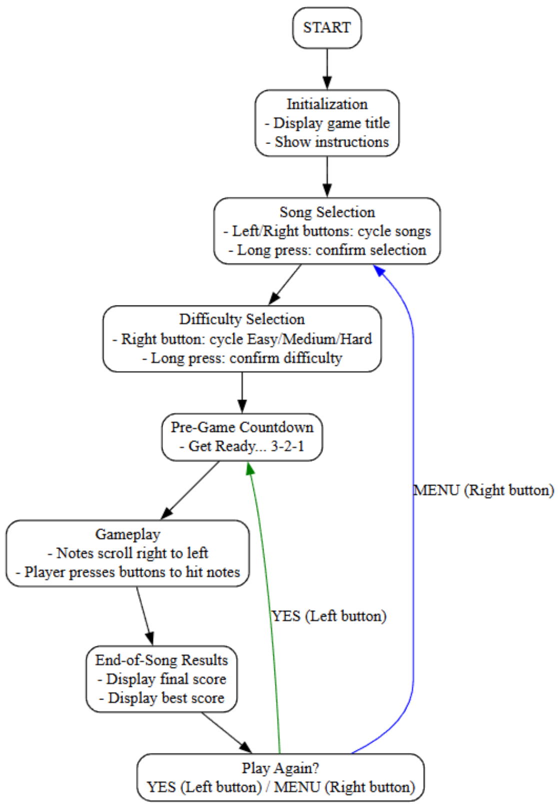

Figure 2. Transition of Different States of the Rhythm Game through Diagram

The player's journey through the game follows a clear, structured path from startup to gameplay and back. When the Arduino powers on, it first runs through a brief intro sequence, the LCD screen will display "Rhythm Game, Game Ready" for two seconds, followed by instructions on how to navigate the menus. This prepares the player for the first interaction. The player is then presented with the Song Selection menu. Using the left and right buttons, they can cycle through the available songs, such as "Happy Birthday" or "Blue Danube." To confirm their choice, the player performs a long press on either button, which locks in their selection. Immediately following the song choice, the Difficulty Selection menu appears. Here, the player uses only the right button. A short click cycles through Easy, Medium, and Hard, and a long press confirms the desired challenge level. With the song and difficulty set, a “Click to Start” prompt appears alongside the selected track. Once the player initiates, the game displays a final "Get Ready..." screen with a 3-2-1 countdown. This gives the player a moment to prepare their fingers on the buttons before the action starts.

Figure 3. LCD Screen as the Game Starts (left to right)

The song begins, and note blocks start scrolling from right to left in their respective lanes. The player's goal is to press the corresponding button for each lane precisely as the block overlaps the "P" target marker. The speed of the blocks is determined by the difficulty chosen earlier. Correct hits play a musical note from the song's melody, while misses produce a low buzz.

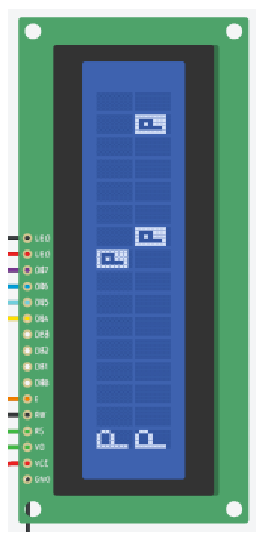

Figure 4. LCD Screen in Game Play

Once the song is complete, the game first displays the player's final score for that attempt, showing how many notes they hit out of the total. After two seconds, it transitions to a "Best Score" screen, showing the highest score achieved for that particular song since the device was powered on. Finally, the player is presented with the "Play again?" menu. They can choose "YES" with the left button to restart the same song with the same difficulty, or "MENU" with the right button to return to the Song Selection screen and begin the entire process again. This creates a continuous and engaging gameplay loop.

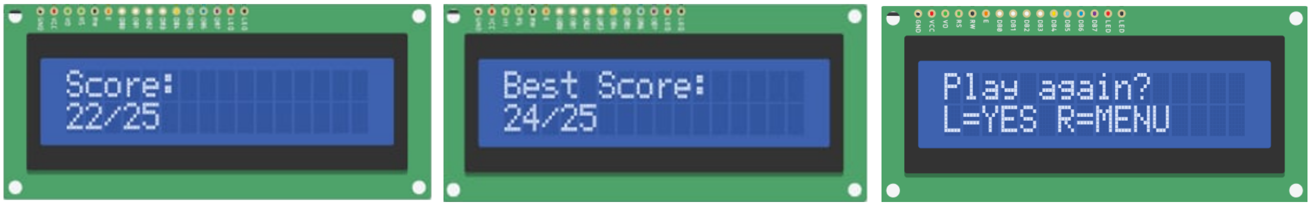

Figure 4. LCD Screen after Game Play

RESULTS AND DISCUSSION

Results

Over the thirty researcher-led play sessions, the Arduino Rhythm Game prototype performed reliably and fulfilled its intended educational and interactive functions. Throughout these sessions, the LCD consistently delivered clear countdown sequences, current and high scores, and player guidance.

Quantitative analysis revealed that, on average, participants played twenty notes per session and succeeded in hitting eighteen correctly within the designated timing window, a 75 percent accuracy rate. The lowest score noted in a session was eight successful hits, while several high scoring runs of 18-23 notes were achieved. In every round, the potentiometer proved effective in adjusting display clarity, enhancing user experience regardless of ambient lighting conditions.

System latency was minimal, with near-instantaneous auditory feedback and visually stable transitions attributed to the frame buffer's management of the LCD. The alternating rows and visual lane offset prevented overlapping visuals, which contributed to easy distinction between lanes and reduced erroneous double presses. Missed notes consistently resulted in prompt error tones and clear visual indicators, ensuring instant feedback and facilitating learning.

Beyond hard data, researchers found that repeated exposure improved their timing and accuracy, illustrating both the cognitive challenge and skill development inherent in the game. No hardware failures or unexpected behaviors were observed, confirming the integration quality and robustness of the system.

Discussion

The findings from this study provide compelling evidence for the potential of rhythm-based, IoT-integrated educational tools to foster both engagement and skill acquisition within a technologically mediated environment. The systematic and repeated testing of the prototype by the research team enabled an in-depth evaluation of both the technical reliability and practical educational value of the Arduino-based Rhythm Game.

Throughout the process, the consistent operation of the hardware, along with responsive software integration, reinforced the suitability of microcontroller platforms like Arduino for project-based learning in electronics and embedded systems. The LCD, piezo buzzer, pushbuttons, and potentiometer each contributed to the system's overall usability and efficacy. The adjustable LCD contrast, in particular, demonstrated an important consideration for accessibility, supporting players in a variety of lighting conditions and making the device flexible for use in different educational or public settings.

The scheduling algorithm, which coordinated the descent of visual blocks with the melodies of songs including Happy Birthday, Jingle Bell, Blue Danube, Nocturne Op9, and Waltz Mirror, proved highly effective for synchronizing physical user actions with digital outputs. This close alignment of visual and auditory cues has been highlighted in prior research as a key contributor to the success of interactive and gamified systems (Xiao et al., 2021; Studley, 2022). The high average success rates and rapid improvement seen across the thirty play sessions suggest that regular engagement with the rhythm game supports the development of timing, reflexes, and hand-eye coordination. These outcomes are consistent with research that links rhythm game participation to cognitive benefits such as improved motor planning, attention, and perceptual acuity.

A further academic implication of this project is the demonstration that foundational IoT education can be greatly enhanced through the inclusion of real-time, interactive interfaces, rather than just focusing on sensor data collection and remote monitoring. By encouraging players to interact physically with the system and receive immediate feedback, the game embodies the concept of "learning by doing." This aligns with established educational theories that emphasize active participation, multisensory stimulation, and immediate feedback as critical factors in skill acquisition and retention (Ong et al., 2022).

In addition, the systematic use of the game by the researchers, who served as both designers and participants, provided a unique opportunity for reflective practice. This practitioner-participant approach, often used in pilot and iterative educational technology development, allowed the team to quickly identify opportunities for minor technical refinements and to document qualitative feedback regarding user experience, clarity of scoring, and intuitiveness of the control interface. The routine achievement of perfect scores after repeated practice further suggests the potential use of the system not only for introductory engagement but also for monitoring user progress over time.

Despite these strengths, there are several limitations and considerations for future development. While the consistent results indicate a high degree of technical stability, the research team may limit the generalizability of the findings. Broader studies should seek to include more diverse participant groups, including those with less experience in electronics, to fully ascertain the device's accessibility and challenge. Furthermore, although the use of the five (5) melodies provided a recognizable and structured context for timing and response measurement, expanding the musical library or allowing for user-created sequences could enhance both engagement and the scope of cognitive tasks required.

Feedback from the sessions also indicated that additional features, such as variable hit windows, adjustable difficulty modes, or expanded audiovisual output (for example, color LCDs or multi-tone sound modules), could further enrich the user experience and provide differentiated learning opportunities. These enhancements could support a wider range of skill levels and educational objectives.

Finally, the integration of cloud connectivity or real-time data logging, which is increasingly important in modern IoT systems, could create new opportunities for remote monitoring, analytics, or classroom integration, extending the impact of the device beyond single-user and local settings.

CONCLUSION AND RECOMMENDATION

The development and testing of the Arduino-based rhythm game prototype demonstrated that the system successfully met its functional objectives. The LCD effectively displayed countdowns, scores, and game states; pushbuttons reliably captured user inputs; and the buzzer provided clear auditory feedback for correct and incorrect actions. The gameplay, with its progressively increasing difficulty, challenged players' reflexes, coordination, and focus. These outcomes confirmed that the prototype not only functioned as intended but also showcased the potential of IoT-based devices in creating interactive and educational systems.

Based on the results, the rhythm game highlighted how IoT components can be integrated to deliver real-time user interaction, reinforcing principles of input-output processing, system feedback, and gamification. The project also demonstrated educational value by showing how rhythm games can improve cognitive skills such as timing, reaction speed, and hand-eye coordination. However, opportunities for improvement were identified, particularly in expanding difficulty levels, enhancing audio-visual features, and incorporating additional scoring or gameplay options to improve user engagement.

In line with these findings, the following recommendations are proposed:

1. Enhancement of Game Features – Building on the successful implementation of adjustable difficulty, future iterations could introduce a dynamic scoring system. This would include mechanics for combos and accuracy streaks to better reward player precision. Furthermore, a dedicated "Practice Mode" could be developed, allowing users to play songs at a slower pace or focus on specific sections, making the game more accessible to beginners.

2. Improved Interactivity – Incorporating more advanced hardware components such as LED indicators, larger displays, or enhanced sound modules can provide richer feedback and a more immersive experience.

3. Educational Integration – The rhythm game can be used as a teaching tool in electronics, programming, and IoT-related subjects to engage students in hands-on learning about embedded systems, real-time processing, and human-computer interaction.

4. Future Research and Development – Researchers and educators may explore expanding the concept by connecting the prototype to cloud-based services or mobile applications, bridging data-driven IoT with real-time interactivity.

The findings of this study confirm that interactive rhythm-based applications, when integrated with IoT and microcontroller platforms, can effectively combine entertainment with education. The project serves as a valuable model for promoting both cognitive skill development and practical knowledge in IoT and embedded systems.

REFERENCES:

- Intelligence, M. (2025, July 8). Internet of Things (IoT) Market Size, Share & Growth Report, 2030. Mordor Intelligence. https://www.mordorintelligence.com/industry-reports/internet-of-things-iot-market
- Ong, C. G., Fermano, J. C., & Daniot II, A. C. P. (2022). An impact study on the Arduino programming training for beginners. University of Science and Technology of Southern Philippines. https://files.eric.ed.gov/fulltext/ED639852.pdf
- Studley, T. (2022). Can competitive digital games support real-time music creation? Journal of Sound and Music in Games, 3(1), 1–19. https://online.ucpress.edu/jsmg/article-abstract/3/1/1/119524
- Xiao, R., Wu, Z., & Hamari, J. (2021). Internet-of-Gamification: A Review of literature on IoT-enabled gamification for User Engagement. International Journal of Human-Computer Interaction, 38(12), 1113–1137. https://doi.org/10.1080/10447318.2021.1990517