

Engaging Learners through a Physical Computing-Based Chess Escape Room

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Introduction

Chess, although cognitively beneficial, is often perceived as less attractive to diverse learners [1]. Scientists have long studied the impact of improving chess skills on human intellectual abilities. It has been found that children who play chess are much more likely to demonstrate better academic results [2]. Meanwhile, escape room elements are often used in the gamification process to further engage the user in the activity [3]. Both chess and escape rooms can be physical or digital [4]. However, it is known that physical interfaces further enhance user engagement. **There is a need for an innovative educational tool that combines the cognitive benefits of chess with the motivational elements of escape rooms and physical computing to enhance learning engagement.** This study proposes an interactive educational tool – chess escape room system – that transforms classic chess gameplay into an engaging, goal-oriented activity through physical computing and serious game design principles [5], [6].

System Development and Implementation

During the system design process, the need for interactive systems, the benefits of physical interfaces in education, and the main principles of escape room design were analyzed. All the intended subsystems of the system have been programmed – chess piece detection, square lighting, sound signals, and task progression.

The developed prototype utilizes a 4x4 physical chessboard (Fig. 1a and 1b) integrated with photoresistors to detect piece placement. LED indicators guide users through tasks, an RGB LCD screen provides visual instructions, and a buzzer delivers auditory feedback. An Arduino UNO microcontroller governs all components and logic. Tasks are managed using matrix-coded puzzles stored step by step in basic arrays. The escape room tasks mimic real game mechanics: learners must correctly place and move chess pieces to achieve a checkmate (Fig. 2).

The following escape room features were implemented to improve user experience and engagement:

- A visual and audible signal is given to the player after each move. Correct and incorrect moves have different and clearly distinguishable signals.
- The number of mistakes allowed to be done is limited.
- Session progress is displayed on the LCD screen.
- Players must solve all tasks within a certain time period.
- Gradual increase in the complexity of the tasks.

Children benefit the most from playing chess as their developing brains are most receptive to the cognitive improvements in mathematics, reading, problem-solving, and strategic thinking that chess provides. Thus, the system underwent usability testing with five middle school students to evaluate its effectiveness as a learning tool through interacting with core gameplay mechanics and filling out the System Usability Scale questionnaire. Evaluation measured

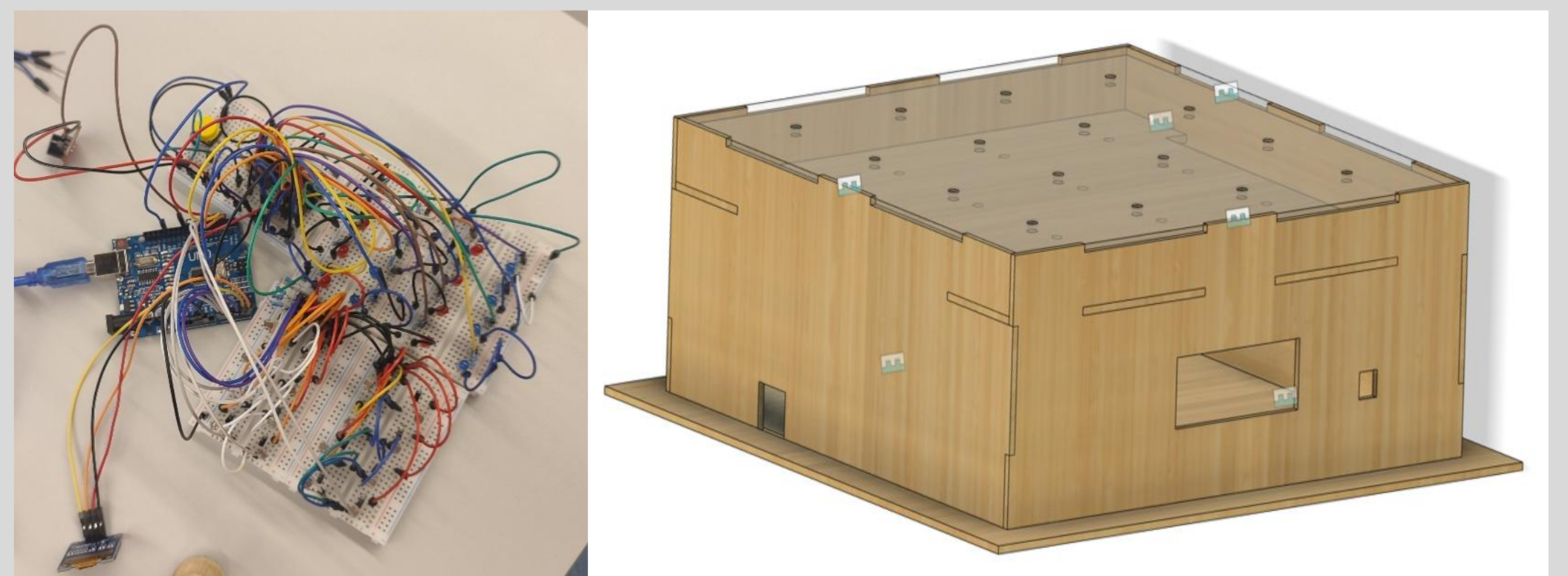


Fig. 1. (a) Complete physical prototype on a breadboard and (b) Chessboard model (Autodesk Fusion)



Fig. 2. Chessboard prototype implementation

the task completion effectiveness and overall user experience through standardized metrics. **Results** from the participant group showed above moderate performance, indicating satisfactory system effectiveness. Moreover, as the complete solution is not expensive and production components are widely accessible, its development documentation could also serve as a basis for computer science classes, making it both an accessible learning tool and a practical programming and engineering project for students.

Conclusion and Future Work

This chess escape room system demonstrates how physical computing and gamified design can enhance informatics education. The proposed system aligns with the goals of serious games in education and it fosters:

- **Computational thinking:** learners practice algorithmic logic and cause-effect analysis through puzzles;
- **Physical computing skills:** exposure to microcontrollers, sensors, and feedback systems;
- **Engagement and motivation:** gamified interaction enhances intrinsic motivation.

This solution is suitable for workshops, after-school clubs, or non-formal education initiatives, especially in primary and lower secondary contexts. Planned extensions include RFID-based piece recognition, expanded board size, and improved 3D printed design. The system could serve as both an effective individual learning tool and an easily replicable, scalable teaching aid, aligning well with current trends in STEAM and inclusive education.

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