

A Scalable, Modular Architecture Enabling Digital Teacher-defined Mobile Escape Rooms

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Abstract: Educational escape rooms offer promising opportunities for increasing engagement and active learning in STEM education, but existing solutions are often based on predefined scenarios and provide limited flexibility for adaptation to different learning objectives and classroom contexts. This paper presents DIETER (Digital EducaTional Escape Room), a modular framework that enables teachers to create customized mobile escape room experiences by combining reusable digital mini-games and external learning activities. The framework aims to shift scenario configuration from developers to educators, allowing learning activities to be adapted to different classroom settings and difficulty levels. This work-in-progress paper introduces the underlying concept and architecture of DIETER and outlines its planned evaluation with teachers and students. The evaluation will investigate the framework's usability, acceptance, learner engagement, and pedagogical potential in classroom contexts. By supporting teacher-defined and reusable escape room configurations, DIETER aims to provide a flexible and scalable approach to game-based learning in STEM education.

Keywords: Digital escape rooms, STEM education, Game-based learning, Mobile mini-games, Modular architecture

1. Introduction

Escape rooms have emerged as a promising approach in game-based learning, offering interactive and collaborative environments that can support problem solving, critical thinking and active learning in educational contexts. In recent years, both physical and digital escape room formats have been increasingly adopted in STEM education to increase student motivation and participation (Vidergo, 2021).

However, most existing escape room implementations are designed as static and self-contained experiences. They are usually developed for specific scenarios and learning objectives, limiting their adaptability and reuse in different classroom settings. Consequently, teachers often have to make significant efforts when creating or modifying escape rooms, thereby reducing their practical application in everyday teaching (Veldkamp et al., 2020).

To address these limitations, this paper presents DIETER, a modular digital escape room framework that allows teachers to design and configure their own escape room experiences. The framework is based on independently developed minigames that can be dynamically combined within a mobile master application. In addition, it supports the integration of external non-digital activities, enabling hybrid escape room scenarios combining digital and physical tasks.

The main contribution of this work lies in the design and implementation of a flexible and scalable system that transfers control from developers to teachers and enables teacher-defined escape room configurations. This paper presents the conceptual design, a functional prototype, and outlines a planned assessment of the framework in educational contexts.

2. Related Work

Educational escape rooms (EERs) have emerged as a promising approach within game-based learning and are increasingly being adopted in STEM education. Prior research suggests that escape room scenarios can support student engagement, collaboration, problem-solving, and motivation by providing interactive and immersive learning environments (Veldkamp et al., 2020; Huang, Kuo and Chen, 2020; Makri, Vlachopoulos and Martina, 2021; Vidergo, 2021). However, existing escape room implementations are often designed around specific learning objectives and scenarios, which can limit their adaptability and reuse across different educational contexts. Their development may also require substantial effort in terms of instructional design, content creation, and technical implementation (Fotaris and Mastoras, 2019).

Several approaches have therefore been proposed to support educators in creating educational escape rooms. For example, Clarke et al. (2017) introduced the *escapED* theoretical framework as a structured design approach for educational escape rooms, while Fotaris and Mastoras (2022) proposed the *Room2Educ8* conceptual framework to guide educators through the development of educational escape room experiences. In addition, López-Pernas et al. (2021) presented *Escapp*, a web-based platform designed to support the management and execution of educational escape rooms.

In contrast, DIETER focuses on the technical composition of reusable learning activities. Rather than requiring teachers to develop complete games themselves, independently developed mini-games can be selected, combined, and complemented by external activities to create customized escape room sequences. This separation between mini-game development and scenario configuration aims to provide teachers with greater flexibility while keeping the technical effort required for creating new learning experiences low.

3. Framework Design and Prototype

This section presents the design and implementation of the proposed framework. It first outlines the underlying conceptual principles, followed by an overview of the system architecture and the current state of the prototype.

3.1 Concept and Design Principles

At the heart of the technical framework is the concept of independently developed mini-games that serve as reusable building blocks. Each mini-game is designed to address specific learning objectives or competencies and can be combined with others to form a complete escape room sequence. This modularity allows teachers to adapt escape rooms to different classroom contexts, difficulty levels, and pedagogical goals, supporting differentiated instruction and tailored learning pathways.

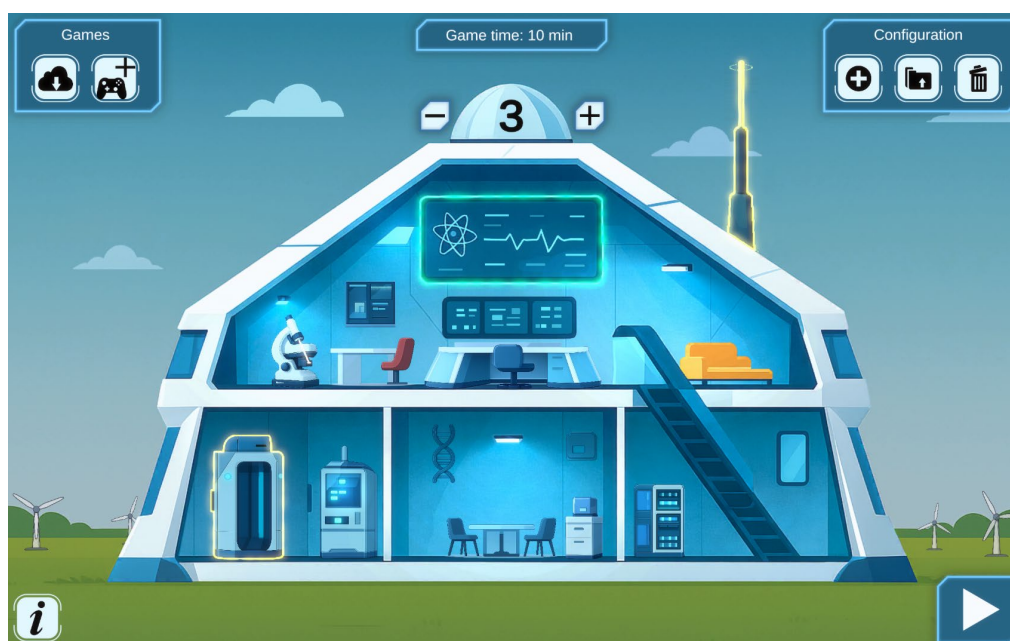


Figure 1: The master app's configuration screen. Yellow-outlined objects allow educators to select a game, while the green-outlined object already has a game assigned

An essential design principle of DIETER is transferring control from developers to educators. Rather than depending on fixed game sequences, teachers can independently create and configure escape room scenarios within the system, as illustrated in Figure 1. For each highlighted object, a game can be assigned. This teacher-controlled setup offers substantial flexibility and allows educators to tailor game-based activities to their own instructional approaches and curriculum goals.

Furthermore, the framework accommodates hybrid learning settings by combining digital and non-digital games. In addition to selecting mini-games from the system, teachers can define their own external games, like problem-solving tasks, which are incorporated into the escape room flow through validation mechanisms in the master application, as illustrated in Figure 2.

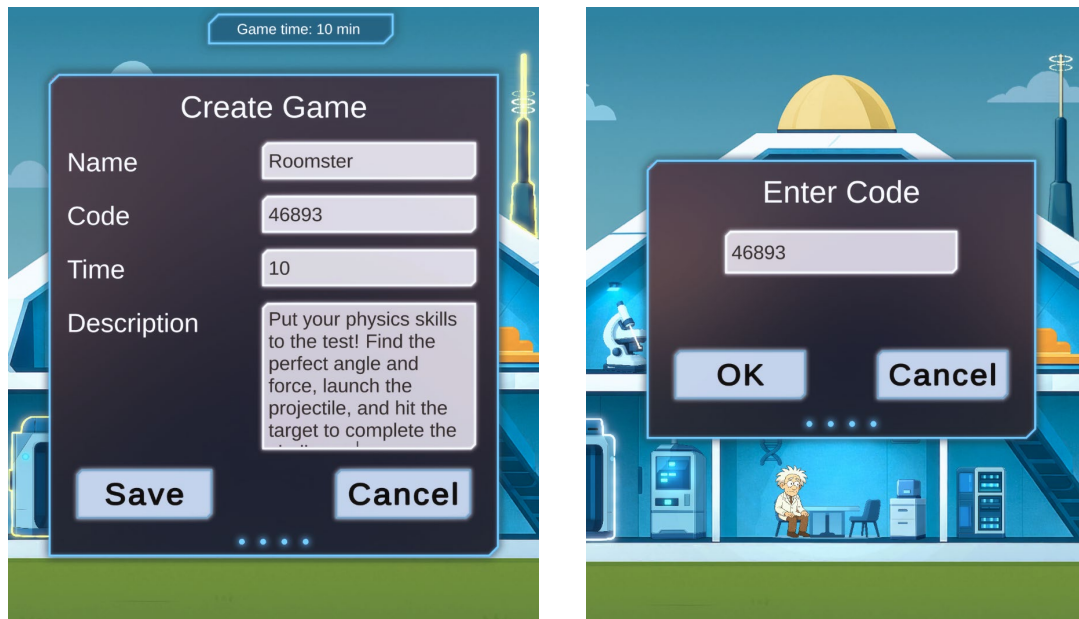


Figure 2: Left: Game creation window, where educators can specify a name, a code students must discover, the available completion time, and a description. Right: Code input field used by students to verify their solution

This design broadens the framework's use beyond strictly digital contexts and supports more varied and enriched learning experiences.

3.2 System Architecture

The architecture of DIETER consists of four main components: a mobile master application, a server, a game management software and an expandable library of mini-games, shown in Figure 3. The master application serves as the primary interface for teachers and students, allowing the configuration and execution of escape room sequences on mobile devices.

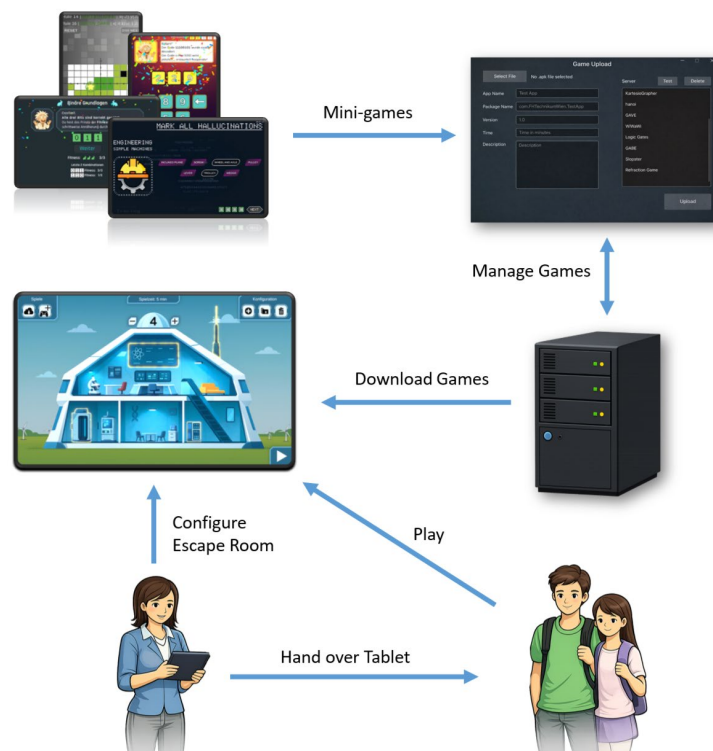


Figure 3: The workflow from game creation and server upload to room configuration in the master app and classroom use by students

Mini-games are developed as standalone Unity-based mobile applications. To ensure seamless integration, each game includes a predefined interface component that enables communication with the master application. This communication mechanism allows the master application to launch individual games and to receive completion signals, enabling coordinated progression through the escape room sequence.

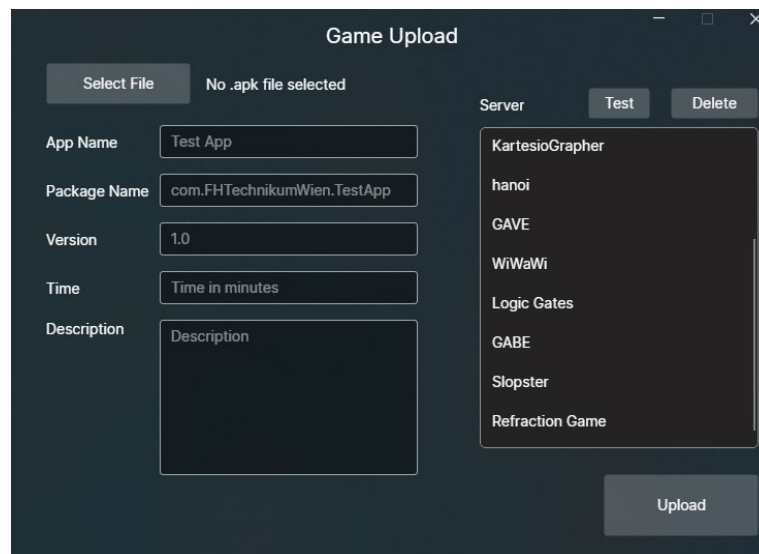


Figure 4: Software for managing mini games

A custom software tool was developed to package mini-games together with relevant metadata, such as descriptions and time constraints, and to upload them to a server, as shown in Figure 4. The server acts as a repository for all available games which can be downloaded and installed via the master app.

This architecture enables a scalable and extensible ecosystem in which new games can be continuously added without requiring changes to the core system. As a result, the framework supports ongoing content expansion and long-term reuse across different educational contexts.

3.3 Current Implementation Status

A functional prototype of DIETER has been implemented, supporting the core workflow from game creation to deployment and integration within the master application. The system currently allows teachers to browse available mini-games, download them from the server, and combine them into structured escape room sequences.

The current mini-game library includes several learning activities with different educational objectives. For example:

- *KartasioGrapher* focuses on reading, plotting, and interpreting points in the Cartesian coordinate system.
- *Der Code des Professors* requires students to convert values between decimal, binary, octal, and hexadecimal number systems in order to unlock a safe.
- *Gen-Lab: Binary Breakout* introduces basic concepts of genetic algorithms through binary encoding, fitness evaluation, and iterative solution improvement.

However, the current state of the system remains a work in progress. The library of available mini-games is still limited and is being actively expanded. Furthermore, aspects such as usability, user interface design, and classroom integration have not yet been systematically evaluated. These limitations highlight the need for further development and empirical validation, which will be addressed in future work.

4. Evaluation Plan

The planned evaluation will involve both teachers and students and will examine how DIETER performs in authentic classroom use.

Teachers will create escape room scenarios with the master application by combining available mini-games and optional external activities. Their feedback will be collected through questionnaires and guided interviews, with a focus on ease of use, perceived usefulness, and suitability for teaching practice.

Students will then use the resulting scenarios in class. Their experience will be examined with regard to engagement, motivation, and overall user experience. Where suitable, established questionnaires will be used. Learning progress will also be assessed through pre- and post-tests aligned with the learning objectives of the selected activities.

The findings will be used to identify strengths and weaknesses of the framework and to guide further development, particularly regarding usability, classroom integration, and educational value.

5. Discussion and Conclusion

The proposed framework shows potential of modular design to address key limitations of existing EERs. By enabling teachers to dynamically combine independently developed mini-games and integrate external activities, DIETER aims to support flexible and customizable learning experiences. This approach may reduce the effort required to create escape rooms and allows adaptation to diverse classroom contexts and learning objectives.

At the same time, several limitations must be considered. The effectiveness of the framework depends on the availability and quality of the mini-game library, which is currently still limited. In addition, the usability of the system for teachers without technical background requires further validation. The integration of multiple components may also introduce challenges in ensuring a coherent learning experience across different activities.

In conclusion, this work-in-progress presents DIETER as a promising approach for enabling teacher-defined digital escape rooms in STEM education. Future work will focus on expanding the game library, improving usability, and conducting empirical evaluations to assess its pedagogical impact in real classroom settings.

Ethics Declaration: No empirical study has been conducted at this stage, and no human participants or sensitive data were involved. Therefore, ethical approval was not required.

AI Declaration: ChatGPT and Writefull were used as editorial support during the writing of this paper. The use was limited to improving wording, grammar and readability.

References

- Clarke, S.J., Peel, D.J., Arnab, S., Morini, L., Keegan, H. and Wood, O. (2017) "EscapED: A Framework for Creating Educational Escape Rooms and Interactive Games to For Higher/Further Education", *International Journal of Serious Games*, 4(3). <https://doi.org/10.17083/ijsg.v4i3.180>
- Fotaris, P. and Mastoras, T. (2019) 'Escape rooms for learning: A systematic review', *Proceedings of the European Conference on Games-based Learning*, 2019-October, pp. 235–243. <https://doi.org/10.34190/GBL.19.179>
- Fotaris, P. and Mastoras, T. (2022) "Room2Educ8: A Conceptual Framework for Designing Educational Escape Rooms", *Proceedings of the 16th European Conference on Games Based Learning*. <https://doi.org/10.3390/educsci12110768>
- Huang, S.-Y., Kuo, Y.-H. and Chen, H.-C. (2020) "Applying digital escape rooms infused with science teaching in elementary school: Learning performance, learning motivation, and problem-solving ability", *Thinking Skills and Creativity*, 37, Article 100681. <https://doi.org/10.1016/j.tsc.2020.100681>
- López-Pernas, S., Gordillo, A., Barra, E. and Quemada, J. (2021) "Escapp: A Web Platform for Conducting Educational Escape Rooms", *IEEE Access*, 9, pp. 38062–38077. <https://doi.org/10.1109/ACCESS.2021.3063711>
- Makri, A., Vlachopoulos, D. and Martina, R.A. (2021) "Digital escape rooms as innovative pedagogical tools in education: A systematic review", *Sustainability*, 13(8), Article 4587. <https://doi.org/10.3390/su13084587>
- Sánchez, A.M. (2023) "Using digital educational escape rooms as a motivational review tool for Economics", *The International Journal of Management Education*, 21(3), Article 100852. <https://doi.org/10.1016/j.ijme.2023.100852>
- Veldkamp, A., van de Grint, L., Knippels, M.-C.P.J. and van Joolingen, W.R. (2020) "Escape education: A systematic review on escape rooms in education", *Educational Research Review*, 31, Article 100364. <https://doi.org/10.1016/j.edurev.2020.100364>
- Vidergor, H.E. (2021) "Effects of digital escape room on gameful experience, collaboration, and motivation of elementary school students", *Computers & Education*, 166, Article 104156. <https://doi.org/10.1016/j.compedu.2021.104156>