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The Impact of Escape Room Activities on Grade 7 Students' Performance in Separation Techniques of Mixtures

Amani Walid Kattouaa

Lebanese University-Faculty of Education Deanery, Beirut, Lebanon

amani_kattouaa@hotmail.com

Abstract

Teaching the separation techniques of mixtures presents challenges in chemistry education, for middle school students. These challenges arise from the abstract nature of the concepts, the use of complex scientific terminology, and the limited perceived relevance to students' everyday lives. Moreover, many schools face restricted access to laboratory resources, which hinders students' ability to engage in hands-on activities that could enhance their understanding. To overcome these obstacles, educators have begun integrating innovative strategies such as educational escape rooms. These game-based learning activities encourage active participation, collaboration, and critical thinking, transforming traditional lessons into engaging, interactive experiences that promote deeper learning. This study explores the impact of an educational escape room on the academic performance of Grade 7 students in learning the separation methods of mixtures. A quasi-experimental design was employed, involving 105 students from a private school in Beirut. They were divided into two groups: an experimental group (n = 53), which participated in the escape room activity, and a control group (n = 52), which received traditional instruction. Both groups completed pre-tests and post-tests to measure their understanding before and after the intervention. Nonparametric statistical analysis revealed no significant difference in pre-test scores (p = 0.797), confirming comparable baseline knowledge. However, post-test results showed a significant advantage for the experimental group (p = 0.001), which achieved a higher mean rank (63.18) than the control group (42.63). These results suggest that escape rooms can enhance students' comprehension. Future studies should examine long-term retention, motivation, and use across other science topics.

Keywords

Separation Techniques, Escape Room, Game-Based Learning, Academic Performance, Chemistry Education

Résumé

L’enseignement des techniques de séparation des mélanges représente un défi en chimie au collège. Ces difficultés découlent de la nature abstraite des concepts, de l’usage d’une terminologie scientifique complexe et du lien limité perçu avec le quotidien des élèves. En outre, de nombreuses écoles disposent d’un accès restreint aux ressources de laboratoire, ce qui limite les possibilités pour les élèves de participer à des activités pratiques favorisant une meilleure compréhension. Pour répondre à ces obstacles, les enseignants adoptent des stratégies innovantes comme les jeux d’évasion pédagogiques. Ces activités ludiques favorisent l’engagement actif, la collaboration et la pensée critique, transformant les leçons classiques en expériences interactives qui encouragent un apprentissage plus profond. Cette étude examine l’impact d’un escape game pédagogique sur la performance académique d’élèves de 7e année dans l’apprentissage des méthodes de séparation des mélanges. Un devis quasi expérimental a été utilisé auprès de 105 élèves d’une école privée à Beyrouth. Ils ont été répartis en deux groupes : un groupe expérimental (n = 53), ayant participé à l’escape game, et un groupe témoin (n = 52), ayant reçu un enseignement traditionnel. Les deux groupes ont passé un prétest et un post-test pour évaluer leur compréhension avant et après l’intervention. L’analyse statistique non paramétrique n’a révélé aucune différence significative entre les scores du prétest (p = 0,797), indiquant un niveau de départ équivalent. Toutefois, les résultats du post-test ont montré un avantage significatif en faveur du groupe expérimental (p = 0,001), avec une moyenne plus élevée, suggérant une meilleure compréhension.

Mots-clés

Techniques de séparation, Salle d’évasion, Apprentissage par le jeu, Performance académique, Enseignement de la chimie

مُستخلص

يُعَدُّ تَعْلِيمُ تَقْنِيَّاتِ فَصْلِ الْمَخَالِيطِ مِنَ التَّحَدِّيَاتِ الْبَارِزَةِ فِي تَعْلِيمِ الْكِيمْيَاءِ، خُصُوصًا لِلطُّلَّابِ فِي الْمَرْحَلَةِ الْمُتَوَسِّطَةِ. تَنْبُعُ هَذِهِ التَّحَدِّيَاتُ مِنْ طَبِيعَةِ الْمَفَاهِيمِ الْمُجَرَّدَةِ، وَاسْتِخْدَامِ الْمُصْطَلَحَاتِ الْعِلْمِيَّةِ الْمُعَقَّدَةِ، بِالإِضَافَةِ إِلَى ضَعْفِ ارْتِبَاطِهَا بِالْحَيَاةِ الْيَوْمِيَّةِ لِلطُّلَّابِ، مِمَّا يَجْعَلُ اسْتِيعَابَهَا أَمْرًا صَعْبًا وَمُعَقَّدًا. عَلَى سَبِيلِ الْمِثَالِ، تُوَاجِهُ الْعَدِيدَ مِنَ الْمَدَارِسِ مَحْدُودِيَّةً فِي الْوُصُولِ إِلَى الْمَوَارِدِ الْمَخْبَرِيَّةِ، مِمَّا يُعِيقُ قُدْرَةَ الطُّلَّابِ عَلَى تَنْفِيذِ الْأَنْشِطَةِ الْعَمَلِيَّةِ الَّتِي تُعَزِّزُ مِنْ فَهْمِهِمُ النَّظَرِيِّ. هَذِهِ الْعَوَائِقُ قَدْ تُؤَثِّرُ سَلْبًا عَلَى تَحْصِيلِهِمُ الْأَكَادِيمِيِّ وَاهْتِمَامِهِمْ بِالْمَادَّةِ الْعِلْمِيَّةِ وَالْعَمَلِيَّةِ أَيْضًا. وَلِمُعَالَجَةِ هَذِهِ الصُّعُوبَاتِ، بَدَأَ الْمُعَلِّمُونَ بِتَطْبِيقِ اسْتِرَاتِيجِيَّاتٍ تَعْلِيمِيَّةٍ مُبْتَكَرَةٍ مِثْلَ غُرَفِ الْهُرُوبِ التَّعْلِيمِيَّةِ، وَهِيَ أَنْشِطَةٌ تَعْلِيمِيَّةٌ تَعْتَمِدُ عَلَى الْأَلْعَابِ. تُعَدُّ استراتيجيّة غُرَفُ الْهُرُوبِ وَسِيلَةً فَعَّالَةً تُشَجِّعُ عَلَى الْمُشَارَكَةِ النَّشِطَةِ، وَالْعَمَلِ الْجَمَاعِيِّ، وَالتَّفْكِيرِ النَّقْدِيِّ، مِمَّا يُحَوِّلُ الدُّرُوسَ التَّقْلِيدِيَّةَ إِلَى تَجَارِبَ تَعْلِيمِيَّةٍ تَفَاعُلِيَّةٍ وَمُمْتِعَةٍ تُعَزِّزُ مِنْ عُمْقِ التَّعَلُّمِ وَالْفَهْمِ وَالاسْتِيعَابِ. تَتَنَاوَلُ هَذِهِ الدِّرَاسَةُ أَثَرَ اسْتِخْدَامِ غُرْفَةِ الْهُرُوبِ التَّعْلِيمِيَّةِ عَلَى الْأَدَاءِ الْأَكَادِيمِيِّ لِطُلَّابِ الصَّفِّ السَّابِعِ فِي تَعَلُّمِ طُرُقِ فَصْلِ الْمَخَالِيطِ. تَمَّ اسْتِخْدَامُ تَصْمِيمٍ شِبْهِ تَجْرِيبِيٍّ شَمِلَ ١٠٥ طُلَّابٍ مِنْ مَدْرَسَةٍ خَاصَّةٍ فِي بَيْرُوتَ، قُسِّمُوا إِلَى مَجْمُوعَتَيْنِ: تَجْرِيبِيَّةٍ (عَدَدُهَا ٥٣) شَارَكَتْ فِي نَشَاطِ غُرْفَةِ الْهُرُوبِ، وَضَابِطَةٍ (عَدَدُهَا ٥٢) تَلَقَّتْ تَعْلِيمًا تَقْلِيدِيًّا. خَضَعَ الطُّلَّابُ لاخْتِبَارَاتٍ قَبْلِيَّةٍ وَبَعْدِيَّةٍ لِقِيَاسِ مُسْتَوَى الْفَهْمِ قَبْلَ وَبَعْدَ التَّدَخُّلِ. أَظْهَرَتِ التَّحْلِيلَاتُ الإِحْصَائِيَّةُ غَيْرُ الْمَعْلَمِيَّةِ عَدَمَ وُجُودِ فُرُوقٍ دَالَّةٍ إِحْصَائِيًّا فِي نَتَائِجِ الاخْتِبَارِ الْقَبْلِيِّ (الْقِيمَةُ الاحْتِمَالِيَّةُ = ٠.٧٩٧)، مِمَّا يَدُلُّ عَلَى تَسَاوِي الْمَعْرِفَةِ الْمُسْبَقَةِ بَيْنَ الْمَجْمُوعَتَيْنِ. فِي الْمُقَابِلِ، أَظْهَرَتْ نَتَائِجُ الاخْتِبَارِ الْبَعْدِيِّ تَفَوُّقًا مَلْحُوظًا لِلْمَجْمُوعَةِ التَّجْرِيبِيَّةِ (الْقِيمَةُ الاحْتِمَالِيَّةُ = ٠.٠٠١). تُشِيرُ النَّتَائِجُ بِوُضُوحٍ إِلَى فَاعِلِيَّةِ غُرَفِ الْهُرُوبِ فِي تَحْسِينِ الْفَهْمِ. وَيُوصَى بِإِجْرَاءِ دِرَاسَاتٍ لَاحِقَةٍ حَوْلَ أَثَرِهَا الْبَعِيدِ عَلَى الدَّافِعِيَّةِ، وَالتَّحْصِيلِ، وَتَنْمِيَةِ التَّفْكِيرِ الْعِلْمِيِّ.

كلمات مفتاحية

تِقْنيّات الفَصْل، غُرْفَة الهُروب، التَّعلُّم القائم على اللَّعب، الأداء الأكاديمي، تَعليم الكِيمياء

1. Introduction

Teaching separation techniques - such as filtration, distillation, and chromatography - at the middle school level presents unique instructional challenges. These methods often appear abstract and disconnected from students' everyday experiences, making them difficult to grasp (Hartman, 2022). The challenge is further compounded by limited access to laboratory resources in many schools, restricting opportunities for hands-on experimentation and conceptual development (Grancharova, 2024). In response, educators have increasingly adopted Game-Based Learning (GBL), a pedagogical approach that integrates game mechanics-such as rules, goals, feedback, and time constraints-to enhance student engagement and academic achievement (Schrader, 2023). A notable application of GBL is the educational escape room, which embeds subject matter into immersive, time-sensitive narratives requiring critical thinking, collaboration, and problem-solving (Makri, 2021). These structured, goal-oriented experiences have shown promise in increasing engagement and fostering cognitive development across disciplines (Grepperud, 2025). This study investigates the impact of educational escape rooms on Grade 7 students' performance in learning separation techniques in chemistry. The guiding research question is: How do escape room activities influence student performance in mastering separation techniques? It is hypothesized that students participating in escape room-based instruction will demonstrate greater academic improvement than those receiving traditional instruction.

1.1. Literature Review

1.1.1. Educational Escape Rooms

Educational escape rooms are instructional activities that engage students in a gamified learning environment. Participants collaborate to solve curriculum-aligned puzzles and tasks within a set timeframe and narrative structure (Vorderobermeier, 2024). Originally created for entertainment, escape rooms have been adapted for classrooms due to their capacity to promote engagement through active, experiential learning (Taraldsen, 2020). When integrated with academic objectives, they foster critical thinking, communication, and deeper interaction with content (Kim, 2024).

1.1.2. Types of Educational Escape Rooms

Educational escape rooms come in different formats, each suitable for specific teaching needs. Immersive escape rooms aim to replicate the original recreational experience by using themed settings and props to increase student involvement (Christopoulos et al., 2023). Paper-based escape rooms use printed puzzles and little or no technology, which makes them practical for schools with limited resources (Carroll & Morse, 2022). Digital escape rooms are fully online, making them useful for distance education or lessons that include digital tools (Clapson et al., 2024). Condensed escape activities are shorter and focus on one learning goal, while keeping students engaged through interactive tasks (Clare, 2016). Breakout boxes are portable kits with puzzles and locks that can be reused, often provided through platforms like Breakout EDU (O′Szabo et al., 2022). In some cases, students create their own escape rooms to show their understanding of a topic, which encourages creative thinking and deeper learning (Veldkamp et al., 2020). These different types show how flexible escape rooms can be in promoting active and student-focused learning.

1.1.3. Escape Rooms in Chemistry Education

Numerous studies have demonstrated the effectiveness of escape rooms in chemistry education. Lathwesen and Belova (2024) developed Acid Base Global, an escape room focused on acid–base reactions and Brønsted–Lowry theory, which led to increased student interest and improved conceptual understanding. Similarly, Elford et al. (2022) incorporated augmented reality into a chemical bonding-themed escape room, which enhanced motivation and comprehension. Naumoska, Dimeski, and Stojanovska (2023) reported that a digital escape room on thermal reactions significantly improved students' conceptual grasp, engagement, and teamwork. Haimovich et al. (2022) found that embedding chemical principles in a historically themed virtual escape room promoted sustained attention and deeper connections to content. These findings suggest that well-structured, contextually relevant escape rooms can support active, student-centered learning in complex chemistry topics.

1.1.4. Assessing the Educational Impact of Escape Rooms: Challenges and Limitations

Despite growing evidence of their benefits, the academic impact of escape rooms remains mixed. Although they reliably increase motivation and engagement (Veldkamp, 2020), their effect on deep conceptual understanding is inconsistent. Vörös and Sárközi (2017) observed that students often retained surface-level information tied to puzzles, with limited long-term understanding unless reinforced through follow-up instruction. Similarly, Mills and King (2019) and Giang et al. (2019) found escape rooms more effective as review tools rather than primary instruction for new material. Additionally, the lack of rigorous assessment methods poses a challenge. Many studies do not incorporate objective measures such as pre- and post-tests. For example, although Eukel et al. (2017) reported statistically significant gains following a pharmacy-themed escape room, they noted that competitive elements and preparatory activities may have influenced outcomes. These findings underscore the need for controlled studies evaluating both engagement and content mastery, particularly in foundational science areas.

1.2. Theoretical Framework

This study is grounded in Game-Based Learning (GBL), an approach that integrates game mechanics into educational experiences to promote engagement and learning (Plass et al., 2015). GBL is rooted in constructivist learning theory, which posits that knowledge is actively constructed through interaction, experience, and collaboration (Qian & Clark, 2016). Educational escape rooms embody this principle by transforming abstract concepts into interactive, socially mediated challenges (von Kotzebue et al., 2022). Situated learning theory further supports this approach, suggesting that meaningful learning occurs when content is embedded in authentic, real-world contexts (Lin Hui Quek et al., 2024). Escape rooms simulate such contexts, helping students connect theoretical chemistry concepts—like separation techniques—to practical applications. Finally, self-determination theory offers insight into the motivational effects of escape rooms. According to Shin and Johnson (2021), intrinsic motivation is enhanced when learners experience autonomy, competence, and relatedness. Escape rooms promote student agency, collaboration, and skill application, fostering persistence and engagement. Collectively, these frameworks justify the integration of educational escape rooms to support both motivation and conceptual understanding in middle school chemistry (Buchner et al., 2022). This study also aligns with the principles of action research, which emphasizes reflective, context-responsive practice carried out by educators in real-world classrooms. As a teacher-led intervention, the escape room activity reflects the action research aim of improving instruction through iterative, evidence-based inquiry rooted in the realities of teaching and learning (Ferland, 2019).

1.3. Significance of the Study

This study contributes to the growing body of research exploring innovative, student-centered strategies in science education. By focusing on the implementation of an educational escape room in a middle school chemistry context, it provides empirical evidence on how game-based methodologies can influence academic performance in a foundational yet often under-engaging topic—separation techniques. The findings offer practical insights for curriculum designers and educators seeking to enhance content delivery through experiential learning, especially in settings with limited laboratory infrastructure. Furthermore, the study addresses the need for controlled research on the effectiveness of immersive learning formats, bridging a gap in existing literature that often prioritizes engagement metrics over measurable academic outcomes. The approach also serves as a potential model for interdisciplinary adaptation in other science domains, promoting a shift from passive reception to active construction of knowledge.

2. Methodology

2.1. Research Design

This study employed a quasi-experimental pretest-posttest control group design to investigate the impact of a physical, hands-on educational escape room activity on Grade 7 students' understanding of separation techniques in chemistry. This design enabled a comparison of learning outcomes between an experimental group and a control group, thus allowing the identification of statistically significant differences attributable to the intervention. Additionally, the study was conducted within the framework of action research, as the intervention was implemented directly by the teacher-researcher in a real classroom setting with the aim of improving instructional practice. As such, the research not only sought to evaluate academic outcomes but also to inform pedagogical decision-making and enhance student engagement through innovative teaching strategies grounded in game-based learning.

2.2. Participants

The study involved 105 Grade 7 students from a private school in Beirut, selected through convenience sampling and randomly assigned to two groups. The experimental group (n = 53) participated in the escape room activity, while the control group (n = 52) received traditional instruction using textbooks, teacher-led discussions, and visual aids. All students had no prior formal instruction on the topic. Parental and student consent was obtained in accordance with ethical research guidelines, and the study was approved by the school administration.

2.3. Instruments

To assess students' conceptual understanding of separation techniques, the researchers developed a 20-item multiple-choice achievement test, which was used as both a pretest and a posttest. The instrument was aligned with the Grade 7 chemistry curriculum and focused on four primary separation methods: filtration, evaporation, distillation, and chromatography. Each item consisted of four answer choices with only one correct response, and the questions were intentionally designed to reflect a range of cognitive levels based on Bloom’s Taxonomy. Specifically, Items 1–10 assessed factual recall and conceptual understanding, Items 11–15 evaluated students’ ability to apply their knowledge to appropriate scenarios, and Items 16–20 focused on critical thinking and real-life situations that required analysis and decision-making. This structure ensured comprehensive coverage of both lower- and higher-order thinking skills related to the topic of separation techniques (see appendix A).

2.3.1. Validation and Piloting

To ensure content validity, the test was reviewed by three chemistry education experts. Their suggestions led to revisions in question wording, content alignment, and distractor plausibility. The revised version was piloted with 30 Grade 7 students at a similar school to test for clarity, completion time, and item difficulty. Students completed the test in 25–30 minutes. Based on pilot results, minor adjustments were made to improve language clarity and ensure age-appropriateness.

2.3.2. Scoring and Reliability

Each question was worth 1 point, for a total possible score of 15 points. The internal consistency of the instrument was calculated using Cronbach's Alpha, yielding a coefficient of $\alpha = 0.962$, indicating excellent reliability. This 15-item test provided a valid and reliable measure of student learning outcomes in both groups, allowing for a direct comparison of academic performance before and after the instructional intervention.

2.4. Procedure

To ensure curriculum integration, the escape room was designed around four core separation techniques—filtration, evaporation, distillation, and chromatography—with each station reflecting stages of the scientific method: predicting outcomes, conducting experiments, analyzing results, and solving conceptual challenges. Visual prompts, manipulatives, and real laboratory tools were embedded to support multimodal learning and engage diverse learners. The teacher's role shifted from content deliverer to facilitator, promoting student autonomy and collaborative exploration. The study was conducted over three weeks, aligned with the school's chemistry timetable of two instructional periods per week. In Week 1, all students completed a 20-item multiple-choice pretest (see Appendix A) to assess baseline understanding. The experimental group then received an orientation covering learning objectives, safety guidelines, and game structure. Students were organized into teams of four with assigned roles (e.g., team leader, materials manager, recorder, clue solver) to enhance collaboration and accountability. Each team received a station map, overview handout, and role-specific instructions. The escape room consisted of four sequential stations, each featuring a hands-on experiment and a content-based puzzle to unlock progression. Examples included decoding a numerical lock using recovered salt mass or matching chromatographic colors to a code (see Appendix B). Time limits were applied to maintain pacing and challenge. In contrast, the control group received the same content through traditional instruction with textbook resources and teacher explanation. In Week 2, both groups performed identical laboratory procedures; however, the experimental group engaged through the gamified escape room, while the control group followed conventional teacher-led methods. Week 3 involved review: the experimental group participated in a debriefing that emphasized problem-solving, teamwork, and real-world application, while the control group underwent a guided teacher-led review. In the final session, students completed a posttest identical in structure to the pretest (see Appendix A). The two-week interval between instruction and assessment was intentional to assess retained understanding rather than short-term recall.

2.5. Data Analysis

To assess the effect of the educational escape room on students' academic performance, quantitative data in the form of post-test scores were collected from both the experimental group (escape room participants) and the control group (traditional instruction). The tests measured students' understanding and application of separation techniques in chemistry, particularly focusing on procedural knowledge through hands-on tasks. Data were analyzed using IBM SPSS Statistics. An inferential statistic was used to examine each group's performance. To determine whether there was a statistically significant difference between the groups, an independent samples t-test was conducted. The level of statistical significance was set at $p < 0.05$.

3. Results

3.1. Test of Normality

The Kolmogorov–Smirnov and Shapiro–Wilk tests were conducted to assess the normality of the pretest and post-test scores. For the pretest scores, the results were significant: $D(105) = 0.096$, $p = .019$ (Kolmogorov–Smirnov) and $W(105) = 0.958$, $p = .002$ (Shapiro–Wilk). Similarly, the post-test scores showed $D(105) = 0.114$, $p = .002$ and $W(105) = 0.916$, $p < .001$. Since all significance values were below the threshold of $\alpha = .05$, the data were considered to deviate significantly from a normal distribution. Therefore, nonparametric tests were used in subsequent analyses. Table 1 shows the tests of normality for pretest and post-test scores.

Table 1: Tests of Normality for Pretest and Post-Test Scores

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Post-Test Score/10	.114	105	.002	.916	105	.000
Pretest Score/10	.096	105	.019	.958	105	.002
a. Lilliefors Significance Correction						

3.2. Comparison of Pretest Scores Between Groups

A Mann–Whitney *U* test was conducted to compare pretest scores between the experimental and control groups. The test revealed no significant difference, $U = 1338.00$, $Z = –0.26$, $p = .797$, indicating that the groups had similar baseline knowledge of separation techniques. Table 2 shows the Mann-Whitney U test for pretest scores by group.

Table 2: Mann–Whitney U Test for Pretest Scores by Group

Test Statistics[a]	
	Pretest Score/10
Mann-Whitney U	1338.000
Wilcoxon W	2716.000
Z	-.257
Asymp. Sig. (2-tailed)	.797
a. Grouping Variable: Group	

3.3. Comparison of Post-Test Scores Between Groups

To evaluate the effect of the escape room intervention, a Mann–Whitney *U* test was performed on the post-test scores. The results showed a statistically significant difference between the groups, $U = 838.50$, $Z = –3.46$, $p = .001$. Table 3 shows the Mann-Whitney U test for post test scores by group.

Table 3: Mann–Whitney U Test for Post-Test Scores by Group

Test Statistics[a]	
	Post-Test Score/10
Mann-Whitney U	838.500
Wilcoxon W	2216.500
Z	-3.462
Asymp. Sig. (2-tailed)	.001
a. Grouping Variable: Group	

The experimental group had a higher mean rank (63.18) compared to the control group (42.63), suggesting that students in the experimental condition outperformed their peers on the post-test. Table 4 shows the mean ranks of post-test scores by group.

Table 4: Mean Ranks of Post-Test Scores by Group

Ranks				
	Group	N	Mean Rank	Sum of Ranks
Post-Test Score/10	Experimental	53	63.18	3348.50
	Control	52	42.63	2216.50
	Total	105		

3.4. Within-Group Learning Gains in the Experimental Group

To examine learning gains within the experimental group, a Wilcoxon signed-ranks test was used to compare pretest and post-test scores. The test indicated a significant increase in performance following the intervention, $Z = –8.92$, $p < .001$.

Table 5: Wilcoxon Signed Ranks Test Comparing Pretest and Post-Test Scores

Test Statistics[a]	
	Post-Test Score/10 - Pretest Score/10
Z	-8.920[b]
Asymp. Sig. (2-tailed)	.000
a. Wilcoxon Signed Ranks Test	
b. Based on negative ranks.	

Furthermore, all 105 students showed positive rank gains, with no negative ranks or ties, indicating consistent and meaningful improvement because of the intervention.

Table 6: Ranks for Wilcoxon Signed Ranks Test Comparing Pretest and Post-Test Scores

Ranks				
		N	Mean Rank	Sum of Ranks
Post-Test Score/10 - Pretest Score/10	Negative Ranks	0[a]	.00	.00
	Positive Ranks	105[b]	53.00	5565.00
	Ties	0[c]		
	Total	105		
a. Post-Test Score/10 < Pretest Score/10				
b. Post-Test Score/10 > Pretest Score/10				
c. Post-Test Score/10 = Pretest Score/10				

4. Discussion

The present findings add to evidence that educational escape rooms (EERs) can enhance student achievement in science. Grade 7 students who participated in our escape-room intervention demonstrated significantly greater gains in identifying laboratory apparatus and explaining separation techniques than those who received conventional instruction. This mirrors results at the tertiary level, where Galindo et al. (2020) found that an inorganic-chemistry escape room strengthened both theoretical understanding and practical skills. Similar performance benefits have been reported in elementary contexts: Huang et al. (2020) documented higher post-test scores in fourth-grade science after a digital educational escape room (DER). These converging findings suggest that, across developmental stages, well-designed escape rooms can consolidate core content and procedural knowledge. Performance patterns in our study also parallel those of Maršálek et al. (2024). In their Moodle-based escape room, middle-school students excelled at tasks grounded in laboratory practice but struggled with abstract calculations—a profile we likewise observed for separation techniques. Such consistency indicates that escape rooms are particularly effective in reinforcing hands-on and procedural aspects of science while revealing where additional conceptual scaffolding is needed. Although our study did not measure affective variables directly, it is notable that other researchers have linked digital escape rooms to improved confidence and sustained attention (Cash et al., 2023) as well as teamwork and multimodal learning opportunities (Clapson et al., 2024). These reports help to contextualize the performance gains observed here: active, puzzle-based formats appear to create conditions that support deeper engagement with content, which in turn can translate into higher achievement. Finally, our results align with those of Lathwesen and Eilks (2024), who documented sizable learning gains from a digital escape room on green chemistry at the high-school level. Together, these studies underscore the adaptability of escape rooms to diverse science topics and grade bands. In summary, this investigation demonstrates that a curriculum-aligned escape room can meaningfully improve middle-school students' mastery of separation techniques. By focusing on procedural tasks embedded in an interactive narrative, the activity leveraged students' existing developmental strengths—collaboration, emerging abstract reasoning, and practical curiosity—to achieve measurable learning outcomes.

5. Limitations and directions for future research

While this study provides evidence that educational escape rooms can enhance student performance in separation techniques, several limitations should be acknowledged. First, the sample was limited to Grade 7 students from a single school, which may restrict the generalizability of the findings to other educational contexts, grade levels, or science topics. Future studies should replicate this design across different schools and curricula to improve external validity. Second, the study focused solely on cognitive outcomes—such as students' ability to identify apparatus and describe processes—without measuring affective dimensions like motivation, engagement, or teamwork. Incorporating mixed-method approaches, such as attitudinal surveys, classroom observations, or student focus groups, would offer a more comprehensive understanding of how escape rooms influence learning experiences. Another limitation concerns the time, planning, and expertise required to implement educational escape rooms effectively. Teachers must invest considerable effort in designing puzzles, managing group dynamics, and aligning tasks with curricular goals. In schools with limited training opportunities or resources, these requirements could pose barriers to adoption. Logistical constraints such as large class sizes, limited classroom space, or strict scheduling can also affect feasibility. Future research should explore how to scale such interventions sustainably—for example, by developing ready-to-use kits or digital templates aligned with national science standards. Investigating how escape rooms can be adapted for inclusive classrooms, including those with students who have special educational needs, would also be a valuable contribution. Lastly, comparing the impacts of digital versus physical escape room formats, and evaluating their effects over extended periods, could provide deeper insights into long-term retention, conceptual transfer, and instructional design best practices.

6. Conclusion

This study investigated the effect of an educational escape room on the academic performance of Grade 7 students learning separation techniques in chemistry. Results indicated that students who engaged in the escape room significantly outperformed their peers in the control group, especially in applying procedural knowledge through hands-on tasks. Unlike many prior studies that emphasize motivation and engagement, this research focused exclusively on performance outcomes. The findings suggest that escape rooms can serve as effective tools for inquiry-based learning, as students engaged in problem-solving, collaboration, and real-world application of abstract concepts. For educators and curriculum designers, this study offers evidence that integrating game-based, inquiry-oriented activities into science instruction can enhance students' understanding of complex topics. For researchers, it highlights the need for further studies that explore the long-term impact of such interventions on knowledge retention and their adaptability to other areas of the science curriculum.

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Appendix A

Test on Separation Techniques

Time Allotted: 30 minutes

Instructions: Choose the best answer for each question. Circle the letter of your choice.

1. Which method is best for separating a mixture of sand and water?

   A. Evaporation
   B. Chromatography
   C. Filtration
   D. Distillation

2. What property of substances does filtration rely on?

   A. Solubility
   B. Boiling point
   C. Particle size
   D. Color

3. What remains on the filter paper after filtration?
   A. Solvent
   B. Residue
   C. Filtrate
   D. Solution

4. What happens to the solvent in evaporation?

   A. It becomes a solid
   B. It is absorbed
   C. It evaporates
   D. It condenses

5. Which technique separates substances based on boiling points?
   A. Filtration
   B. Distillation
   C. Decantation
   D. Chromatography

6. What is the main purpose of chromatography in separation?

   A. To dry mixtures
   B. To identify components in a mixture
   C. To filter large particles
   D. To mix two substances

7. Which method is best for separating salt from saltwater?

   A. Filtration
   B. Distillation
   C. Evaporation
   D. Chromatography

8. Why can distillation be used to purify water?
   A. Water boils at a higher temperature than impurities
   B. Impurities evaporate first
   C. Water freezes easily

D. Impurities are filtered out

9. Which technique is commonly used to identify dyes in inks?

A. Filtration
B. Evaporation
C. Chromatography
D. Distillation

10. How can sand and iron filings be separated?

A. Filtration
B. Chromatography
C. Magnetic separation
D. Distillation

11. You accidentally mix cooking oil with water. What technique should you use to separate them?

A. Filtration
B. Chromatography
C. Decantation
D. Distillation

12. To separate a mixture of alcohol and water, which technique is best?

A. Filtration
B. Chromatography
C. Evaporation
D. Distillation

13. To separate colored dyes in ink, which technique is best?

A. Chromatography
B. Evaporation
C. Filtration
D. Decantation

14. To separate soil, salt, and water, what is the correct sequence?

A. Filtration → Evaporation
B. Chromatography → Distillation
C. Filtration → Distillation
D. Decantation → Evaporation

15. Which technique allows collection of both solute and solvent from a solution?

A. Filtration
B. Chromatography
C. Distillation
D. Decantation

16. Tiny plastic beads are mixed with water. Which separation method is best?

A. Chromatography
B. Filtration

C. Evaporation
D. Distillation

17. A juice company wants to remove pulp from orange juice. What technique should they use?

A. Chromatography
B. Filtration
C. Distillation
D. Evaporation

18. You find a mixture of salt, soil, and water. Which steps help you recover all three?

A. Evaporation → Chromatography
B. Filtration → Evaporation
C. Chromatography → Filtration
D. Distillation → Decantation

19. A scientist compares ink samples from a note and several pens. Which method should they use?

A. Filtration
B. Evaporation
C. Chromatography
D. Decantation

20. A student wants to purify muddy water at home. What is the correct order?

A. Distillation → Chromatography
B. Filtration → Boiling
C. Chromatography → Evaporation
D. Evaporation → Filtration

Appendix B

Clue Cards Samples

Clue Card 1: Filtration Station

RIDDLE:

I keep the big and let the small go,

Through paper I pass, steady and slow.

What am I?

(Use your answer to unlock the next step!)

Clue Card 2: Evaporation Station

TASK:

Calculate the mass of salt recovered.

Clue: The code is the last two digits of the mass in milligrams.

(Be precise!)

Clue Card 3: Distillation Station

PUZZLE:

Which liquid boils first?

A. Water (100°C)

B. Alcohol (78°C)

C. Both at once

(Use the correct option's number to unlock the code: A=1, B=2, C=3)

Clue Card 4: Chromatography Station

CHALLENGE:

Carefully observe the separated colors from your black ink chromatogram.

Use the Color Code Key below to decode a 3-digit combination based on the left-to-right order of the colors that appear on your paper.

Red = 3

Yellow = 7

Blue = 4

Green = 8

Your Task:

Examine the color sequence on your chromatography paper.

Record the colors in the order they appear from left to right.

Convert each color into its corresponding digit using the code key.

Combine the digits to form your 3-digit code.