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Let's Escape! The Impact of a Digital-Physical Combined Escape Room on Students' Creative Thinking, Learning Motivation, and Science Academic Achievement

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Abstract: Digital and physical escape rooms have been suggested as practical and effective approaches to game-based learning and have recently gained momentum. The deficit of scholarly works that simultaneously implement both types of escape rooms legitimizes this study's significance and appropriateness. The researchers systematically combined digital and physical escape rooms and integrated them into fifth-grade science lessons (experimental group N = 22; control group N = 21). Considering that creative thinking is one of the essential competencies in the competitive world, learning motivation is a crucial factor contributing to students' learning, and academic achievement is a criterion for learning outcomes. The Torrance Test of Creative Thinking (fluency, flexibility, originality, and elaboration), the Learning Motivation Scale (value, expectation, affect, and executive volition), and the science achievement exam were used to quantitatively investigate students' learning effectiveness. The results indicated that the experimental group's creative thinking and learning motivation outperformed the control group significantly. Nonetheless, both groups showed no significant difference in science academic achievement. The present study verifies that a digital–physical combined escape room is an effective and practical approach that has the potential to be widely used in schools to benefit students' learning. Some discussions, educational implications, and suggestions for future studies and practices are offered.

Keywords: game-based learning; escape room; creative thinking; learning motivation; science academic achievement

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1. Introduction

Children not only enjoy themselves while playing a game but also learn in the process of playing. Rushton and King [1] indicated that play is a pedagogical vehicle for learning STEM subjects. Garaigordobil and Berrueco [2] also found that play can develop children's creative thinking. Game-based learning and gamification are considered feasible methods to develop students' 21st-century skills (e.g., critical thinking and collaboration), stimulate learning motivation, and promote a sense of enjoyment in learning [3,4]. Among various kinds of game-based learning, escape rooms have gained momentum in education practices and research recently. Nicholson [5] defined escape rooms as "live-action team-based games where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal (usually escaping from the room) in a limited amount of time". Recreational escape rooms originated in Japan in 2007 and grew rapidly from 2012–2013 [5]. Borrowing from the concept of a recreational escape room, teachers create a compelling narrative and embed knowledge into several puzzles, in which students are required to use course materials and knowledge to solve a series of puzzles and then find a way/code to succeed in an escape room [6]. Educational escape rooms have been increasingly integrated into courses since 2017 [7,8], and their application encompasses various fields, including programming [6], mathematics [9], medication [10,11], and social science [12].

Educational escape rooms have received attention in these years and are still in the early stage. Educators usually encounter some challenges when designing escape rooms: the requirement of broad space and specific equipment, the consumption of much time in preparing and conducting escape rooms, and the difficulty in embedding learning objectives into puzzles [13]. In a regular school setting, it is sometimes a challenge for teachers to iron out the abovementioned problems. Considering these, some educators have started using digital escape rooms, in which students can enjoy escape rooms through online platforms everywhere. Teachers can organize an escape room without concern for space and equipment limitations. However, it is believed that physical and digital escape rooms have their own separate strengths and constraints. For example, digital escape rooms cannot provide students with hands-on experience, authentic work environments, or a feeling of "escaping" from a room in the same way physical escape rooms can [14]. To augment student learning effects, educators can conduct digital and physical escape rooms sequentially, letting their strengths complement each other.

Although some studies have claimed that escape rooms can effectively develop students' creative thinking [15], they have not conducted experimental activities to test the effect scientifically. There is a need for empirical evidence about how escape rooms affect students' creative thinking [14]. Recently, creative thinking has received more and more emphasis due to the dire need for innovation in industries. Creative thinking refers to the ability to generate novel and valuable ideas that can lead to positive change [16]. Generally, creative thinking includes four abilities: fluency, flexibility, originality, and elaboration [17]. These abilities are indispensable for students to survive in the highly competitive world. Learning motivation is also a critical factor influencing students' learning. Students with high motivation are willing to overcome every bottleneck and persist in their studies [18]. This study aims to systematically design digital and physical escape rooms, conduct them, and examine their impact on the students' creative thinking, motivation, and academic achievement.

Past scholarly work primarily focused on adults, especially undergraduate students, but the effectiveness of escape rooms on primary school students was seldom explored. Makri et al. [7] reviewed the prior research and indicated that there is a need to investigate the impact of escape rooms on primary school students. Lathwesen and Belova [14] found that most studies did not use a comparison and treatment group design. The empirical evidence of escape rooms' learning effect is still inadequate and requires more comparison and treatment group design in this field. To bridge the research gap, the researchers appropriately designed physical and digital escape rooms based on the escapeED framework [19], which was conducted with reference to the steps of an educational escape room activity [20]. The current study employed a quasi-experimental design to examine the impact of the escape room intervention on primary school students' learning in science lessons. The followings are the questions of the research:

1. Is there any difference between the experimental and control groups in the students' creative thinking (fluency, flexibility, originality, and elaboration)?
2. Is there any difference between the experimental and control groups in the students' learning motivation (value, expectation, affect, and executive volition)?
3. Is there any difference between the experimental and control groups in the students' science academic achievement?

1.1. The Benefits of Digital and Physical Escape Rooms

Physical and digital escape rooms have their own strengths and constraints. The prior studies found several benefits of using a physical educational escape room in students' learning, for instance, consolidating content knowledge; triggering students' learning interests, enjoyment, and motivation; and cultivating their communication skills [8,14]. Moreover, the immersive environment and the simulation of authentic work situations in escape rooms can provide students with hands-on experience [21]. The immersive learning environment is a crucial strength for physical escape rooms, as most existing digital settings are considered to be low-tech and cannot provide an immersive experience [14]. However, there are some limitations and challenges when educators design escape rooms, including budget restrictions, classroom and specific equipment availability, the limited number of players, materials that need to be multiplied, and investment of time [7,13,22].

Digital escape rooms have also received tremendous attention recently, as educators can design and conduct a digital escape room without worrying about the limitations of space and specific equipment. As with physical escape rooms, digital escape rooms can also be used to stimulate students' collaboration and motivation and contribute to knowledge acquisition [7,23,24]. However, it is difficult for educators to design complicated digital puzzles as they design a physical escape room. For instance, students do not need to find a tangible item or unlock a real chest in digital puzzles, and some digital puzzles are produced by Google Forms [25,26]. Digital puzzles can be regarded as a battery of tests for individuals in which students do not need to work in a group [24]. The benefit is that they can be easily designed to examine students' content knowledge in specific fields directly. Makri et al. [7] said that "*digital puzzles required players to write or execute codes, allowing them to test and improve skills (e.g., programming skills), whereas physical puzzles are of great help for enhancing both the immersion of the experience and student engagement in the narrative.*" Furthermore, in a remote-learning setting, educators cannot ensure that students complete each puzzle without outside help (e.g., looking up answers on a cell phone or the internet) or "carrying" other students [25].

Past scholarly works have theoretically identified that puzzle-driven escape rooms can help improve a student's learning motivation, key competencies, and many high-order capabilities, including creativity, communication, and academic achievement. The potential effects/impacts and restrictions concerning the employment of physical escape rooms and digital ones are articulated and discussed, which helped the current study to develop a theoretical foundation for the merger of physical and digital escape rooms. Physical and digital escape rooms both have a positive impact on students' learning, and it is believed that both types of escape rooms have their own pros and cons (see Figure 1). The best way to conduct an escape room may be to combine physical and digital rooms, complementing each other and maximizing the students' learning. Thus, based on the past scholarly works and theoretical foundation, the study held physical and digital escape rooms sequentially in elementary school science classes. It is hypothesized, with theoretical support, that the intervention can contribute to the student's creative thinking, learning motivation, and academic achievement.

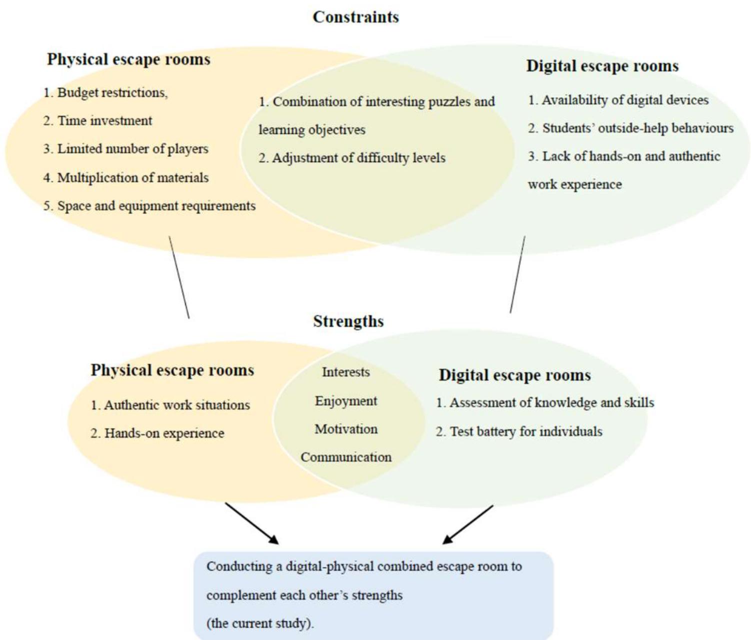


Figure 1. The constraints and strengths of physical and digital escape rooms.

1.2. The Design of Escape Rooms

The origin of educational escape rooms is an adaptation of recreational games. Therefore, most existing research has not designed escape rooms from theory or frameworks [8]. It is essential for educators to adopt a game-based framework and carefully design escape rooms so that students' game experiences can link to learning goals and key competencies [7]. Clarke et al. [19] proposed the EscapED framework, including six stages that should be considered when designing escape rooms: Participants, Objectives, Theme, Puzzles, Equipment, and Evaluation. In the Participants stage, designers should analyze the demography of targeted players, difficulty levels, and mode. Then, the learning objectives of the games need to be set. These may be academic achievements or soft skills (e.g., creative thinking and communication). Furthermore, to maintain players' motivation and interests, designers should develop a compelling narrative in the Theme stage. In the Puzzle stage, the most challenging part, designers have to design interesting puzzles, and all puzzles should reflect learning objectives. In addition, instructions, rules, and hints should be determined. In the Equipment stage, designers must think about specific equipment and props (including digital devices and real-life actors) needed in the game. The last stage is Evaluation, in which educators have to determine which methods and tests are used to evaluate participants' learning outcomes. Besides the five stages mentioned above, Botturi and Babazadeh [13] identified five game elements (narrative, game-flow, puzzles, equipment, and learning process) and four context elements (players, constraints, evaluation, and debriefing). Educators must consider all elements before conducting escape rooms in their classes.

Once narratives and puzzles are determined, educators should think about the procedure to conduct escape rooms. Abdul Rahim et al. [20] proposed five steps for typical educational escape rooms: (a) a pre-activity test assessment, (b) a game briefing, (c) the ER activity, (d) a post-activity knowledge assessment and perception survey, and (e) a debriefing. Pre- and posttests are essential to examine escape rooms' effects scientifically. Lathwesen and Belova [14] found that only a few studies used pre–post surveys to measure escape rooms' learning effect and affective outcomes. There is a need for more empirical evidence in this field. The game briefing stage refers to instructions before the outset of the game. Moore and Campbell [21] indicated that students might feel confused if a game does not have a clear start. The confusion may lead to students' non-success in games. At the end of escape rooms, a debriefing is a crucial part and cannot be neglected, in which players talk about their feelings, ask questions, and discuss the game [5]. To help students connect game experience and learning objectives, teachers can discuss puzzles and talk about content knowledge behind each puzzle. Without a debriefing stage, the discrepancy between perceived goals and actual goals may be caused.

2. Method and Material

2.1. Participants

There were 22 (10 boys and 12 girls) students in the experimental group and 21 (10 boys and 11 girls) in the control group. All the participants were fifth graders (11–12 years old) from two classes in Taiwan. The participants had not experienced an educational escape room; thus, it was a new task and experience for the students.

2.2. The Design of the Escape Rooms

To ensure educational escape rooms were appropriately developed and reflected learning objectives, the current study followed the six stages of the escapeED framework [19] to design digital and physical escape rooms. Six components in the framework were considered: Participants, Objectives, Theme, Puzzles, Equipment, and Evaluation. A brief description of each stage is shown inTable 1. The researchers thoroughly thought about each stage and carefully designed escape rooms according to each component. The following section introduces a detailed introduction of digital and physical escape rooms.

Table 1. The introduction of the six stages (Participants, Objectives, Theme, Puzzles, Equipment, and Evaluation) of the escapeED framework in the study.

Stage		Digital Escape Room	Physical Escape Room
Participants	User Type	Elementary school fifth graders in an urban school.	
	Time	30 min	40 min
	Difficulty	The puzzles cannot be too complicated to solve, as the participants were elementary school fifth graders. The primary purpose of the escape rooms was to stimulate students' learning motivation in science lessons.	
	Mode	Cooperation based.	
	Scale	22 students.	
Objectives	Learning Objectives	Science academic achievement: (a) Discerning and understanding the properties of acid and alkaline solutions. (b) Understanding the concepts and applications of force and friction.	
	Solo/Multidisciplinary	One discipline: science.	
	Affective Skills	Learning motivation.	
	Soft Skills	Creative thinking.	
Theme	Mode	Escaping a locked room within a set time.	
	Narrative Design	An evil scientist kidnapped students and put them into a mysterious laboratory. Students had to escape the laboratory.	
	Standalone/Nested:	A one-off session	
Puzzles	Learning Objectives	Each puzzle required students to use what they learned in the previous science lesson to find the answer. Therefore, before escape rooms, the students had some time to review the previously taught lesson.	
	Instructions	Before the escape rooms, the teacher explained the rules of the games to help students know how to "escape."	
	Clues/Hints	Students just needed to use scientific knowledge to solve every puzzle sequentially.	Once students solved a puzzle, they could get a clue for the next puzzle. The teacher would provide a hint if they did not know what they should do.
Equipment	Location/Space Design	Students participated in digital escape rooms in a computer classroom.	Students participated in an escape room in a class, which was big enough for students to walk around (see Figure 5).
	Physical Props	The riddles were shown on computers. In addition, there were cards for each puzzle. Only with the cards could the participants find the correct answers (see Figure 4).	Students manipulated different items in every puzzle. For example, in the first puzzle, students had to find four conical flasks and test tubes and use purple cabbage juice to identify the acidity and alkalinity of solutions.
	Technical Props	Students needed computers to join the digital escape rooms.	-

Table 1. *Cont.*

Stage		Digital Escape Room	Physical Escape Room
Evaluation	Testing	Two science teachers tested the escape rooms before students participated.	
	Reflection	After the escape room intervention, the teacher helped students reflect on what knowledge was embedded in the puzzles.	
	Evaluate Learning Objectives	The pre- and posttests were conducted to examine students' improvement in creative thinking, learning motivation, and academic achievement.	

2.2.1. Digital Escape Rooms

Two digital escape rooms for two science lessons ("Aqueous Solution" and "Force and Motion") were developed and conducted on the Holiyo platform (https://holiyo.tn.edu.tw/game/game_platform/login.html, accessed on 9 August 2022), which allowed teachers to design their own escape rooms for students. The home page of the escape rooms is shown in Figure 2. Dark red and black were adopted as background colors to create a mysterious atmosphere. The two digital escape rooms each had six puzzles (see Figure 3). Besides the digital escape rooms, the teacher also designed cards for each puzzle. Students worked in groups of three and had to use knowledge about "Aqueous Solution" and "Force and Motion" to solve puzzles. After each digital escape room, a debriefing was conducted to help students reflect on what they learned during the escape room.

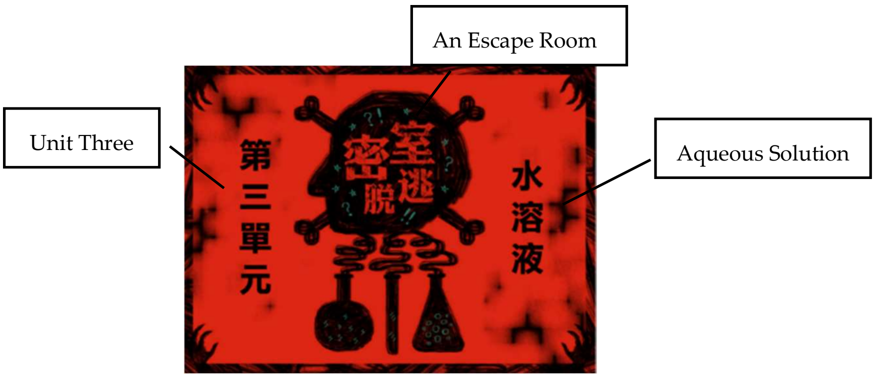


Figure 2. The homepage of the digital escape rooms.

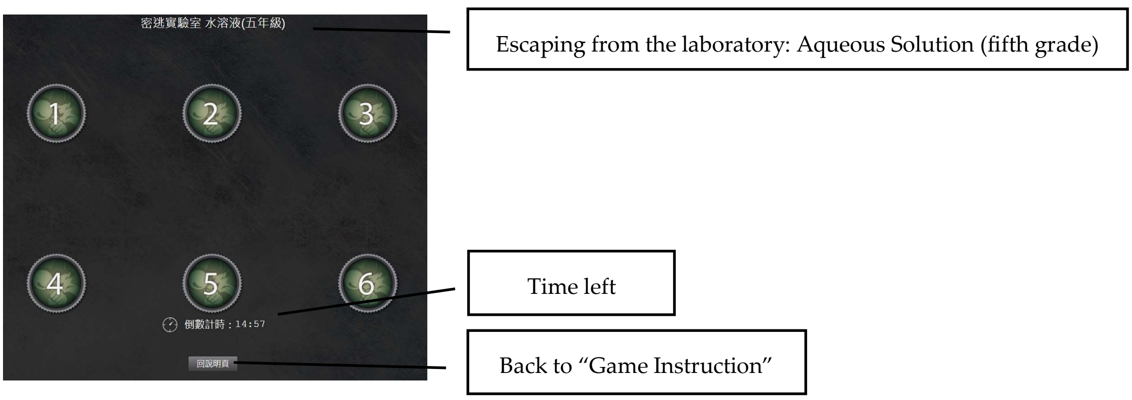
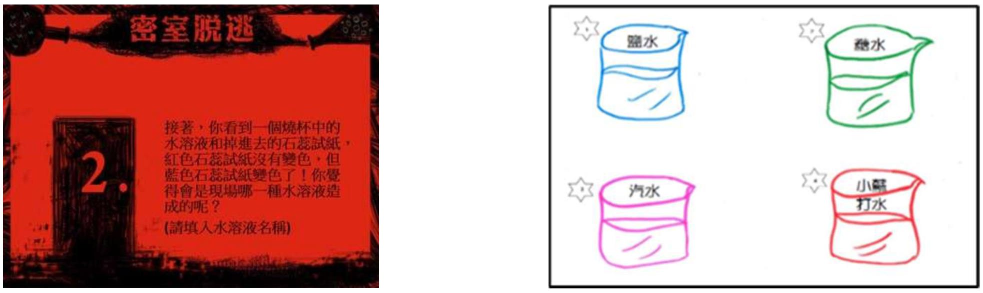


Figure 3. The interface of the digital escape rooms. There were six puzzles in the digital escape rooms. The bottom of the page shows the time left.

The narrative of the first digital escape room for "Aqueous solution" was that students were kidnapped by an evil scientist and put into a mysterious laboratory. There were various solutions and documents scattered on the ground. To escape from the laboratory, students had to discern the acid and alkaline solutions and determine the conductive solutions that could help them open an electric door and then escape. An example of a puzzle is shown in Figure 4. In the puzzle, students had to identify which solutions were acid and alkaline. Students had four cards representing a saline solution, sugar water, soda water, and baking soda, and they had to enter the correct answer to the puzzle. In the "Force and Motion" digital escape room, the game began with the narrative that the students were caught again by the evil scientist and put into a totally different laboratory. This time, students had to use their knowledge of "Force and Motion" to solve six puzzles and then escape from the laboratory.



(**a**) (**b**)

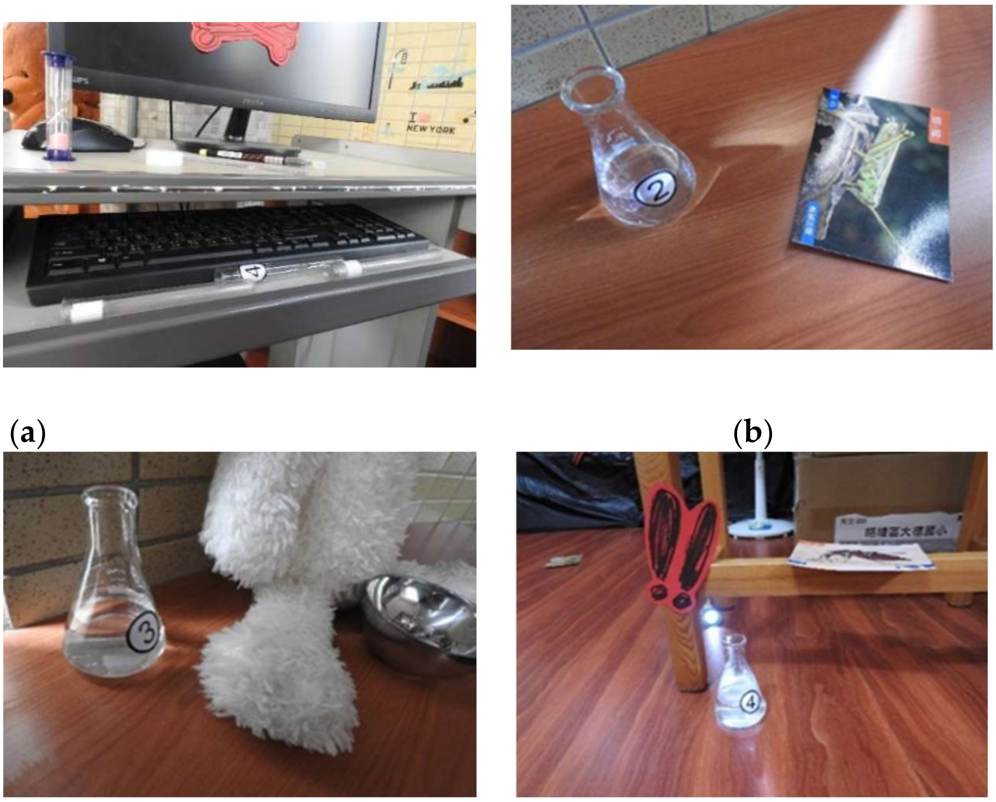
Figure 4. An example of a puzzle and corresponding cards. (**a**) Description of the question and the English translation in the puzzle: You found a solution in a beaker with litmus papers in it. The color of a red litmus paper did not change, but a blue litmus paper turned red. Which solution may be in the beaker? (Enter the name of the solution). (**b**) Description of the cards used in the first digital escape room and the English translation: A saline solution (blue), sugar water (green), soda water (purple), and baking soda (red).

2.2.2. Physical Escape Rooms

The teacher arranged a classroom for a physical escape room, with five puzzles in the room. All props and equipment were scattered around the room (see Figure 5). All puzzles required students to use what they learned from two science lessons, "Aqueous Solution" and "Force and Motion." Students worked in groups of three and had to find items they needed to solve each puzzle, get a code, and then escape from the room.

Figure 5. A panorama of the physical escape room.

The five interconnected puzzles used in the physical escape room were as follows: In the first puzzle, students needed to find four conical flasks with different solutions (see Figure 6). Then, students dripped purple cabbage juice into each solution to identify whether the solutions were acid or alkaline. The solutions turned into different colors according to the degree of acidity and alkalinity, and the different colors represented different codes on the wallpaper (see Figure 7). Students decoded the meaning of the colors according to the clues on the wallpaper and then obtained a password to unlock the first chest (see Figure 8), in which there was a clue for the next puzzle. In order to help the students to link what they learned with the problems encountered in real-life scenarios, the students were asked to solve real-world problems. In the second puzzle, students learned how to measure weight. Students were provided with a spring balance. The chest code was the total weight of the items hidden in dolls scattered in the room. In the hands-on problem-solving task, the students needed to appropriately apply the knowledge of weight and weight measurement to the task (see Figure 9). In the third puzzle, students needed to use litmus papers to examine the acid and alkali levels of different daily solutions (soda water and juice). While acidic water made the litmus paper red, the alkaline solution made it blue. The students used the instrument to identify the acid and alkaline levels of the solutions and find the correct code to unlock the treasure chest (see Figure 10). In the fourth puzzle, students learned about the concept of velocity in daily life (e.g., the meaning of km/hr) and the different characteristics and speeds of different kinds of transportation (e.g., railway and plane). The code was hidden in a world map. Only when the students identified different velocities and transport characteristics could they resolve the puzzle and obtain the code from the map (see Figure 11). In the fifth puzzle, students categorized different kinds of force and movement states in daily life (e.g., kicking a football, dribbling a basketball, pressing clay, stretching a spring). The correct classification enabled the students to find the correct code (see Figure 12).



(a) (b) (c) (d)

Figure 6. Conical flasks and test tubes in the escape room: Different conical flasks and test tubes were scattered and hidden in the escape room. Students had to find them in the first puzzle. (**a**) A test tube hidden behind the keyboard. (**b**) A conical flask on a desk. (**c**) A conical flask hidden behind a doll. (**d**) A conical flask hidden under a table.

Figure 7. The poster shows different codes behind different colors. Different solutions showed different colors when students dripped the purple cabbage juice into them. Students used the wallpaper to decode the meaning of the colors.

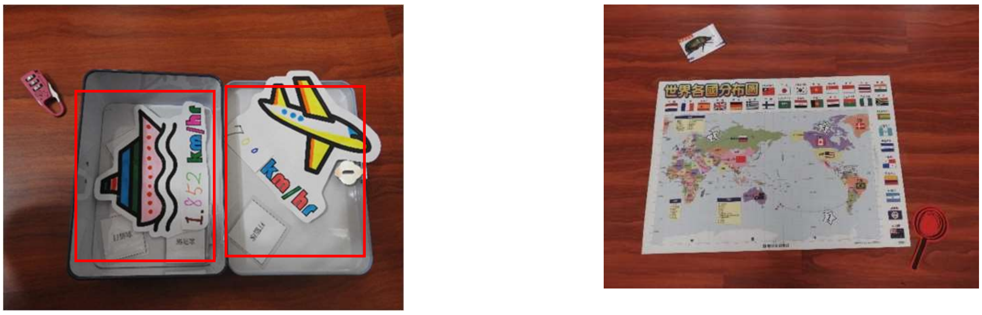
Figure 8. Chest in the first puzzle. Once students figured out the code in the first puzzle, they could use the code to unlock the chest and get the clue for the next puzzle.

(**a**) (**b**) (**c**)

Figure 9. Dolls and spring balance in the second puzzle. (**a**) A spring balance scale: students were asked to find components of the spring balance scale and assemble them. (**b**,**c**) The two soft toys: Students had to use the spring balance scale to measure the precise weights of the items from the two soft toys.

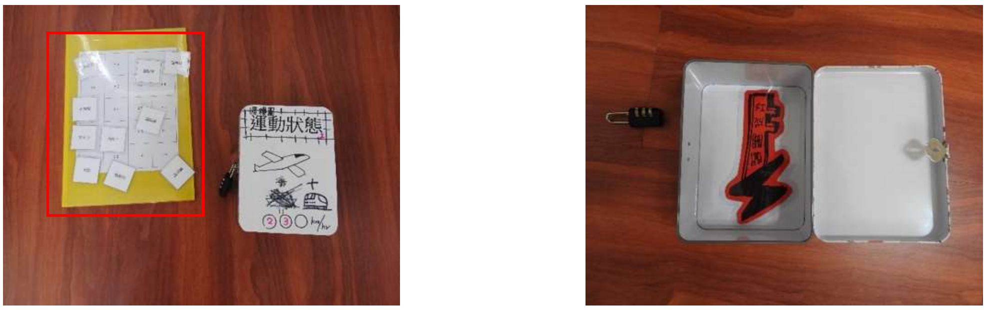
(**a**) (**b**)

Figure 10. Litmus papers in the third puzzle. Students were asked to use litmus papers to examine the acid and alkali levels of different daily solutions (soda water and juice). The correct identification of the acid and alkaline levels in the solutions enabled the students to unlock the treasure chest and successfully enter the next puzzle—"Motion and Transport." (**a**) Litmus papers in a treasure chest. (**b**) The riddle card in the puzzle.



(**a**) (**b**)

Figure 11. Different transport cards and a world map in the fourth puzzle. (**a**) Students were asked to identify the different velocities and transport characteristics. (**b**) Once they could identify the different velocities and transport characteristics, they could figure out the puzzle and get a code from the map.



(**a**) (**b**)

Figure 12. Cards for different kinds of force and the last treasure chest. (**a**) Students had to correctly classify various kinds of force in daily life and arrange the cards appropriately. (**b**) The correct classification enabled the students to unlock the last treasure chest.

2.3. Research Instruments

2.3.1. The Chinese Version of the Torrance Test of Creative Thinking (Chinese TTCT)

The students' creative thinking was measured by the Chinese TTCT [27], one of the most widely used creative thinking tests. The indicators of the test are as follows. (a) Fluency refers to the number of different ideas. (b) Flexibility refers to the diverse categories of ideas. (c) Originality refers to the novelty (a statistical rarity) of ideas. (d) Elaboration refers to the number of additional ideas added to the responses.

The test included two subtests. (a) Figural test: Respondents were asked to develop as many visual designs as possible based on a given Chinese character, "人" ("Ren", which means a human in Chinese). The subtest measured respondents' four creativity dimensions: fluency, flexibility, originality, and elaboration. Each dimension's reliability (Cronbach's α) was 0.96, 0.94, 0.86, and 0.91, respectively. (b) Verbal test: Respondents have to think about unusual uses of bamboo chopsticks. The subtest measured respondents' three creativity dimensions: fluency, flexibility, and originality. The reliability (Cronbach's α) of each dimension was 0.99, 0.95, and 0.91, respectively.

2.3.2. Learning Motivation Scale (LMS)

The students' learning motivation was measured using the Learning Motivation Scale (LMS) [28], a five-point Likert scale. There are four subscales with 35 items in total. The subscales are as follows. (a) Value refers to students' perceptions of the importance and usability of the lesson. There are seven items in the section. An example of a question: "I believe that reading academic books is important for students." (b) Expectation refers to students' expectations for their success or failure in their academic learning. There are six items in the section. An example of a question: "I think I can learn academic knowledge well all the time." (c) Affect refers to students' positive/negative affections when learning and studying. There are ten items in the section. An example of a question: "I enjoy reading academic books." (d) Executive volition refers to students' ability to control their behaviors and thoughts to maintain their engagement in academic learning. There are 16 items in the section. An example of a question: "Although I feel tired when doing homework, I persist in writing until I finish it." The reliability (Cronbach's α) of each dimension was 0.89, 0.87, 0.94, and 0.90, respectively.

2.3.3. Science Achievement Exam

The science achievement exam was developed by teachers to assess students' science academic achievement in science lessons thrice a semester. Students had 60 min to complete the test. The first and second achievement tests were used as pre- and posttests in the study. The first test topic consisted of two parts: "The Observation of the Sun" and "The World of Plants," while the second test was composed of "Aqueous Solution" and "Force and Motion." The first test served as a criterion to examine whether the experimental and control group students' science academic performances were similar before the intervention. To ensure the exams' content validity, teachers developed two-way specification tables according to four of Bloom's [29] categories in the cognitive domain when developing the tests, including Knowledge (8 items), Comprehension (10 items), Application (13 items) and Analysis (5 items). The reliability (Cronbach's α) of the first test was 0.78, and the second test was 0.71.

2.4. Experimental Procedure

A pretest–posttest control group design was used to investigate students' creative thinking, learning motivation, and science academic achievement. The schedule of the experimental procedure is shown in Table 2. Students in the experimental and control groups participated in a ten-week science lesson for 120 min each week, in which two digital escape rooms and one physical escape room were held for the experimental group during the science lesson. The science topics included "Aqueous Solution" and "Force and Motion". Before teaching the first science topic, the teacher conducted the pretest, in which students spent 60 min completing the Chinese TTCT and 20 min on the LMS.

Table 2. The schedule of the experimental procedure.

<table>
<tr><th>Week</th><th>Experimental Group
(22 Students)</th><th>Control Group
(21 Students)</th></tr>
<tr><td>Pretest</td><td colspan="2">Creative thinking (60 min)
Learning motivation (20 min)
Science achievement exam (60 min)</td></tr>
<tr><td>1</td><td rowspan="4">Science lesson: Aqueous Solution</td><td rowspan="5">Science lesson: Aqueous Solution</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td><td>The first digital escape room</td></tr>
<tr><td>6</td><td rowspan="3">Science lesson: Force and Motion</td><td rowspan="5">Science lesson: Force and Motion</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td><td>The second digital escape room</td></tr>
<tr><td>10</td><td>The physical–digital escape room</td></tr>
<tr><td>Posttest</td><td colspan="2">Creative thinking (60 min)
Learning motivation (20 min)
Science achievement exam (60 min)</td></tr>
</table>

After the pretest, the escape room intervention was implemented on the experimental group. The difference between the experimental and control groups was the implementation of escape rooms. Both groups learned the same science topics taught by the teacher using the same teaching method (didactic instruction and group discussion). The first science topic was "Aqueous Solution," The students learned about the properties of acid and alkaline solutions and how to use acid-based indicators. The first digital escape room was conducted in the experimental group after the students learned the course materials of the first lesson. After the first digital escape room, the science lesson moved to the next topic, "Force and Motion." Students learned what velocity and friction are, how to measure force and weight (e.g., using spring balance), and the application of friction in our lives. The second digital escape room was employed when the lesson was finished. To help students review what they learned in the previous lessons, the teacher designed a physical escape room and then held it in the last week. All escape rooms required students to use what they learned in the science lessons to solve puzzles and "escape" from the room.

After the intervention, a posttest was implemented. Students took the Chinese TTCT for 60 min and the LMS for 20 min. The researchers did not conduct science achievement tests in person, as the tests were conducted by the school to assess whole-school student science learning. After receiving all the data, the researchers analyzed the collected data to examine the impact of the intervention on students' creative thinking, learning motivation, and science academic achievement.

Abdul Rahim et al. [20] proposed that typical educational escape rooms comprise five steps: a pre-activity test/survey, a game briefing, an escape room activity, a post-activity test/survey, and a debriefing. The current study referred to these steps when conducting both digital and physical escape rooms each time. The digital and physical escape room intervention session is shown in Table 3.

Table 3. The session of digital and physical escape rooms.

Session	Purpose	Time
A pretest/survey	The researchers conducted the pretest during the pretest week (see Table 2.)	80 min
Review	All puzzles required students to use scientific knowledge learned in the science lessons. The teacher helped students review the previously taught lesson, helping them remember what they had learned.	30 min
Game briefing	The teacher introduced the escape room's rules and divided students into groups of three.	20 min
Escape rooms	Students participated in escape rooms.	Digital rooms: 30 min Physical rooms: 40 min
Debriefing	After students finished the escape rooms, the teacher helped students reflect on what knowledge was embedded in the puzzles. This reflection stage consolidated knowledge retention.	30 min
A posttest/survey	The researchers conducted the posttest during the posttest week (see Table 2.)	80 min

3. Result

The paired sample *t*-test and covariance analysis (ANCOVA) were used to test the collected quantitative data. The paired sample *t*-test was carried out to examine improvements in the students' creative thinking, learning motivation, and science academic achievement in the experimental and control groups. One-way ANCOVA was performed to determine whether there was a significant difference in students' creative thinking, learning motivation, and academic achievement between the two groups.

3.1. Creative Thinking

The paired sample *t*-test result of the TTCT (verbal test) is shown in Table 4. The result showed a significant improvement in the experimental group's overall creative thinking, fluency, flexibility, and originality, while no significant improvement was found in the control group's overall creative thinking, fluency, flexibility, and originality. The results indicated that room escape intervention can significantly enhance students' creative thinking. The ANCOVA result of the TTCT (verbal test) is shown in Table 5. There were significant differences between the experimental and control groups' overall creative thinking, fluency, and flexibility, while no statistical difference was found in the aspect of originality. A high effect size was found in overall creative thinking ($\eta 2 = 0.41$) and each dimension, fluency ($\eta 2 = 0.49$), flexibility ($\eta 2 = 0.56$), and originality ($\eta = 0.16$).

Table 4. Result of the paired sample *t*-test on creative thinking (verbal test).

Variable	Experimental Group							Control Group						
	Pretest		Posttest		Paired *t*-Test			Pretest		Posttest		Paired *t*-Test		
	M	SD	M	SD	t	d	diff.	M	SD	M	SD	t	d	diff.
Overall	147.40	18.64	178.93	32.96	−4.92 *	1.18	post > pre	138.3	18.58	134.02	14.28	0.935	0.26	n.s.
Fluency	48.54	6.83	61.24	10.82	−5.86 *	1.40	post > pre	45.46	6.08	44.29	4.35	0.745	0.22	n.s.
Flexibility	48.82	6.89	61.36	9.26	−7.21 *	1.54	post > pre	45.36	7.07	43.97	5.55	0.801	0.22	n.s.
Originality	50.04	6.82	56.33	14.78	−2.06	0.55	n.s	47.57	6.84	45.76	5.57	1.05	0.29	n.s

* $p < 0.05$ Effect sizes (ES): d = 0.2–0.5 (small effect), d = 0.5–0.8 (moderate effect), and d ≥ 0.8 (large effect) [30].

Table 5. Result of ANCOVA on creative thinking (verbal test).

Group	Experimental Group	Control Group	ANCOVA		
	Adjusted M	**Adjusted M**	**F**	η^2	**Post hoc**
Overall	178.93	134.02	28.16 *	0.41	experimental > control
Fluency	61.24	44.29	39.12 *	0.49	experimental > control
Flexibility	61.36	43.97	50.03 *	0.56	experimental > control
Originality	56.33	45.76	7.78	0.16	n.s.

* $p < 0.05$. Effect size (ES): $0.01 \leq \eta^2 \leq 0.059$ (small effect), $0.059 \leq \eta^2 \leq 0.138$ (moderate effect), and $\eta^2 \geq 0.138$ (large effect) [30].

The paired sample *t*-test result of the TTCT (Figural test) is shown in Table 6. The result showed a significant improvement in the experimental group's overall creative thinking, fluency, flexibility, and originality, but not in elaboration. No significant improvement was found in the control group's overall creative thinking, fluency, flexibility, originality, and elaboration. The result indicated that the intervention can significantly increase students' creative thinking. The ANCOVA result of the TTCT (figural test) is shown in Table 7. There were statistical differences between the experimental and control groups' overall creative thinking, fluency, flexibility, originality, and elaboration. A high effect size was found in overall creative thinking (η2 = 0.54), fluency (η2 = 0.46), flexibility (η2 = 0.61), and originality (η2 = 0.43), while there was a medium effect in size elaboration (η2 = 0.12). The result indicated that the experimental group students outperformed the control group students in the creative thinking test after the escape room intervention on the experimental group.

Table 6. Result of the paired sample *t*-test on creative thinking (figural test).

Variable	Experimental Group							Control Group						
	Pretest		**Posttest**		**Paired *t*-Test**			**Pretest**		**Posttest**		**Paired *t*-Test**		
	M	**SD**	**M**	**SD**	**t**	**d**	**diff.**	**M**	**SD**	**M**	**SD**	**t**	**d**	**diff.**
Overall	191.55	14.18	236.93	35.91	−7.26 *	1.66	post > pre	187.93	20.72	187.93	20.72	1.20	0.35	n.s.
Fluency	46.34	4.05	61.87	11.92	−7.52 *	1.75	post > pre	46.16	5.42	46.16	5.42	0.60	0.19	n.s.
Flexibility	46.92	6.89	6.96	61.64	−11.5 *	1.73	post > pre	46.13	6.81	46.13	6.81	0.74	0.21	n.s.
Originality	47.03	5.54	59.10	14.71	−4.48	1.09	post > pre	47.27	5.63	47.27	5.63	0.78	0.21	n.s
Elaboration	51.25	8.06	54.32	14.52	−0.93	0.26	n.s.	48.36	8.68	48.36	8.68	1.45	0.38	n.s.

* $p < 0.05$ Effect sizes (ES): d = 0.2–0.5 (small effect), d = 0.5–0.8 (moderate effect), and d ≥ 0.8 (large effect) [30].

Table 7. Result of ANCOVA on creative thinking (figural test).

Group	Experimental Group	Control Group	ANCOVA		
	Adjusted M	**Adjusted M**	**F**	**η2**	**Post hoc**
Overall	236.93	182.24	46.74 *	0.54	experimental > control
Fluency	0.22 †	0.07 †	34.52 *	0.46	experimental > control
Flexibility	0.99 †	0.62 †	62.39 *	0.61	experimental > control
Originality	3.08 †	1.48 †	29.94 *	0.43	experimental > control
Elaboration	54.32	45.79	5.62 *	0.12	experimental > control

* $p < 0.05$ † Nonlinear transformation Effect size (ES): $0.01 \leq \eta^2 \leq 0.059$ (small effect), $0.059 \leq \eta^2 \leq 0.138$ (moderate effect), and $\eta^2 \geq 0.138$ (large effect) [30].

3.2. Learning Motivation

The paired sample *t*-test result of the LMS is shown in Table 8. The result showed a significant improvement in the experimental group's overall learning motivation, value, expectation, affect, and executive volition, while no significant improvement was found in the control group's overall learning motivation, value, expectation, and affection. In addition, the control group's executive volition was significantly decreased. The result indicated that escape room intervention can enhance students' learning motivation in all aspects.

The ANCOVA result of the LMS is shown in Table 9. There was a statistical difference in the two groups' overall learning motivation, affect, and executive volition but not in value and expectation. A high effect size was found in overall learning motivation (η = 0.29) and affection (η = 0.20), while a medium effect size was found in value (η = 0.06), expectation (η = 0.07), and volition (η = 0.11). The result indicated that experimental group students had a higher learning motivation, especially the affect and executive volition dimensions, than control group students after the escape room intervention.

Table 8. Result of the paired sample *t*-test on learning motivation.

Variable	Experimental Group							Control Group						
	Pretest		Posttest		Paired *t*-test			Pretest		Posttest		Paired *t*-test		
	M	SD	M	SD	t	d	diff.	M	SD	M	SD	t	d	diff.
Overall	129.140	23.76	148.00	21.87	−5.70 *	0.83	post > pre	141.48	15.52	133.05	24.06	1.74	0.42	n.s.
Value	27.82	5.42	31.82	5.00	−2.87 *	0.77	post > pre	30.00	4.01	29.71	5.49	0.21	0.06	n.s.
Expectation	22.27	5.16	23.86	4.28	−2.31 *	0.34	post > pre	23.43	4.17	22.43	4.51	0.84	0.23	n.s
Affect	39.00	10.60	42.91	7.99	−2.99 *	0.42	post > pre	38.24	6.96	36.71	8.08	0.92	0.20	n.s.
Volition	40.05	9.77	49.41	9.26	−3.72 *	0.98	post > pre	49.81	6.26	44.19	11.28	2.29 *	0.62	post > pre

* $p < 0.05$ Effect sizes (ES): d = 0.2–0.5 (small effect), d = 0.5–0.8 (moderate effect), and d ≥ 0.8 (large effect) [30].

Table 9. Result of ANCOVA on learning motivation.

Group	Experimental Group	Control Group	ANCOVA		
	Adjusted M	Adjusted M	F	η2	Post hoc
Overall	133.05	148.00	16.30	0.29	experimental > control
Value	29.71	31.82	2.43	0.06	n.s
Expectation	22.43	23.86	2.95	0.07	n.s
Affection	36.71	42.91	9.90 *	0.20	experimental > control
Volition	49.41	44.19	5.10 *	0.11	experimental > control

* $p < 0.05$ Effect size (ES): $0.01 \leq \eta^2 \leq 0.059$ (small effect), $0.059 \leq \eta^2 \leq 0.138$ (moderate effect), and $\eta^2 \geq 0.138$ (large effect) [30].

3.3. Science Academic Achievement

The paired sample *t*-test result of the science achievement exam is shown in Table 10. The result revealed a significant improvement in both the experimental and control groups' academic achievement, indicating that students who received and did not receive the escape room intervention had a significant improvement in their science academic achievement.

Table 10. Result of the paired sample *t*-test on science academic achievement.

Variable	Experimental Group							Control Group						
	Pretest		Posttest		Paired *t*-Test			Pretest		Posttest		Paired *t*-Test		
	M	SD	M	SD	t	d	diff.	M	SD	M	SD	t	d	diff.
Overall	81.36	12.61	87.41	7.22	3.02 *	0.59	post > pre	81.90	10.89	86.57	11.53	−2.66 *	0.42	post > pre

* $p < 0.05$ Effect sizes (ES): d = 0.2–0.5 (small effect), d = 0.5–0.8 (moderate effect), and d ≥ 0.8 (large effect) [30].

The ANCOVA result of the science achievement exam is shown in Table 11. There was no statistical difference between the experimental and control groups' science academic achievement, and a small effect size was found (η = 0.002). The result indicated that the experimental group students did not outperform the control group students in academic achievement after the escape room intervention in the experimental group. However, both groups' academic achievement could improve significantly.

Table 11. Result of ANCOVA on science academic achievement.

Group	Experimental Group	Control Group	ANCOVA		
	Adjusted M	Adjusted M	F	η2	Post hoc
Overall	7621.33 †	7690.05 †	0.08	0.002	n.s

* $p < 0.05$ † Nonlinear transformation. Effect size (ES): $0.01 \leq \eta^2 \leq 0.059$ (small effect), $0.059 \leq \eta^2 \leq 0.138$ (moderate effect), and $\eta^2 \geq 0.138$ (large effect) [30].

4. Discussion

The primary aim of the study was to examine the impact of the escape room intervention on students' creative thinking, learning motivation, and academic achievement. There was a significant difference between the experimental and control groups' creative thinking (see Tables 5 and 7). The result also indicated that the experimental group students' three dimensions of creative thinking significantly improved, including fluency, flexibility, and originality (see Tables 4 and 6). Although some articles reported escape rooms' positive effects on students' creative thinking, they seldom scientifically conducted experimental interventions to collect empirical evidence, or they omitted control groups [15]. Therefore, this study bridges the research gap by quantitatively examining the escape room intervention's impact on students' creative thinking. In the study research, students worked in groups to solve several puzzles in an escape room. The problem-solving process requires individuals to think about every possible solution. In addition, teammates' ideas could stimulate their thoughts, helping them consider a matter or a question from various perspectives. As Torrance [31] mentioned, the problem-solving process can be regarded as an exhibition of creative thinking.

Learning motivation is a crucial factor contributing to students' learning. The escape room intervention resulted in better learning motivation for students in the experimental group compared to the control group. Regarding each dimension, the results indicated that there was a significant difference in students' "affect" and "executive volition" but they were nonsignificant in the dimensions of "value" and "expectation". Students who received the escape room intervention had a positive affect when learning. The finding corroborated the prior scholarly work that found escape rooms can contribute to students' positive affections and emotions (e.g., fun, enjoyment, and amusement) when they study [12,23,25]. In the research of Huang et al. [32], they found that digital escape room-infused teaching primarily and positively impacted students' "affect" dimension for learning science but did not impact the "executive volition" dimension. The possible explanation might be that Huang et al. only conducted digital escape rooms (on the Holiyo platform) in the lesson. In addition, according to the students' responses, they suggested adjusting the difficulty level of the game. The research by Huang et al. [32] shed light on the constraints of digital escape rooms. It is challenging for teachers to design complicated digital puzzles and immersive settings as physical ones [14]. As shown in Figure 1, the strength of digital puzzles is in assessing students' knowledge and skills acquisition but not providing an immersive and hands-on experience. Gómez-Urquiza et al. [22] and Macías-Guillén et al. [33] found that students in physical escape rooms are motivated to strive for accomplishments and do high-demand things. The current study conducted digital and physical escape rooms sequentially. In the physical one, students were placed in a messy and mysterious room. They had to find clues and specific items and manipulate various experiments (using litmus paper and a spring balance) to solve every puzzle. The combination of physical and digital escape rooms yielded a more powerful impact on the students' motivation. Students motivated themselves and had a willingness to overcome every bottleneck when learning.

Although no significant difference in academic achievement was yielded between the experimental and control groups (see Table 11), the paired *t*-test results revealed that both the experimental and control group students' science academic achievements significantly improved (see Table 10). Similar results were found in prior studies [21,24,34–37], in which participants who experienced escape rooms had a significant improvement in their learning outcomes, demonstrating that escape rooms can effectively contribute to students' knowledge acquisition and retention of knowledge [9]. However, the prior scholarly work seldom included a control group; thus, it was difficult for them to compare the results with other groups and conclude that an escape room intervention can help students learn better and outperform students who do not experience escape rooms. In contrast to a previous finding [9], no significant difference was yielded in academic achievement between the experimental and control groups. The evidence indicated that whether escape rooms are implemented or not, students can learn well in science lessons. However, it should be noted that the science achievement exams primarily assessed students' knowledge retention, not high-order thinking skills. The results may differ if future studies systematically assess students' high-order thinking, such as synthesis and evaluation. Despite the non-significant difference between the two groups, both groups had significantly improved science academic achievement. In addition, according to the result, escape room intervention can contribute to other cognitive and affective skills, such as creative thinking and learning motivation.

Limitations and Implications for Future Study

The research included a limited number of participants due to the limitations of classrooms and equipment. Future research should include more students if approved by the school administration. Secondly, the research was conducted pretest and posttest but not postpone-test. It is essential to investigate whether escape rooms have a long-term effect on students' learning. Escape rooms are a nascent and emergent game-based teaching method. A novel effect should be noted in this field [10]. Students' learning motivations and affections might not be triggered once they become accustomed to escape rooms. Lastly, future research can include qualitative data to corroborate quantitative data and thoroughly understand why and how escape rooms can impact students' learning, identifying components contributing to their creative thinking, motivation, and academic achievement.

Moreover, the primary aim of an escape room is not only to provide a hands-on experience but also to simulate real-world scenarios. It is essential for educators and researchers to integrate real-world tasks in escape rooms so that students may know how to use their knowledge and understand the link between course materials and daily life. For instance, campus-based escape rooms can be developed to help students apply their knowledge in surrounding areas, manipulate experiments, and come up with creative solutions for real-world problems.

5. Conclusions

While digital and physical escape rooms are suggested as practical and effective approaches to game-based learning, it is challenging to find studies that implement both types of escape rooms—the deficit of scholarly works legitimizes this study's significance and appropriateness. The study implemented a digital and physical combined escape room to complement each other's strengths, verifying that this approach can improve students' learning quality; fill the research gap; and potentially make theoretical, methodological, and practical contributions to the knowledge and field. Evidence indicated that the digital–physical combined approach can effectively improve students' creative thinking, stimulate their learning motivations (especially their affection and executive volition in learning), and improve their academic achievement. This study also opens a dialogue on the platforming of digital learning and life scenario problem-solving for better educational practices.

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