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Escape Rooms for Education: A Meta-analysis

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This meta-analysis aims to investigate the effectiveness of educational escape rooms in improving learning outcomes and fostering positive attitudes. Specifically, it seeks to examine their impact on the acquisition of content knowledge and the development of attitudes. Additionally, the study conduct a moderator analysis to explore how variables such as subject matter, types of escape rooms, and participants' age may influence these effects. After systematically screening the literature, 22 studies were deemed eligible for inclusion in the meta-analysis. The findings demonstrated a high effect size in knowledge gains and moderate effect size in attitude change, with 0.86 and 0.63, respectively. Interestingly, the moderator analysis did not uncover any statistically significant distinctions in effect sizes based on the three aforementioned moderators. In conclusion, this study affirms the effectiveness of educational escape rooms across a variety of academic disciplines and offers valuable insights for educators and practitioners interested in employing escape rooms as a means of educational innovation.

Keywords: meta-analysis, moderator analysis, publication bias, escape rooms, STEM education

INTRODUCTION

Emerging initially in 2007 as a recreational game, escape rooms have now been embraced as an educational tool for both entertainment and experiential learning (Fotaris & Mastoras, 2019). Combining elements of immersive storytelling and problem-solving, escape rooms, or escape games, refer to live-action and time-constrained games where a team of players solves puzzles and identifies patterns to achieve a shared goal, usually escape from a room (Nicholson, 2015). Solving escape room puzzles requires not only communication and teamwork, but also higher-order thinking skills such as critical thinking, analysis, and synthesis (Avargil et al., 2021;

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Nicholson, 2016). Thus, escape rooms have drawn greater attention from teachers and educators who develop them as active learning environments to increase motivation and foster learning (Borrego et al., 2017; Franco & DeLuca, 2019).

Educational escape rooms are increasingly employed as collaborative and interactive learning activities where learners actively solve puzzles and enjoy the feeling of autonomy, enabling a shift toward student-centered and self-directed learning (Giang et al., 2020; Guckian et al., 2020). Prior research has indicated that learning in escape rooms increases learners' perceived immersion, motivation, and engagement (Borrego et al., 2017; Ouariachi & Wim, 2020; Veldkamp et al., 2022), factors that positively correlate with knowledge gains and retention (Rutledge et al., 2018). The collaborative nature of escape rooms encourages learners to actively discuss and debate potential solutions, fostering communication and collaboration that promote collaborative learning (Gerlach, 1994; Veldkamp et al., 2022). Moreover, students perceive educational escape rooms as more useful and engaging compared to typical classroom experiences, which leads to improved academic performance (Cain, 2019; López-Pernas et al., 2019a). However, despite these positive findings, there is currently a lack of collective evidence regarding the extent to which escape rooms enhance learning and attitude (Ouariachi & Wim, 2020), emphasizing the need for a comprehensive review of the literature.

We acknowledge that there have been several reviews on escape rooms. Fotaris and Mastoras (2019) reported a systematic review of the current status and practices in educational escape rooms, validating their potential of using escape rooms to support learning across disciplines. Another review conducted by Veldkamp et al., (2020) found that compared to control groups, groups using escape rooms benefit more in terms of attitudinal factors, including enjoyment and engagement. However, knowledge gains were rarely supported with corroborating evidence, despite self-perceived learning reported by learners and teachers. In a review by Lathwesen and Belova (2021) on escape rooms in STEM education, it was argued that while using educational escape rooms can engage learners, more evidence is needed to verify their effectiveness. Therefore, a meta-analysis examining the effectiveness of educational escape rooms on knowledge and attitude is still warranted.

More specifically, many empirical studies focus on a narrower scope of educational settings for escape rooms. For example, Burbage and Pace (2024) conducted a scoping review on international allied health professions escape rooms based on thirty-four published articles. Implementing escape rooms are burgeoning in subject domains such as chemistry, physics, biology, math, computer science, general science, environmental science, and medicine (Lathwesen & Belova, 2021). Nonetheless, a meta-analytic approach to investigate the escape rooms' effect sizes on major outcomes, such as knowledge gains and attitude change, is still absent.

To bridge the gap, this study took the initiative and conducted a meta-analysis that examines the effectiveness of escape rooms in enhancing knowledge and attitude across various domains. By elucidating the empirical evidence and synthesizing findings from existing research, this study holds important implications for educators and game designers alike. The results of this meta-analysis can provide valuable insights into the potential of using escape rooms to effectively enhance learning, guiding educators in designing meaningful and impactful learning experiences. We ask two research questions:

1. How effective are escape rooms for achieving learning gains and attitude change?
2. Do the effect sizes for knowledge gain and attitude change vary based on the type of escape rooms, the target population, and the subject area?

METHOD

Research Design

The objective of this study is to aggregate and statistically assess the results of separate studies that investigate the use of escape rooms in an educational setting. To accomplish this, we employed the meta-analysis approach, which allows for an overarching examination of quantitative data from various independent studies focusing on specific topics (Cleophas & Zwinderman, 2017; Schwarzer et al., 2015). We conducted meta-analysis according to the following procedure; first, we identified the scope of the literature. Second, we collected literature based on the inclusion criteria. Third, we coded the literature to extract necessary information for the statistical analysis. Fourth, we conducted statistical analysis with R to measure effect size and publication bias. Fifth, we interpreted the findings in the following sections of this paper (Borenstein et al., 2009; Pigott, 2012).

Literature Search

Studies were searched in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis method (Page et al., 2021). The authors performed searches in five major education databases with the keyword “escape room”. As escape room is a clearly defined concept (Nicholson, 2015; Taraldsen et al., 2022), no other term was considered for search accuracy. The total search result had 845 studies from Web of Science (n = 435), APA PsycNet (n = 55), Education Source (n = 246), ERIC Proquest (n = 35), and Sage Journals (n = 72).

Inclusion and Exclusion Criteria

The inclusion criteria for this study are as follows: the intervention must (a) empirically measure the impact of escape rooms on students’ learning gains and/or affective domains; (b) employ an experimental design with both a control group and an experimental group; and (c) provide the necessary data for calculating effect sizes including sample sizes, mean scores, and standard deviations of pre- and post-tests. Studies were included only if they met all three inclusion criteria. For the screening process, the researchers reviewed the titles, keywords, and abstracts to determine if the paper was an empirical study of implementing an escape room for education. Non-empirical studies and review studies were excluded in this phase, leaving 234 articles for full-text screening. They were then examined to ascertain if they met the inclusion criteria, including the research design and reported data. After eliminating 59 non-empirical studies and 126 studies lacking a control group in their design according to the PRISMA framework (Page et al., 2021), 22 articles were identified as meeting all the criteria and were included in the meta-analysis. The search and screening procedure is summarized in Figure 1.

Coding Framework

The coding of the selected articles followed an open coding process (Creswell & Creswell, 2017; Tamur et al., 2020). The researchers collected information about the author, published year, target population, subject area, dependent variables, type of escape room (digital/physical), and both the control group and experimental group's sample sizes, mean score, and standard deviation. Studies for learning gains were coded as 'knowledge' for the effective variable, while those for the affective domain were coded as 'attitude'. The affective domains included self-efficacy (n = 2), motivation (n = 2), creative thinking (n = 2), emotion (n = 1), self-confidence (n = 1), interest (n = 1), frustration (reverse coded; n = 1), activation (n = 1), and cooperative learning (n = 1). As general creative thinking is a context-free, non-school-learned ability (Hong & Milgram, 2010), we categorized it as attitude, not knowledge.

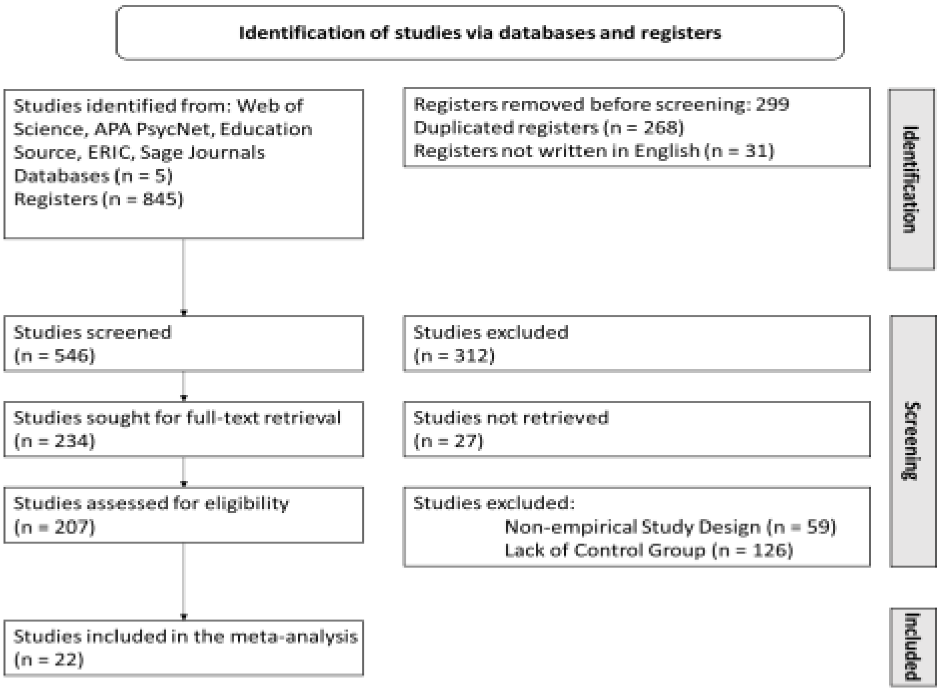

Figure 1
PRISMA flow diagram for data collection

Calculation of Effect Sizes

Cohen's d statistic and Hedges' g statistic are the two most common statistics used in meta-analysis to measure the effect sizes of individual studies. While Cohen's d does not guarantee that the theoretical mean is identical to δ, the effect size of the population, Hedge's g complements the problem by multiplying correlation factor, J (Borenstein et al., 2009). This enables the expected value of g-statistic to be equal to δ, thus making it an unbiased estimator. When we denote $\overline{X_1}$ and $\overline{X_2}$ as the means of groups 1 and 2, S_p as the pooled standard deviation, and S_1^2 and S_2^2 as the variances of groups 1 and 2, the formula used for Hedge's d is as follows,

$$\text{Hedges}'g = J \cdot d, \qquad J = 1 - \frac{3}{4 \cdot (n_1 + n_2) - 9}, \qquad d = \frac{\bar{X}_1 - \bar{X}_2}{S_p}$$

$$S_p = \sqrt{\frac{(n_1 - 1) \cdot S_1^2 + (n_2 - 1) \cdot S_2^2}{n_1 + n_2 - 2}}$$

$$\text{Variance(g)} = J^2 \times \left(\frac{n^1 + n^2}{n^1 n^2} + \frac{\delta^2}{2(n^1 + n^2)}\right)$$

In addition, moderator analysis on three predictors was executed to explore potential difference in the effectiveness of escape rooms in various contexts. The moderator variables in this study were (a) escape room type (physical, digital, both), (b) topic (medical, STEM, non-STEM), and (c) participants' age (K-12, college, adults). The moderators were chosen based on the most distinctive features of the escape room research designs reported in the selected studies. The moderator analysis was conducted with Qb values to determine the homogeneity between different subgroups. Based on the results of single factor ANOVA analysis, statistically significant Qb values mean that there is a difference in the average effect size for each variable class. When we denote MS_E as the mean square value of the effect sizes and n_j as the sample size from each subgroup, the formula for the moderator analysis using the Qb value is as follows.

$$SE_{ANOVA} = \sqrt{\frac{MS_E}{n_j}}, \quad Q_{between} = \frac{Absolute\ Difference\ between\ Subgroups}{SE_{ANOVA}}$$

For the meta-analysis, we used the R package "metafor" to calculate effect sizes. "metafor" package provides an average effect size with confidence intervals for each class of variables as well as homogeneity between groups (Lortie & Filazzola, 2020). For the moderator analysis, the author calculated the Qb values on Excel spreadsheet following the formula. The results of the statistical analysis is described in the findings.

FINDINGS

Publication Bias

To assure the reliability of this meta-analysis, publication bias was determined with funnel plots and Rosenthal's Fail-safe N (FSN) test (Borenstein et al., 2009). The result showed a symmetry distribution (b = 0.55, z = 0.63, p = 0.53) for knowledge gains and an asymmetry distribution (z = 4.32, p < .001) for attitude change (Figure 3). The limit estimate was -1.69 (CI: -2.78, -0.59) for attitude change, indicating the funnel plot was weighted towards the negative. For attitude change, we estimated the number of missing studies on the left side to be five with a standard error of 2.56 using the REML method. The adjusted tau square value is 1.09 with a standard error of 0.42. The value of I square and H square also slightly changed to 96.61% and 29.54, respectively. The test for heterogeneity still had a statistically significant result (Q = 445.55, df = 15, p < .001). The newly estimated effect size was 0.46 (SE = 0.27, z = 1.73, p = 0.08) with a confidence interval from -0.06 to 0.99. Thus, after controlling for the publication bias with the trim-and-fill method, we could find that the effect sizes for attitude change decreased to the extent of being statistically insignificant at the alpha level of 0.05.

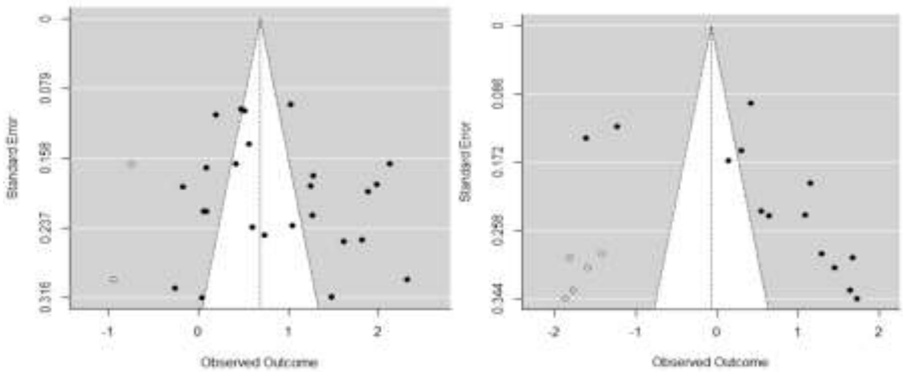

Figure 2
Funnel plot with trim-and-fill method (left: knowledge gains, right: attitude change)

As the distribution in the funnel plot was not statistically symmetrical, the Rosenthal FSN statistics were examined to determine the reliability of the collected studies for both knowledge gains (Fail-safe N = 4,208, p < .001) and attitude change (Fail-safe N = 161, p < .001). Both were calculated to be greater than the critical value, which is 145 for knowledge gains and 85 for attitude change. Thus, it can be concluded that there is little publication bias in educational escape rooms' impact on knowledge gains and attitude change.

Heterogeneity and Overall Effect Size

To answer the first research question, a random-effects model was run with an estimator from the REML method to measure the effectiveness of escape rooms on knowledge gains. Tau square, the estimated amount of total heterogeneity, was 0.54, with a standard error of 0.1646. Total heterogeneity (I square) was 94.69%, and sampling variability (H square) was 18.83. The test for heterogeneity showed significant heterogeneity (Q = 367.01, df = 25, p <.001).

The random-effects model estimated the overall effect size of escape rooms on knowledge gains as 0.86 (SE = 0.15, z = 5.75, p < .001) with a confidence interval from 0.57 to 1.15. Based on Thalheimer and Cook (2002)'s classification of effect sizes, this shows a high level effect size of escape rooms on knowledge gains change in education. The studies' individual effect sizes are reported in the forest plot (Figure 3).

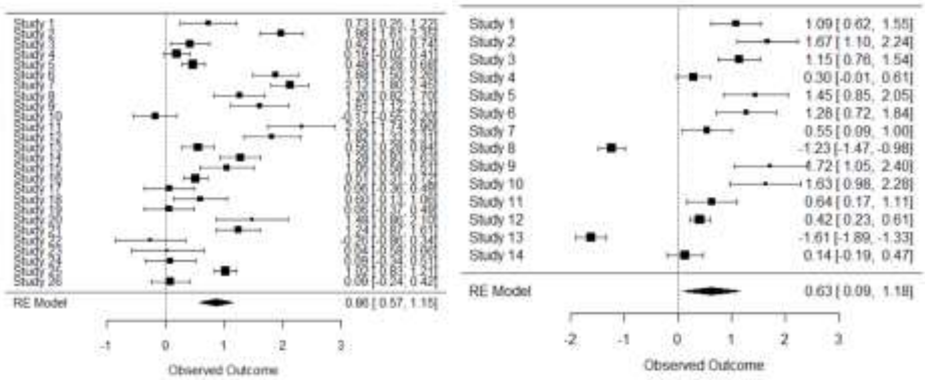

Figure 3
Forest plot for escape rooms (left: knowledge gains, right: attitude change)

For the attitude change, random-effects model was run with an estimator from the REML method and estimated the total amount of heterogeneity as 1.02 with a standard error of 0.42. Total heterogeneity (I square) was 96.68% and sampling variability (H square) was 30.14. The test for heterogeneity showed a significant heterogeneity (Q = 430.16, df = 13, p <.001). This may be due to the diversity of the variables included in the attitude analysis.

The random-effects model estimated the overall effect size of the escape rooms for the attitude change as 0.63 (SE = 0.28, z = 2.27, p = 0.02) with a confidence interval from 0.09 to 1.18. Based on Thalheimer and Cook (2002)'s classification of effect sizes, this shows a moderate effect size of escape rooms on the attitude change in education. Effect sizes of individual studies are attached in Appendices 1 and 2.

Moderator Variable Analysis

Next, we investigated the moderator effects of escape room types, subject areas, and participant age on the effect sizes of escape rooms to answer the second research question. Qb values and p values are provided in Table 1.

Table 1
Results of moderator analysis

Moderator	Subgroups comparison	Qb values	P values
Room types	Physical – digital	4.80	0.54
	Physical – both	0.32	
	Digital – both	4.48	
Topics	Medical – NonSTEM	1.70	0.07
	Medical – STEM	0.93	
	NonSTEM – STEM	2.63	
Participants' age	K12 – college	3.99	0.27
	K12 – adults	2.45	
	College – adults	1.54	

The critical Qb value at a 95% confidence interval at the alpha level of 0.05 is 3.445. As some of the obtained values are smaller than the critical value and the overall p value is greater than 0.05, it can be concluded that the distribution has a heterogeneous structure. Thus, although there may be slight difference in the effectiveness of escape rooms according to the room types or participants' age, the effect sizes of escape rooms between subgroups did not have a statistically significant difference.

DISCUSSION

The impact of escape rooms in education has been increasingly explored in various settings, including healthcare, STEM, and K-12. To provide a holistic view on its effectiveness on knowledge gains and attitude change, this paper took a meta-analytic approach based on 22 studies. 126 studies were not included in the meta-analysis as their results relied on students' subjective reactions such as satisfaction or entertainment. This shows that although educational escape rooms are getting much attention from educators and practitioners, relatively little research has been conducted in a rigorous manner.

We checked the sample's reliability before conducting meta-analysis by examining publication bias with funnel plots and Rosenthal's Fail-safe N (FSN) test. Both tests showed that the sample is statistically unbiased and thus, it is safe to proceed with the meta-analysis.

For the first research question, we investigated the effect sizes of escape rooms on knowledge gains and attitude change. The general Hedges' g values for escape room's effect size in knowledge gains and attitude change are 0.86 and 0.63, respectively. This indicated that escape room has a high effect size in knowledge gains while having a moderate effect size in attitude change (Thalheimer & Cook, 2002). The moderate overall effect size in attitude change can be explained by the high variance of the effect sizes of individual studies, which means that some studies reported that escape rooms were highly effective in attitude change while other studies were not. This may be due to the diversity of the educational settings, such as subject areas, participants' age, or escape room types.

Thus, for the second research question, we conducted a moderator variable analysis on escape room types, subject areas, and participant age. Although the moderator analysis did not report a statistically significant result at the alpha level of 0.05, we could see that some Qb values between subgroups were higher than the critical value of 3.445. This implies that when implementing escape rooms for educational purposes, the practitioners have to consider the specific context for the optimal learning experience.

Given the similarities between escape rooms and other instructional methods such as project-based learning or simulation-based learning with physical or digital learning materials, the finding that the escape rooms are significantly effective in knowledge gains and attitude change is not surprising. The study of Putra et al. (2021) exploring blended project-based learning (bPBL) model in geography education aligned well with escape rooms, considering the interactive and interdisciplinary nature of both approaches. In their study, results indicated that blended PBL had a positive influence on students' spatial thinking abilities and geography skills. By integrating bPBL into geography education, students demonstrated improved attitudes towards learning the subject (Putra et al., 2021). In the same vein, the incorporation of puzzles, codes, and spatial challenges in escape rooms can enhance students' spatial thinking abilities, helping them visualize and navigate complex concepts in a fun and engaging manner.

In addition, escape rooms rely heavily on various instructional materials such as clues, props, and visual aids to create an immersive and interactive learning experience. The findings of Kul et al. (2018) supported the notion that the use of instructional materials, like those employed in escape rooms, can significantly enhance students' learning outcomes. The combination of tactile, auditory, and visual materials in escape rooms can cater to diverse learning needs, providing students with multiple pathways to comprehend complex concepts and develop problem-solving strategies. As implied from the findings of our study, Kul et al.'s (2018) study emphasized the importance of considering instructional characteristics when designing learning environments.

On top of that, Ben Ouahi et al. (2022) indicated that incorporating interactive simulations could enhance learning activities in classrooms and help students effectively understand science concepts, fostering the development of higher-order skills such as analysis, evaluation, scientific research, discovery, and problem-solving. Escape rooms are considered similar to interactive simulations in the sense that they can create dynamic and realistic scenarios, where students must think critically and apply their knowledge and skills in a simulated context in order to find solutions.

As demonstrated by the parallels of escape rooms, project-based learning, and simulation-based learning, educational escape rooms are perceived to be theoretically grounded on game-based learning (Veldkamp et al., 2020; Fotaris & Mastoras, 2019). However, depending on the researchers' focus, other various theories can be invited to justify the design or make sense of the collaboration happening in the escape room. For example, Zaug et al. (2022) adopted situated learning theory in explaining how escape rooms promote teamwork in dentistry education. A couple of systematic reviews on escape rooms employed socio-constructivist approach because participants construct their own knowledge through real-time problem-solving experiences in escape rooms (Taraldsen et al., 2022; Lathwesen & Belova, 2021). A recent scoping review by Burbage and Pace (2024) indicates that only four studies out of thirty-four studies explicitly mentioned their theoretical framework in the escape room research, which were all different from one another. This diversity in theoretical frameworks imply the versatility of escape rooms, reemphasizing the need of systematic and rigorous approach to understand the concept.

The findings from this study have several implications. First, the meta-analytic results provide a rigorous synthesis of existing research, helping educators and practitioners make evidence-based decisions. Preparing an escape room activity is usually consuming more time and effort than other activities, which is acknowledged to be one of the main reasons why educators are hesitant to implement it. However, this evidence provides good rationale and motivation for them to implement escape room activities across contexts. Second, as the overall result was positive for both knowledge gains and attitude change, escape rooms possess much potential to be used for education. This calls for the need of teacher professional development programs and resources, where practitioners can learn more about how to effectively integrate escape rooms into their teaching practices. Third, although the overall positive results, there were some mixed results from several studies in terms of attitude change, thus making the overall effect size moderate. The moderator analysis in this study did not find a statistically significant indicator of this conflict. This may mean undocumented features, such as technical glitches, the granularity of instructions, or the quality of escape rooms, have affected learners' attitude. As noted by several researchers (Babazadeh et al., 2022; Clare, 2016; Korayem et al., 2022), designing a good educational escape room is a challenging task. Along with the second implication, this means that a specific guideline for developing escape room activities is needed for a broader use.

CONCLUSION

Escape rooms have the potential to serve as an innovative and immersive educational tool, providing unique learning experiences that engage students in higher-order skills such as problem-solving, critical thinking, and decision-making. In this meta-analysis, the overall effect sizes of escape rooms calculated by random-effects model were 0.86 and 0.63 for knowledge gains and attitude change, respectively. The effect sizes indicated that escape rooms are highly effective in knowledge gains and moderately effective in attitude change. However, a moderator analysis conducted on escape room types, subject areas, and participants' age did not show a statistically significant difference in effect sizes of escape rooms. Based on the findings, we provided several potential explanations on the results and implications.

LIMITATIONS

For this meta-analysis, we aggregated studies conducted in different disciplines. Thus, it is important to note that readers should interpret the results carefully and consider the context in which educational escape rooms are being used. Moreover, there was an asymmetry detected in the funnel plot for attitude change. It was corrected with the trim-and-fill method (Duval & Tweedie, 2000) in our analysis but the raw data was used in the meta-analysis to see the reported effect sizes in the selected papers. It should be noted that the effects of escape rooms on the attitude change may be skewed to be positive in the research results than it actually may be. Lastly, the collaborative nature of escape rooms promotes teamwork, which is often explored in relevant studies. However, this study did not examine the effect size of escape rooms on teamwork as there was not enough number of well-designed studies. There is a need to explore the impact of escape rooms on teamwork and collaboration in a more systematic manner. In addition to teamwork, other variables of escape rooms, such as the differences in puzzle task design, for example, whether it is sequential or not, or the role of facilitators, can serve as potential moderators in a further meta-analysis.

REFERENCES

Note: references with asterisks at the end are included in the meta-analysis.

Avargil, S., Shwartz, G., & Zemel, Y. (2021). Educational Escape Room: Break Dalton's Code and Escape!. *Journal of Chemical Education*, *98*(7), 2313-2322. https://doi.org/10.1021/acs.jchemed.1c00110

Babazadeh, M., Botturi, L., & Reggiani, G. (2022, September). Let's jazz: A case study on teaching music with educational escape rooms. In *European Conference on Games Based Learning* (Vol. 16, No. 1, pp. 656-665).

Ben Ouahi, M., Lamri, D., Hassouni, T., Ibrahmi, A., & Mehdi, E. (2022). Science Teachers' Views on the Use and Effectiveness of Interactive Simulations in Science Teaching and Learning. *International Journal of Instruction*, *15*(1), 277-292.

Berthod, F., Bouchoud, L., Grossrieder, F., Falaschi, L., Senhaji, S., & Bonnabry, P. (2020). Learning good manufacturing practices in an escape room: Validation of a new pedagogical tool. *Journal of Oncology Pharmacy Practice*, *26*(4), 853-860.*

Borenstein, M., Hedges, L.V., Higgins, J.P.T. and Rothstein, H.R. (2009). Effect Sizes Based on Means . In Introduction to Meta-Analysis (eds M. Borenstein, L.V. Hedges, J.P.T. Higgins and H.R. Rothstein). https://doi.org/10.1002/9780470743386.ch4

Borrego, C., Fernández, C., Blanes, I., & Robles, S. (2017). Room escape at class: Escape games activities to facilitate the motivation and learning in computer science. *JOTSE*, *7*(2), 162-171.

Buchner, J., Rüter, M., & Kerres, M. (2022). Learning with a digital escape room game: before or after instruction?. *Research and practice in technology enhanced learning*, *17*(1), 10.*

Burbage, A. K., & Pace, A. A. (2024). A scoping review of international allied health professions escape room practices and scholarship. *Medical Teacher*, 1-16.

Cai, S. (2022). Harry Potter Themed Digital Escape Room for Addressing Misconceptions in Stoichiometry. *Journal of Chemical Education*, *99*(7), 2747-2753.

Cain, J. (2019). Exploratory implementation of a blended format escape room in a large enrollment pharmacy management class. *Currents in Pharmacy Teaching and Learning*, *11*(1), 44-50. https://doi.org/10.1016/j.cptl.2018.09.010

Clare, A. (2016). *Escape The Game: How to make puzzles and escape rooms*. Smashwords Edition.

Cleophas, J. T., & Zwinderman, H. A. (2017). *Modern meta-analysis: Review and update of methodologies*. Springer International Publishing Switzerland.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Duval, S., & Tweedie, R. (2000). Trim and fill: A simple funnel-plot– based method of testing and adjusting for publication bias in metaanalysis. *Biometrics, 56*(2), 455–463.

Faysal, L. R., Yasmin, R., Zaman, A., & Khan, R. A. (2022). Effectiveness of medical escape room on learning of undergraduate medical students in comparison with case-based learning in teaching of clinical dermatology. *Rawal Medical Journal*, *47*(1), 187-187.*

Fotaris, P., & Mastoras, T. (2019, October). Escape rooms for learning: A systematic review. In *Proceedings of the European Conference on Games Based Learning* (pp. 235-243).

Franco, P. F., & DeLuca, D. A. (2019). Learning through action: Creating and implementing a strategy game to foster innovative thinking in higher education. *Simulation & Gaming*, *50*(1), 23-43. https://doi.org/10.1177/1046878118820892

Gerlach, J. M. (1994). Is this collaboration? In K. Bosworth & S. J. Hamilton (Eds.), Collaborative learning: Underlying processes and effective techniques, new directions for teaching and learning, No. 59 (pp. 5–14). Jossey-Bass Publishing.

Giang, C., Chevalier, M., Negrini, L., Peleg, R., Bonnet, E., Piatti, A., & Mondada, F. (2020). Exploring escape games as a teaching tool in educational robotics. In *Educational Robotics in the Context of the Maker Movement* (pp. 95-106). Springer International Publishing.

Gordillo, A., López-Fernández, D., López-Pernas, S., & Quemada, J. (2020). Evaluating an educational escape room conducted remotely for teaching software engineering. *IEEE Access*, *8*, 225032-225051.*

Guckian, J., Eveson, L., & May, H. (2020). The great escape? The rise of the escape room in medical education. *Future healthcare journal*, *7*(2), 112. https://doi.org/10.7861/fhj.2020-0032

Gutiérrez-Puertas, L., Márquez-Hernández, V. V., Román-López, P., Rodríguez-Arrastia, M. J., Ropero-Padilla, C., & Molina-Torres, G. (2020). Escape rooms as a clinical evaluation method for nursing students. *Clinical Simulation in Nursing*, *49*, 73-80.*

Harden, T. (2022). *Game-based learning and the coherence principle: Their effects on learning outcomes and self-efficacy* (Doctoral dissertation, Idaho State University).*

Hong, E., & Milgram, R. M. (2010). Creative thinking ability: Domain generality and specificity. *Creativity Research Journal*, *22*(3), 272-287.

Kavanaugh, R., George, S., Lamberton, N., Frenzel, J. E., Cernusca, D., & Eukel, H. N. (2020). Transferability of a diabetes escape room into an accelerated pharmacy program. *Currents in Pharmacy Teaching and Learning*, *12*(6), 709-715.*

Korayem, G. B., Alshaya, O. A., Kurdi, S. M., Alnajjar, L. I., Badr, A. F., Alfahed, A., & Cluntun, A. (2022). Simulation-Based Education Implementation in Pharmacy Curriculum: A Review of the Current Status. *Advances in medical education and practice*, 649-660.

Kul, Ü., Çelik, S., & Aksu, Z. (2018). The impact of educational material use on mathematics achievement: A meta-analysis. *International Journal of Instruction, 11*(4), 303–324.

Kuo, H. C., Pan, A. J., Lin, C. S., & Chang, C. Y. (2022). Let's Escape! The Impact of a Digital-Physical Combined Escape Room on Students' Creative Thinking, Learning Motivation, and Science Academic Achievement. *Education Sciences*, *12*(9), 615.*

LaPaglia, J. A. (2020). Escape the evil professor! Escape room review activity. *Teaching of Psychology*, *47*(2), 141-146.*

Lathwesen, C., & Belova, N. (2021). Escape rooms in STEM teaching and Learning—Prospective field or declining trend? A literature review. *Education Sciences*, *11*(6), 308. https://doi.org/10.3390/educsci11060308

Lin, F. J., Wang, C. P., Zhung, H. C., Wang, H. Y., Wang, S. M., Li, C. T., ... & Hou, H. T. (2017, July). Paper romance©-an educational simulation game for learning Papermaking with contextual scaffoldings for elementary students: The evaluation of learning performance and flow state. In *2017 6th IIAI International Congress on Advanced Applied Informatics (IIAI-AAI)* (pp. 1007-1008). IEEE.*

López-Belmonte, J., Segura-Robles, A., Fuentes-Cabrera, A., & Parra-González, M. E. (2020). Evaluating activation and absence of negative effect: Gamification and escape rooms for learning. *International journal of environmental research and public health*, *17*(7), 2224.*

López-Pernas, S., Gordillo, A., Barra, E., & Quemada, J. (2019a). Examining the use of an educational escape room for teaching programming in a higher education setting. *IEEE Access*, *7*, 31723-31737.

López-Pernas, S., Gordillo, A., Barra, E., & Quemada, J. (2019b). Analyzing learning effectiveness and students' perceptions of an educational escape room in a programming course in higher education. *IEEE Access*, *7*, 184221-184234.*

Lortie, C. J., & Filazzola, A. (2020). A contrast of meta and metafor packages for meta-analyses in R. *Ecology and Evolution*, *10*(20), 10916.

Macías-Guillén, A., Díez, R. M., Serrano-Luján, L., & Borrás-Gené, O. (2021). Educational hall escape: Increasing motivation and raising emotions in higher education students. *Education Sciences*, *11*(9), 527.*

Magreñán, Á. A., Jiménez, C., Orcos, L., & Roca, S. (2023). Teaching calculus in the first year of an engineering degree using a Digital Escape Room in an online scenario. *Computer Applications in Engineering Education*, *31*(3), 676-695.*

Musil, B., Gartner, S., Pesek, I., & Krašna, M. (2019, May). ICT competences assessment through ICT escape room. In *2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (pp. 622-626). IEEE.*

Nicholson, S. (2015). Peeking behind the locked door: A survey of escape room facilities. Retrieved from http://scottnicholson.com/pubs/erfacwhite.pdf

Nicholson, S. (2016). The state of escape: Escape room design and facilities. *Meaningful Play*, 18-26.

Norville, K., Philip, A., & Halford, Z. (2023). The design, implementation and evaluation of hybrid cancer clinic simulations: Escaping the norm. *Journal of Oncology Pharmacy Practice*, *29*(1), 162-169.*

Ouariachi, T., & Wim, E. J. (2020). Escape rooms as tools for climate change education: an exploration of initiatives. *Environmental Education Research*, *26*(8), 1193-1206.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Bmj*, *372*.

Palasik, B. N., Cho, H. J., Atanda, A., & Yuet, W. C. (2022). An escape room activity to teach transitions-of-care: Student perceptions and lessons learned. *Pharmacy Education*, *22*(1). 664-671.

Pigott, T. D. (2012). *Advances in Meta-Analysis*. Chicago, IL, USA: Springer is part of Springer Science+Business Media.

Putra, A. K., Deffinika, I., & Islam, M. N. (2021). The Effect of Blended Project-Based Learning with STEM Approach to Spatial Thinking Ability and Geographic Skill. *International Journal of Instruction*, *14*(3), 685-704.

Richter, L. M., & Frenzel, J. E. (2021). Designing an escape room to increase pharmacy preceptor knowledge of the Pharmacists' Patient Care Process. *American journal of pharmaceutical education*, *85*(1). 8073.*

Rodriguez-Ferrer, J. M., Manzano-León, A., Cangas, A. J., & Aguilar-Parra, J. M. (2022). A web-based escape room to raise awareness about severe mental illness among university students: randomized controlled trial. *JMIR Serious Games*, *10*(2), e34222.*

Rodríguez-Ferrer, J. M., Manzano-León, A., Fernández-Jiménez, C., Aguilar-Parra, J. M., Cangas, A. J., & Luque de la Rosa, A. (2022). The use of digital escape rooms in nursing education. *BMC Medical Education*, *22*(1), 1-8.*

Rutledge, C., Walsh, C. M., Swinger, N., Auerbach, M., Castro, D., Dewan, M., ... & Chang, T. P. (2018). Gamification in action: theoretical and practical considerations for medical educators. *Academic Medicine*, *93*(7), 1014-1020. https://doi.org/10.1097/ACM.0000000000002183

Schwarzer, G., Carpenter, J. R., Rücker, G., Schwarzer, G., Carpenter, J. R., & Rücker, G. (2015). Small-study effects in meta-analysis. *Meta-analysis with R*, 107-141. https://doi.org/10.1007/978-3-319-21416-0_5

Tamur, M., Juandi, D., & Kusumah, Y. S. (2020). The Effectiveness of the Application of Mathematical Software in Indonesia; A Meta-Analysis Study. *International Journal of Instruction*, *13*(4), 867-884.

Taraldsen, L. H., Haara, F. O., Lysne, M. S., Jensen, P. R., & Jenssen, E. S. (2022). A review on use of escape rooms in education–touching the void. *Education Inquiry*, *13*(2), 169-184.

Thalheimer, W., & Cook, S. (2002). How to calculate effec sizes from published research articles: A simplefied methodology. Work-Learning Research. Retrieved from https://pdfs.semanticscholar.org/d7f0/c3a171f fd6bad4297feeb708a2d79e06da8b.pdf?_ga=2.149295606.1950164162.1568100777-2068894367.1568100777.

Veldkamp, A., Daemen, J., Teekens, S., Koelewijn, S., Knippels, M. C. P., & van Joolingen, W. R. (2020). Escape boxes: Bringing escape room experience into the classroom. *British Journal of Educational Technology*, *51*(4), 1220-1239. https://doi.org/10.1111/bjet.12935

Veldkamp, A., Rebecca Niese, J., Heuvelmans, M., Knippels, M. C. P., & van Joolingen, W. R. (2022). You escaped! How did you learn during gameplay?. *British Journal of Educational Technology*, *53*(5), 1430-1458. https://doi.org/10.1111/bjet.13194

von Kotzebue, L., Zumbach, J., & Brandlmayr, A. (2022). Digital escape rooms as Game-Based learning environments: A study in sex education. *Multimodal Technologies and Interaction*, *6*(2), 8.*

APPENDIX 1

Hedges' g of individual studies on attitude change

No.	Author	Year	Population	Subject	Escape Room Type	Hedge's *g*
1	Richter et al.	2021	adults	medical (pharmacy)	physical	0.89
2	Macías-Guillén et al. (a)	2021	college	non-STEM (marketing)	physical	1.10
3	Macías-Guillén et al. (b)	2021	college	non-STEM (marketing)	physical	1.69
4	von Kotzebue et al. (a)	2022	K12	non-STEM (sex education)	digital	1.16
5	von Kotzebue et al. (b)	2022	K12	non-STEM (sex education)	digital	0.30
6	López-Belmonte et al. (a)	2020	adults	non-STEM (education)	physical	1.48
7	López-Belmonte et al. (b)	2020	adults	non-STEM (education)	physical	1.31
8	Buchner et al.	2022	adults	non-STEM (law)	digital	0.56
9	Rodriguez-Ferrer et al.	2022	college	medical	digital	1.23
10	Kuo et al. (a)	2022	K12	STEM (science)	both	1.75
11	Kuo et al. (b)	2022	K12	STEM (science)	both	1.66
12	Kuo et al. (c)	2022	K12	STEM (science)	both	0.65
13	Rodriguez-Ferrer et al. (a)	2022	college	medical (nursing)	digital	0.42
14	Rodriguez-Ferrer et al. (b)	2022	college	medical (nursing)	digital	1.62
15	Harden	2022	college	STEM (information literacy)	digital	0.14

APPENDIX 2

Hedges' g of individual studies on knowledge gains

No.	Author	Year	Population	Subject	Escape Room Type	Hedge's *g*
1	LaPaglia	2020	college	non-STEM (psychology)	physical	0.96
2	Musil et al.	2019	adults	STEM (ICT competency)	physical	0.75
3	Kavanaugh et al. (a)	2020	college	medical (pharmacy)	physical	1.99
4	Kavanaugh et al. (b)	2020	college	medical (pharmacy)	physical	0.42
5	Palasik et al. (a)	2022	college	medical (pharmacy)	physical	0.19
6	Palasik et al. (b)	2022	college	medical (pharmacy)	physical	0.48
7	Berthod et al.	2019	adults	medical (pharmacy)	physical	1.89
8	Gutiérrez-Puertas et al.	2020	college	medical (nursing)	physical	2.13
9	Norville et al. (a)	2023	college	medical (pharmacy)	physical	1.28
10	Norville et al. (b)	2023	college	medical (pharmacy)	physical	1.63
11	Macías-Guillén et al.	2021	college	non-STEM (marketing)	physical	0.18
12	von Kotzebue et al. (a)	2022	K12	non-STEM (sex education)	digital	2.34
13	von Kotzebue et al. (b)	2022	K12	non-STEM (sex education)	digital	1.84
14	Lin et al. (a)	2017	K12	non-STEM (education)	digital	0.56
15	Lin et al. (b)	2017	K12	non-STEM (education)	digital	1.29
16	López-Pernas et al. (a)	2019b	college	STEM (engineering)	physical	1.06
17	López-Pernas et al. (b)	2019b	college	STEM (engineering)	digital	0.51
18	Buchner et al. (a)	2022	adults	non-STEM (law)	digital	0.07
19	Buchner et al. (b)	2022	adults	non-STEM (law)	digital	0.61
20	Buchner et al. (c)	2022	adults	non-STEM (law)	digital	0.06
21	Magrenan et al.	2022	college	STEM (mathematics)	digital	1.50
22	Faysal et al.	2022	college	medical	physical	1.25
23	Cai, SY (a)	2022	college	STEM (chemistry)	digital	0.26
24	Cai, SY (b)	2022	college	STEM (chemistry)	digital	0.04
25	Kuo et al.	2022	K12	STEM (science)	both	0.09
26	Gordillo et al.	2020	college	STEM (engineering)	digital	1.03
27	Harden	2022	college	STEM (information literacy)	digital	0.09