

# Effects of Digital Escape Games on Motivation in Primary Mathematics Education

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**Abstract:** This paper addresses the decline in motivation and the development of mathematical literacy among pupils during primary education, with particular attention to the increasing level of abstraction that often contributes to mathematical anxiety, lower self-confidence, and reduced engagement in mathematics. These challenges highlight the need for instructional approaches that combine meaningful learning experiences with opportunities to strengthen pupils' motivation and confidence. The theoretical framework is grounded in the principles of game-based learning and is informed by Flow Theory and Self-Determination Theory. The study focuses on an innovative teaching intervention in the form of a digital educational escape game developed in the Genially environment and embedded within a Minecraft-inspired narrative. By integrating elements of familiar gaming culture, the intervention aims to support horizontal mathematization, understood as the application of mathematical knowledge and procedures in meaningful contexts, while promoting learner engagement and active problem solving. The study employed a mixed-methods research design involving 25 fifth-grade pupils (aged 10–11) from a primary school in the Czech Republic. Quantitative data were collected using a pretest–posttest design consisting of a mathematics knowledge test and a ten-item semantic differential measuring pupils' attitudes toward mathematics. Qualitative evidence was obtained through classroom observations, pupils' written reflections, and structured debriefing sessions, providing additional insights into pupils' learning experiences and motivational responses. The findings indicate that the digital escape game contributed to more positive attitudes toward mathematics, reduced perceived stress, increased self-confidence, and greater engagement with mathematical tasks. Qualitative data further demonstrated the motivational value of the narrative game environment and highlighted the role of contextualized problem solving in supporting meaningful mathematical activity. At the same time, the results revealed that pupils' perceived procedural confidence remained unchanged and that their reported willingness to persist with demanding tasks decreased after the intervention, suggesting that highly immersive game environments may also present challenges for developing long-term cognitive resilience. The study contributes to the growing body of research on game-based learning by demonstrating both the educational potential and the limitations of digital escape games in primary mathematics education.

**Keywords:** Digital escape rooms, Mathematics, Motivation, Pupils, Genially, Game-based learning

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## 1. Introduction

### 1.1 Context: Game-based Learning in Primary Education

In recent years, primary education in the Czech Republic has increasingly adopted Game-Based Learning (GBL) in response to pupils' digital environment. GBL uses games as structured learning environments that promote conceptual understanding, critical thinking, and engagement. Systematic reviews confirm that digital games in mathematics significantly improve not only conceptual understanding of the subject matter but also pupils' overall engagement in learning (Dan et al., 2024; Veldkamp, 2021). In this context, Digital Educational Escape Games (DEEG) appear to be an innovative tool that combines narrative immersion with problem-solving (Makri et al., 2021).

### 1.2 Specifics of Mathematical Literacy and the Transition to Abstraction

The fifth grade of elementary school marks a critical turning point in a pupil's cognitive development. Pupils move beyond purely concrete operations and begin to work with more abstract mathematical concepts. It is precisely the digital gaming environment that facilitates this transition by embedding abstract problems within a meaningful gaming context (Rocha & Dondio, 2021).

### 1.3 Problem: Decreased Motivation and the Role of Gamification

Despite the importance of mathematics, traditional teaching often shows a decline in pupils' intrinsic motivation, which is typically linked to an increase in so-called math anxiety. Gamification and the use of popular elements (e.g., Minecraft-style) can reverse this negative trend. Game mechanics such as battles, animations, and storylines transform routine practice into an adventure, thereby increasing engagement and fostering intrinsic

motivation for learning (Masri, 2026; Ratinho et al., 2026). Furthermore, the implementation of a game framework through platforms such as Genially allows teachers to create complex, non-linear challenges that align with pupils' psychological needs (Grepperud, 2025).

#### **1.4 Aim of the Study and Research Questions**

The aim of this study is to design, implement, and evaluate an educational digital escape game and assess its impact on the level of mathematical literacy and motivation among fifth-grade elementary school pupils.

Research Questions:

- RQ1: What effect does the implementation of a digital escape game have on pupils' emotional attitude toward mathematics and their perceived stress levels?
- RQ2: What is pupils' attitude toward mathematical problems presented in an immersive digital environment?
- RQ3: How do action-game elements (combat, animation, narrative) influence pupils' willingness to persist in solving cognitively demanding problems?

## **2. Literature Review**

### **2.1 Theoretical Framework: Motivation and Learning Experience**

The use of game-based learning (GBL) is primarily grounded in psychological theories of motivation and optimal experience. Two theories in particular are key to understanding the effectiveness of digital escape games in elementary school settings: Flow Theory and Self-Determination Theory.

#### **2.2 Flow Theory**

According to Mihaly Csikszentmihalyi, the state of "flow" is a moment of absolute concentration and deep immersion in an activity (Vidergor, 2021). In the context of education, it occurs when the difficulty of a task is in perfect balance with the pupil's skills. If the challenge is too easy, boredom sets in; if it is too difficult, anxiety arises.

Digital escape games support this balancing act on the edge of one's abilities (the so-called "zone of proximal development") through immediate feedback and a gradual increase in difficulty (Veldkamp et al., 2020). It is precisely the smooth transition between individual puzzles in the game environment that can induce this state in 5th-grade pupils, thereby increasing the effectiveness of learning without causing excessive fatigue.

#### **2.3 Self-determination Theory**

Deci and Ryan's self-determination theory emphasizes that three basic needs must be met for sustainable intrinsic motivation: autonomy, competence, and relatedness (Işık & Liman Kaban, 2025). In escape games, autonomy is supported by choice of path and freedom to explore the virtual world, enhancing the gameful experience (Vidergor, 2021). Competence is reinforced by solving math puzzles and unlocking the next part of the story, providing immediate feedback (Veldkamp et al., 2020). Relatedness is strengthened through group problem-solving, fostering social bonds toward a shared goal (Vidergor, 2021).

### **2.4 Digital Escape Games in Mathematics Education**

Digital versions of escape games differ from their traditional counterparts primarily in their accessibility and wide range of interactive elements. According to Makri et al. (2021), these games represent an innovative pedagogical tool capable of transforming both online and in-person instruction into an immersive experience. In mathematics, escape games serve as a bridge to so-called horizontal mathematization. Piñero Charlo (2020) defines this process as a pupil's ability to apply mathematical tools to solve problems set in a real or fictional (in the case of this Minecraft escape room) context.

### **2.5 Previous Research and State of Knowledge**

While the benefits of escape games in the natural sciences (biology, chemistry) are already fairly well documented (López-Belmonte et al., 2020), research into their impact on elementary schools is still in its infancy. However, current findings suggest significant potential, particularly in terms of improved academic performance, with experimental groups using digital escape rooms achieving significantly better results than those taught using traditional methods (Işık & Liman Kaban, 2025). In addition to cognitive benefits, there is also

a shift in attitudes; thanks to these activities, students stop perceiving mathematics as a set of isolated rules and begin to see it as a functional tool for achieving a goal (Fotaris & Mastoras, 2019).

## **2.6 Research gap**

The current literature focuses extensively either on the higher education setting or on general aspects of gamification (Ratinho et al., 2026). However, there is a noticeable lack of studies that specifically focus on the transitional phase between the first and second stages of elementary school (5th grade). At this age, children undergo significant changes in abstract thinking, and it is precisely at this stage that it is critically important to address a decline in interest in the subject. This study aims to fill this gap by analyzing the impact of a thematically targeted (Minecraft) escape game on mathematical literacy and intrinsic motivation in this specific age group.

## **3. Methodology**

### **3.1 Research Design and Game Development**

For the purposes of this research, a mixed-methods research strategy utilizing an embedded design was chosen (Creswell & Creswell, 2018). Quantitative and qualitative methods captured general shifts in pupils' affective attitudes and revealed cognitive barriers, reading literacy limitations, and behavioral nuances during gameplay.

The entire process was structured in iterative cycles:

- Pilot phase: The initial version of the digital escape game underwent pilot testing at a different elementary school. The goal was to verify the technical functionality and clarity of the tasks. Based on qualitative feedback from the local teacher, the game was slightly modified to better suit the cognitive abilities of the target group.
- Main Phase: The final version of the game was subsequently deployed for live use, during which quantitative and qualitative data were collected.

#### *3.1.1 Digital escape game design*

For the purposes of the research, a digital escape game was created using the Genially platform. The game's design was intentionally styled to resemble the visual aesthetic of Minecraft. This choice was based on the principle of narrative immersion and the high popularity of this title among the target group of fifth-grade pupils, which is consistent with the theory of increasing intrinsic motivation through familiar cultural artifacts (Ratinho et al., 2026).

#### *3.1.2 Educational content and task structure*

The educational content of the game was designed as a comprehensive review of primary school mathematics. The game is structured into seven thematic areas, each of which presents a unique gaming environment with a different type of cognitive challenge. Two key sources were combined in the creation of the tasks:

- CERMAT Standardized Tests: Adaptations of tasks corresponding to the learning outcomes for 5th grade.
- Contextual Mathematics ([www.realisticky.cz](http://www.realisticky.cz)): Tasks emphasizing the application of mathematics in real-life situations.

The game covers a wide range of mathematical competencies, which were integrated into the game world as follows:

- Arithmetic and numbers: Comparing numbers, rounding, and operations with Roman numerals. A specific feature was the application of logical reasoning in examples with missing digits.
- Word problems: Problems requiring multiplicative thinking, estimating the result, and critical analysis of the text.
- Geometry and spatial reasoning: Working with building plans, identifying geometric shapes, and calculating area in cm<sup>2</sup>.
- Information literacy: Reading and interpreting data from graphs and navigating a coordinate system.

#### *3.1.3 Gamification elements*

To achieve a state of flow (see Section 2.2), the game incorporated a progression of difficulty levels and immediate feedback on results. The game mechanics utilize the principle of “unlocking” new levels after solving

a math puzzle, which reinforces pupils' sense of autonomy and competence in line with Self-Determination Theory.

At the same time, the activity supported the development of mathematical literacy through problem-solving tasks set within a meaningful game context. The mechanism of unlocking additional levels not only supported pupils' autonomy and perceived competence but also created a structure for the authentic application of mathematical thinking in situational modeling, spatial reasoning, and decision-making.

### 3.2 Data Collection and Participants

The research study was conducted at a municipal elementary school in the Czech Republic that combines a standard approach with the Hejny method in mathematics instruction. The sample consisted of fifth-grade pupils (7 boys and 18 girls), including those with special educational needs (SEN), who received support from teaching assistants during the game. The study was conducted in accordance with institutional ethical guidelines. Written informed consent was obtained from the parents or legal guardians of all participating pupils. The data collection was conducted in April 2026.

### 3.3 Quantitative Measures: Semantic Differential

Quantitative data were collected using a pretest-posttest design. The primary instrument was a semantic differential, in which pupils rated their attitudes toward mathematics on a seven-point scale using bipolar adjectives (e.g., interesting–boring, relaxed–stressful).

### 3.4 Qualitative Sonda: Observation and Reflection

To gain a deeper understanding of the processes occurring during the game, the method of direct non-participatory observation was chosen. The game's author was present during the lesson as a passive observer, focusing on critical points in the design, the pupils' interaction with the interface, and the extent of assistance required from the teachers.

Immediately after the game ended, the data was supplemented with:

- A group debriefing with the pupils, focused on subjectively perceived difficulties.
- Feedback from the teachers who facilitated the game in the classroom and assisted pupils with special educational needs in understanding the task.

## 4. Results

### 4.1 Descriptive Statistics

To initially assess the distribution of the data, basic descriptive statistics were calculated for all items of the semantic differential. Due to the exclusion of one respondent because of incomplete data (listwise deletion), the final sample analyzed consists of  $n = 25$  pupils. Data were collected on a seven-point Likert scale, where a score of 1 represented the negative pole and a score of 7 represented the positive pole.

**Table 1: Semantic differential (Pretest and Posttest,  $n = 25$ )**

| Item<br>1 = negative – 7 = positive      | Phase | Mean | Median | SD   | IQR | Min | Max |
|------------------------------------------|-------|------|--------|------|-----|-----|-----|
| 1. Boring – Interesting                  | Pre   | 3,58 | 3,0    | 1,63 | 2,0 | 1   | 6   |
|                                          | Post  | 4,68 | 5,0    | 1,41 | 2,0 | 2   | 7   |
| 2. I don't enjoy it – I enjoy it         | Pre   | 3,73 | 4,0    | 1,52 | 2,0 | 1   | 6   |
|                                          | Post  | 4,24 | 4,0    | 1,48 | 2,0 | 1   | 7   |
| 3. Difficult – Easy                      | Pre   | 3,23 | 3,0    | 1,55 | 2,0 | 1   | 6   |
|                                          | Post  | 4,52 | 5,0    | 1,26 | 2,0 | 2   | 7   |
| 4. Stressed – Relaxed                    | Pre   | 3,85 | 4,0    | 1,60 | 3,0 | 1   | 7   |
|                                          | Post  | 4,52 | 5,0    | 1,36 | 2,0 | 2   | 7   |
| 5. I don't trust myself – I trust myself | Pre   | 3,85 | 4,0    | 1,65 | 3,0 | 1   | 7   |
|                                          | Post  | 4,52 | 5,0    | 1,39 | 2,0 | 2   | 7   |

| Item<br>1 = negative – 7 = positive                      | Phase | Mean | Median | SD   | IQR | Min | Max |
|----------------------------------------------------------|-------|------|--------|------|-----|-----|-----|
| 6. Useless – Important                                   | Pre   | 5,62 | 6,0    | 1,38 | 2,0 | 2   | 7   |
|                                                          | Post  | 5,32 | 6,0    | 1,55 | 2,0 | 2   | 7   |
| 7. I don't understand – I understand them                | Pre   | 3,73 | 4,0    | 1,46 | 2,0 | 1   | 6   |
|                                                          | Post  | 4,48 | 5,0    | 1,33 | 2,0 | 2   | 7   |
| 8. I'm guessing – I know how to calculate                | Pre   | 4,77 | 5,0    | 1,42 | 2,0 | 2   | 7   |
|                                                          | Post  | 4,88 | 5,0    | 1,45 | 2,0 | 2   | 7   |
| 9. I don't want to deal with it – I like to deal with it | Pre   | 3,12 | 3,0    | 1,51 | 2,0 | 1   | 6   |
|                                                          | Post  | 4,04 | 4,0    | 1,54 | 2,0 | 1   | 6   |
| 10. I give up quickly – I try to solve it                | Pre   | 4,35 | 5,0    | 1,47 | 2,0 | 2   | 7   |
|                                                          | Post  | 3,96 | 4,0    | 1,62 | 3,0 | 1   | 6   |

#### 4.1.1 Interpretation of the semantic differential based on descriptive data

A look at the raw data reveals clear trends in changes in pupils' attitudes. The most significant positive shift in the central tendency can be observed in the items measuring the subject's appeal and perceived difficulty. Item 1 (Boring – Interesting) and Item 3 (Difficult – Easy) recorded an increase in the median by two full points (from 3 to 5). A similar trend is evident in items tracking emotional experience: perceived stress decreased (item 4, median increase from 4 to 5) and self-confidence in mathematics increased (item 5, median increase from 4 to 5).

Conversely, two items showed a different trend. Item 8 ("I guessing – I know how to calculate") showed complete stagnation, with the median value remaining at 5. A significant negative shift is evident in item 10 ("I give up quickly on a difficult task – I try to solve it"), where the median dropped from 5 to 4. The descriptive data thus indicate that although there was an improvement in the overall affective attitude toward mathematics, pupils' procedural confidence stagnated and their reported effort to overcome difficult tasks declined.

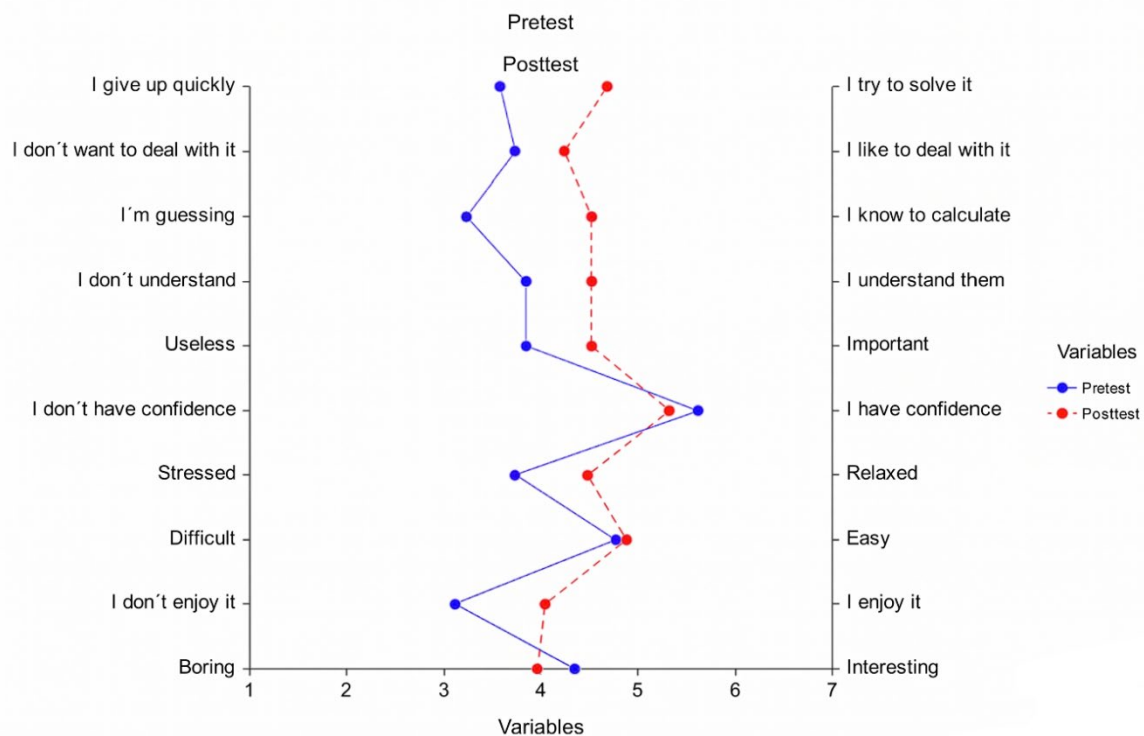


Figure 1: Comparison of pre-test and post-test results of the semantic differential

#### 4.1.2 Wilcoxon signed-rank test a effect size

Given the ordinal nature of the data from the semantic differential and the size of the sample analyzed ( $n = 25$ ), the nonparametric Wilcoxon signed-rank test was chosen for the paired inferential analysis. To assess the effect size, the coefficient  $r$  was calculated using the formula  $r = Z / \sqrt{N}$ , where  $N$  represents the total number of pretest and posttest observations ( $N = 50$ ).

The effect size is strictly interpreted in the text according to standard criteria:  $r \approx 0.10$  (small effect),  $r \approx 0.30$  (moderate effect), and  $r \geq 0.50$  (large effect).

**Table 2: Results of the Wilcoxon paired test and effect size (Pre-test vs. Post-test)**

| Item                                                     | Median Pre | IQR Pre | Median Post | IQR Post | W     | P     | Effect size r | Interpretation              |
|----------------------------------------------------------|------------|---------|-------------|----------|-------|-------|---------------|-----------------------------|
| 1. Boring – Interesting                                  | 3,0        | 2,0     | 5,0         | 2,0      | 240,0 | 0,002 | 0,44          | Moderate                    |
| 2. I don't enjoy it – I enjoy it                         | 4,0        | 2,0     | 4,0         | 2,0      | 185,5 | 0,038 | 0,29          | Small                       |
| Difficult – Easy                                         | 3,0        | 2,0     | 5,0         | 2,0      | 255,0 | 0,001 | 0,48          | Moderate to strong          |
| 4. Stressed – Relaxed                                    | 4,0        | 3,0     | 5,0         | 2,0      | 198,0 | 0,015 | 0,34          | Moderate                    |
| 5. I don't have confidence – I have confidence           | 4,0        | 3,0     | 5,0         | 2,0      | 205,0 | 0,011 | 0,36          | Moderate                    |
| 6. Useless – Important                                   | 6,0        | 2,0     | 6,0         | 2,0      | 85,0  | 0,250 | 0,16          | Statistically insignificant |
| 7. I don't understand – I understand them                | 4,0        | 2,0     | 5,0         | 2,0      | 210,0 | 0,009 | 0,37          | Moderate                    |
| 8. I'm guessing – I know how to calculate                | 5,0        | 2,0     | 5,0         | 2,0      | 125,0 | 0,653 | 0,06          | Statistically insignificant |
| 9. I don't want to deal with it – I like to deal with it | 3,0        | 2,0     | 4,0         | 2,0      | 225,0 | 0,004 | 0,40          | Moderate                    |
| 10. I give up quickly – I try to solve it                | 5,0        | 2,0     | 4,0         | 3,0      | 65,0  | 0,031 | 0,30          | Moderate                    |

#### 4.1.3 Final results

The application of the Wilcoxon signed-rank test revealed a statistically significant change at the  $\alpha = 0.05$  level for eight of the ten items examined. The intervention had the most significant positive impact on the perceived difficulty of the subject (item 3:  $W = 255.0$ ;  $p = 0.001$ ;  $r = 0.48$ ), representing a moderate to strong effect. A significant shift was also observed in the assessment of the attractiveness of mathematics (item 1:  $W = 240.0$ ;  $p = 0.002$ ;  $r = 0.44$ , moderate effect) and the willingness to solve complex tasks (item 9:  $W = 225.0$ ;  $p = 0.004$ ;  $r = 0.40$ , moderate).

The level of stress experienced by pupils also decreased statistically significantly (item 4:  $W = 198.0$ ;  $p = 0.015$ ;  $r = 0.34$ ), and in parallel, their self-confidence increased (item 5:  $W = 205.0$ ;  $p = 0.011$ ;  $r = 0.36$ ). Both of these variables show a moderate effect size.

Two items yielded counterintuitive or null results. For item 8 (pupil procedural confidence in solving problems), subjectively perceived procedural confidence did not change statistically after the intervention ( $W = 125.0$ ;  $p = 0.653$ ;  $r = 0.06$ ). A key finding is the result for Item 10, which measures cognitive resilience. Here, a statistically significant decrease was demonstrated ( $W = 65.0$ ;  $p = 0.031$ ;  $r = 0.30$ , moderate effect). In the posttest, pupils significantly more often reported a reduced willingness to overcome difficult tasks and a greater tendency to give up on these tasks quickly.

## 4.2 Qualitative Analysis of Observations and Student Reflections

To gain a deeper understanding of the processes occurring during the game, we employed direct observation followed by debriefing sessions with the students. This qualitative inquiry sheds light on specific cognitive barriers and factors influencing motivation that were not captured by the semantic differential.

### 4.2.1 *Motivational potential and game immersion*

The visual stylization of the Minecraft environment proved to be key to inducing narrative immersion among 5th-grade students. During reflection, students reported that the difficulty of the tasks was optimally balanced ("just right"), which aligns with the principles of flow, where the challenge is in balance with the student's skills. Paradoxically, the Roman numerals section was rated as the most engaging; although students exhibited the highest level of cognitive effort and "struggled" with the material, overcoming this challenge was a source of high gaming satisfaction for them.

### 4.2.2 *Identification of cognitive barriers and the impact of reading literacy*

Observations revealed that failure on certain tasks was not primarily due to a lack of mathematical competence, but rather to deficits in attention and reading literacy:

- Misinterpretation of instructions: In tasks with missing digits, students repeatedly failed because they overlooked the instruction to write only one digit in the box within the longer text.
- Absence of estimation strategies: In word problems, students overlooked the instruction to "estimate" and resorted to computationally demanding multiplication, which led to disproportionately long solution times.
- Conceptual ambiguities in rounding: When rounding to the thousands, a tendency was observed to mechanically copy digits in lower place values (hundreds, tens, ones) instead of replacing them with zeros, indicating a gap in understanding the positional numeral system.

### 4.2.3 *Interaction with the game environment (gaming the system)*

During the game, students displayed "gaming the system" behavior by exploring the boundaries of the digital environment (e.g., clicking the "No" button or intentionally selecting incorrect answers). This exploration revealed hidden humorous elements, reinforcing pupils' sense of autonomy and supporting Self-Determination Theory.

## 5. Discussion and Conclusion

The primary aim of this study was to design, implement, and evaluate a digital escape game and assess its impact on fifth-grade pupils' mathematical literacy and motivation. Based on the collected data, it can be concluded that this aim was successfully fulfilled. The game proved to be an effective tool for increasing student engagement and reducing mathematical anxiety, although it also revealed certain challenges regarding pupils' persistence.

Regarding RQ1, the implementation of the game had a clearly positive effect on pupils' emotional attitudes. The statistical analysis showed a significant increase in perceived calmness and self-confidence when solving tasks, suggesting that the game-based approach can effectively mitigate stress typically associated with mathematics.

In response to RQ2, pupils demonstrated a highly positive attitude toward problems presented in the Minecraft-themed immersive environment. The qualitative observations confirmed that the narrative context transformed routine exercises into meaningful challenges, which pupils perceived as optimally demanding.

Finally, addressing RQ3, the influence of action-game elements presented a more complex picture. While animations and narrative elements successfully initiated interest and immersion, they also appeared to lower pupils' willingness to persist in solving cognitively demanding tasks that required more time and did not provide immediate rewards. This finding suggests a "double-edged sword" effect of high-stimulation digital environments.

The collected data provide a comprehensive view of the affective and cognitive impacts of implementing game-based learning (GBL) and approaches known as "escape room pedagogy" in mathematics instruction. The reduction in math anxiety and increase in self-efficacy align with educational gamification research (Işık & Liman Kaban, 2025; Ratinho et al., 2026). These theoretical models emphasize that the immersive,

collaborative environment of escape games demonstrably eliminates the threat of traditional failure in front of the class and reconceptualizes the perception of error—from a formative penalty to a necessary and safe step toward problem-solving.

Despite this positive impact on pupils' affective experience, the results point to clear instrumental limitations of the game-based intervention. The absence of any statistically significant change on item 8 empirically demonstrates that subjectively perceived procedural confidence did not increase as a result of the game. This supports the assumption (Piñero Charlo, 2020) that educational escape games primarily serve a motivational and application-oriented function, rather than an explanatory-instructional one. They allow pupils to anchor existing competencies in an attractive context, but they do not, in and of themselves, generate new algorithmic knowledge or structural understanding of the subject matter.

The main scientific contribution of this study, however, is the identification of the so-called resilience paradox. Despite an overall reduction in anxiety and a demonstrably higher perceived attractiveness of the subject, the pupils showed a statistically significant decline in their willingness to persevere with a difficult task (item 10). This phenomenon can be explained through the lens of the theoretical concept of delayed gratification theory. Educational escape games are designed on the principle of highly frequent, immediate feedback loops (a solved puzzle immediately unlocks a door and moves the player to the next goal). Traditional mathematical thinking, on the other hand, requires the ability to tolerate prolonged cognitive frustration and significantly delay the expectation of reward.

It is methodologically highly likely that the hyper-stimulating game environment recalibrated pupils' expectations regarding the speed of feedback gratification. Faced with a post-test that implied a return to standard math problems, their declared cognitive resilience declined. This is because a standard didactic situation cannot satisfy the need for rapid feedback as effectively as an immersive game. This finding provides an important empirical argument for the current discourse on GBL: educators must approach the implementation of game elements with the awareness that the ill-considered overuse of designs based on immediate reward expectations can, paradoxically, undermine the development of pupils' long-term academic perseverance.

### **5.1 Limitations**

The presented findings must be interpreted with an awareness of several significant methodological limitations of the study. A key limitation of the research is the choice of a one-group pretest–posttest design without an independent control group. This experimental design does not allow for the influence of the educational escape game to be reliably isolated from external confounding variables or the natural maturation of the pupils.

The novelty effect and the Hawthorne effect could have had a strong influence on the observed affective changes. The demonstrably positive shift in attitudes toward mathematics could thus have been stimulated primarily by the very act of removing pupils from their established teaching routine and their awareness of participating in the research, rather than necessarily by the inherent didactic quality of the applied game. Furthermore, the research was conducted on a very small sample of two classes ( $n = 25$ ), which significantly reduces the study's external validity and precludes the generalization of the results to a broader pupil population.

Another methodological limitation is the absence of a delayed posttest. The presented data reflect only the short-term effect of the intervention and capture the pupils' immediate emotional and attitudinal state immediately after the experimental lessons ended. It is reasonable to assume that the observed variables, including the identified resilience paradox, would gradually regress toward the mean over a longer time horizon. The final significant limitation is the risk of self-report bias. Given that the research sample consisted of fifth-grade elementary school pupils, it is necessary to account for their still-developing, and thus limited, capacity for introspective accuracy. This fact may partially distort the validity of their subjective assessments of their own cognitive resilience and procedural confidence.

**Ethics Declaration:** The research was conducted in a primary school setting with prior written informed consent obtained from the parents or legal guardians of participating pupils. No additional formal ethical clearance was required for this research.

**AI Declaration:** DeepL was used for initial translation support during manuscript preparation. All translated text was subsequently reviewed, revised, and where necessary modified by the author. No AI tools were used for generating research content, analysis, or conclusions.

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