

Exploring the Impact of Incorporating Digital Escape Room on Learners' Performance and Motivation in Environmental Sustainability Education

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Abstract: Environmental education has been conducted to equip learners with relevant environmental conservation knowledge for many years. However, learners seldom put the knowledge into practice and even have few ideas about how to protect the earth. Accordingly, continuous attention to this issue is necessary to enhance the effectiveness of environmental education. One of the strategies is gamification through technological application, which could enhance learning interaction and motivation with learners. The current study developed an online environment with the concept of escape room in the experimental group on the basis of a gamification strategy. With the immersion of the escape room, learners were encouraged to protect nature in a playful and challenging way. This empirical study was implemented to examine whether the online environment could promote learners' understanding and motivation. Our findings showed that the learners' performance in experimental group was significantly higher than that in the control group, highlighting the effectiveness of the digital escape room in enhancing learning performance. Nevertheless, there were no statistically significant differences in motivation between the groups, although the experimental group exhibited consistently higher mean motivation scores, suggesting a positive trend that warrants further research.

Keywords: Gamification, escape room, environmental sustainability education, technology enhanced learning, sustainable development goals (SDGs)

1. Introduction

Environmental education has been carried out for several decades across different educational stages, even beyond the boundaries of schools, such as public sectors, enterprises or non-profit organizations (Alam, 2023). As the United Nations has proclaimed seventeen sustainable development goals (SDGs) since 2015, it is more and more critical for all educational levels to integrate education for sustainable development (ESD) into current course scheme (Kioupi & Voulvoulis, 2019; Tryggvason et al., 2023). Resources conservation and recycling are increasingly becoming necessary for schools to design and implement (Kirchherr & Piscicelli, 2019). However, it still remains challenging for effectively guiding students to put environmental sustainability knowledge into practice. Hence, many researchers have successively tried to infuse novel instructional technologies and innovations into environmental sustainability education (Janakiraman et al., 2021; Yang et al., 2012).

Over the past years, a large number of empirical studies (Aksel Stenberdt & Makransky, 2023; Georgiou et al., 2023; Harker-Schuch et al., 2020; Janakiraman et al., 2021; Yang et al., 2017) supported that applying digital gamification as a learning strategy could have positive impacts on promoting students to learn environmental issues for ESD. As transformative technology continues to shape the evolving landscape of gamified learning experiences, the exploration

of innovative pedagogies becomes imperative. Meanwhile, an emerging gamified approach called 'escape room' is gradually booming in the research context of environmental sustainability education (Lopez-Belmonte et al., 2020; Ouariachi & Wim, 2020). Escape rooms in educational contexts allow learners to collaboratively solve a series of gamified puzzles within a limited time (Huang et al., 2020). With the use of information technology, rapidly growing research related to digital escape room (DER) found to have the potential to enhance teaching and learning across various disciplines (Bezençon et al., 2023; Chou et al., 2020; Huang et al., 2020; Vidergor, 2021). Most DER studies were developed in the subject area of science, technology, engineering, and mathematics. Nevertheless, Makri et al. (2021) reported that less attention has been paid to DER research design, data collection, assessment tools, and result analysis. Moreover, relevant studies in elementary and secondary education are comparatively few (Fotaris & Mastoras, 2019; Makri et al., 2021).

In order to strengthen elementary school students' environmental knowledge and learning motivation on environmental sustainability education, this study endeavors to develop an online interactive environment which incorporated digital escape room approach into the issues of environmental sustainability. Learners in the given context were encouraged to learn the environmental knowledge on protecting the earth in a full of pleasurable and challenging way. Therefore, the research purpose of this study is to investigate the effects of integrating digital escape room on learners' performance as well as motivation within the current learning context. In this quasi-experimental study, learners were divided into an experimental group and a control group. In this regard, the research questions were formulated as follows.

- I. Are there any significant differences in performance between the pretest and posttest in the experimental group embedded in the current digital escape room learning environment as compared with the control group?
- II. What are the effects of the current digital escape room on the elementary school students' motivation for learning to protect nature?

2. Literature review

2.1 Gamification in Education

Conventional pedagogies have seemed no longer to be the only approach for fostering students to understand the importance of protecting surroundings. Gamification refers to incorporate game-like elements and game design techniques into non-game contexts to engage and motivate participants (Thisgaard & Makransky, 2017). The core idea of gamification is the logic that the game elements' motivational strength can be transferred into educational contexts (Bezençon et al., 2023). Recent years, gamification in education was popular in the early 2010s and defined as using game-based mechanics, aesthetics and game thinking to engage people, motivate actions, promote learning, and solve problems (Cheng & Carolyn Yang, 2023; Hamari et al., 2014). Moreover, it could further be regarded as the application of game elements or structures to instructional practices in the formal context of the classroom. However, whether or not gamification is effective and beneficial to learning remains further investigated. Girard et al. (2013) and Hamari et al. (2014) reported that many studies had shown no difference in learning between serious game group and control group, although learners' motivation, satisfaction, and engagement outperformed.

2.2 Notion of the Escape Room

Escape rooms evolved from Japan initially designed for adult recreational purposes (Barzilai & Blau, 2014). It was defined as the game in which a team of people must "escape" from a room filled with challenges within a given time limit (Makri et al., 2021). The application of escape rooms to educational contexts has become more popular as a way to engage learners in many disciplines, such as healthcare, STEM subjects, computer science, chemical engineering, pharmacy, physics, mathematics, biology, and many others (Barzilai & Blau,

2014; Cheng & Carolyn Yang, 2023; Makri et al., 2021). Positive attributes of educational escape rooms have been identified as experiential and immersive, problem solving, critical thinking, collaboration, and sense of urgency (Ouariachi & Wim, 2020).

2.3 Digital Escape Room (DER)

DER is an innovative instructional approach incorporating digital materials with reality (Chou et al., 2020; Huang et al., 2020). Most research regarding escape rooms focused on physical ones. Digital escape rooms as an emerging phenomenon still need to be further investigated (Ferns et al., 2022; López-Pernas et al., 2022). For the past years, the research related to digital escape rooms (DER) have been much increasing. However, most participants were from higher education or secondary education. The number of articles which focused on primary education was lower (Bezençon et al., 2023; Lopez-Belmonte et al., 2020; Veldkamp et al., 2022). The impact of DER on learning outcomes have been assessed, such as critical thinking, problem-solving, and collaboration skills (López-Pernas et al., 2022; Makri et al., 2021). Accordingly, there is little attention has been paid to the research design and methods applied in data collection, assessment tools, and the analysis of results in DER studies proposed by Makri et al. (2021). It remains ambiguous whether or not DER combining with mobile technology can facilitate the student learning or engagement (Chou et al., 2020). The limitations and challenges would be foreseen in terms of budget, classroom availability, and a lack of time to prepare classes (Vidergor, 2021).

3. Methods

3.1 Participants

The participants were the elementary school students of a regular public school in Taiwan, distributed into the control group (N=26) and the experimental group (N=28) respectively from two classes. All of them had the experience in taking Computer and Information course for one year at school. Accordingly, they were capable of operating the current digital escape room game platform as well as responding to the online pretest, posttest and questionnaire form via computers.

3.2 Research Design

A quasi-experimental research design was applied to the current study embedded in an existing three-week educational context. The pretest and posttest survey were respectively distributed one week before and after the intervention. The participants from the experimental and control groups were all required to take the pretest and posttest surveys at the same time and interval. The difference between both groups is whether or not learners were instructed by the designed digital escape room.

The subject domain of this study belongs to environmental education focused on how to protect nature. The instructional features and learning contents of the current digital escape room were designed based on sustainable development goals (SDGs).

3.3 Experimental Procedure

The procedure of this study included three steps (Figure 1). At the beginning, each participant was invited to fill out the pretest (the environmental knowledge test), which took approximately 20 mins for the first week. In the intervention phase, the participants from the experimental and control groups were respectively guided to learn the environmental course by the digital escape room and video-based instruction during the following one week. Both the groups had to watch the relevant clips, complete the required tasks, and figure out all the puzzles. In the

third week, each participant was further asked to fill out the posttest including the environmental knowledge test and motivation questionnaire, which took approximately 30 mins. The questions used in the posttest of the environmental knowledge were identical to those in the pretest.

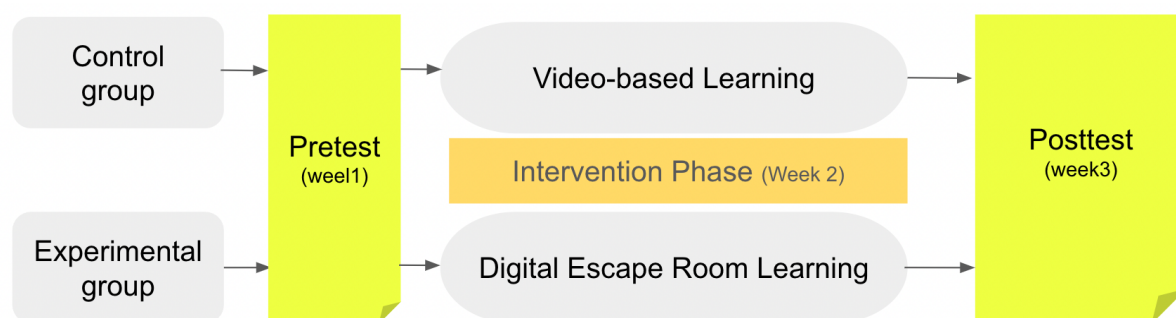


Figure 1. Research procedure.

3.4 Instruments

This current study applied pre and post environmental knowledge tests to identify learners' performance toward the digital escape room. The environmental knowledge test specifically focused on the issues of protecting nature presented in the course materials was rigorously reviewed by the experienced teachers. On the other hand, the self-reported data from the questionnaire using a five-point Likert scale (ranging from one indicating "strong disagreement" to five indicating "strong agreement") were carried out to assess learners' motivation. The measurement which included "intrinsic motivation" and "extrinsic motivation" dimensions demonstrated a high level of reliability.

3.5 Data Analysis

In addition to collecting environmental knowledge test scores to assess learners' performance with the current digital escape room compared to the control group, we analyzed self-reported motivation data (intrinsic and extrinsic) using descriptive statistics, including mean and standard deviation. Further evaluation of the digital escape room was conducted using paired and independent samples t-tests via SPSS. The assumptions for these tests—independence of observations, absence of significant outliers, normal distribution of data, and homogeneity of variances—were all met in the study.

4. Results and Discussion

Table 1 displays the results of paired t-tests comparing the differences in learners' performance between the pretest and posttest for both the experimental and control groups. For the experimental group, the mean score at the pretest was 65.00 with a standard deviation (SD) of 9.31, while at the posttest, the mean score increased to 85.46 (SD = 9.44). The paired t-test resulted in a statistically significant difference ($t = -11.093$, $p < .001$), indicating a substantial improvement in performance from the pretest to the posttest. Similarly, for the control group, the mean score at the pretest was 65.46 (SD = 9.11), which slightly increased to 76.54 (SD = 9.07) at the posttest. The paired t-test also revealed a statistically significant difference ($t = -6.570$, $p < .001$), suggesting an improvement in performance from the pretest to the posttest, although not as pronounced as the experimental group.

These results imply that both groups experienced an enhancement in performance from the pretest to the posttest. However, the experimental group exhibited a significantly greater improvement compared to the control group. The findings support the effectiveness of

integrating the current digital escape room implemented in the experimental group compared to the control group, as evidenced by the larger increase in scores.

Table 1. *The results of paired t-tests showing the differences in learners' performance between the pretest and the posttest for the experimental and control groups.*

Groups	Pretest Mean (SD)	Posttest Mean (SD)	<i>t</i>	<i>p</i>
EG	65.00 (9.31)	85.46 (9.44)	-11.093***	.000
CG	65.46 (9.11)	76.54 (9.07)	-6.570***	.000

Note1. *** $p < .001$.

Note2. EG and CG refer to the experimental (N=28) and control groups (N=26) respectively.

Table 2 illustrates the pretest and posttest evaluation results, along with the independent sample t-test analysis. The pretest scores showed no significant difference between the experimental (M=65.00, SD = 9.31) and control (M=65.46, SD = 9.11) groups, $t=.184$, $p>.05$. This indicates that both groups had comparable levels of prior environmental knowledge. Conversely, the posttest scores revealed a significant difference between the experimental (M=85.46, SD = 9.44) and control (M=76.54, SD = 9.07) groups, $t=-3.538$, $p<.05$. Obviously, learners in the experimental group, who engaged with the digital escape room, demonstrated significantly higher posttest scores compared to those in the control group. The results of this study align with existing research (Huang et al., 2020) indicating the effectiveness of gamified digital escape rooms infused with science teaching in enhancing better educational outcomes. These findings suggest that the current digital escape room effectively enhanced learners' performance.

Table 2. *The results of independent sample t-tests showing the differences in learners' performance of the pretest and posttest between the experimental and control groups.*

Performance	Groups	Mean	SD	<i>t</i>	<i>p</i>
Pretest	EG	65.00	9.31	.184	.855
	CG	65.46	9.11		
Posttest	EG	85.46	9.44	-3.538*	.001
	CG	76.54	9.07		

Note1. * $p < .05$.

Note2. EG and CG refer to the experimental (N=28) and control groups (N=26) respectively.

Table 3 displays the independent samples t-tests comparing learners' both intrinsic and extrinsic motivation between the experimental group and the control group. For intrinsic motivation, the experimental group had a mean score of 4.01 (SD = .72), and the control group had a mean score of 3.72 (SD = .95). The t-test analysis yielded $t = -1.289$, $p = .203$, indicating no significant difference between the groups. For extrinsic motivation, the experimental group had a mean score of 4.05 (SD = .82), while the control group had a mean score of 3.71 (SD = .98). The t-test results showed $t = -1.399$, $p = .168$, also indicating no significant difference.

Overall motivation scores were slightly higher for the experimental group (M = 4.03, SD = .58) compared to the control group (M = 3.71, SD = .81). The t-test analysis for overall motivation revealed $t = -1.673$, $p = .100$, which did not reach the threshold for statistical significance. These results suggest that, while there were no statistically significant differences in intrinsic, extrinsic, or overall motivation between the experimental and control groups, the experimental group consistently showed higher mean motivation scores across all categories.

Similar findings have been observed in previous research, where gamified educational environments were shown to enhance student motivation, even if not always reaching statistical significance. For instance, Hamari et al. (2014) and Vidergor (2021) found that gamification can lead to relatively increased motivation in educational contexts. This trend, though not statistically significant, may indicate a positive influence of the current digital

escape room on learners' motivation, warranting further investigation with a larger sample size or additional motivational measures.

Table 3. *The results of independent sample t-tests showing the differences in learners' motivation between the experimental and control groups.*

Motivation	Groups	Mean	SD	<i>t</i>	<i>p</i>
Intrinsic	EG	4.01	.72	-1.289	.203
	CG	3.72	.95		
Extrinsic	EG	4.05	.82	-1.399	.168
	CG	3.71	.98		
Overall	EG	4.03	.58	-1.673	.100
	CG	3.71	.81		

Note1. EG and CG refer to the experimental (N=28) and control groups (N=26) respectively.

5. Conclusions

The empirical study conducted to assess the impact of the digital escape room provides valuable reference into its effectiveness. Anticipating positive performance in terms of increased knowledge acquisition and enhanced learning motivation toward nature and life protection, the results had the potential to contribute significantly to the field of e-learning and environmental education. By immersing learners in a playful and puzzled educational environment, the current digital escape room goes beyond the mere dissemination of information; it actively encourages participants to adopt and practice proper measures in their daily lives. In this study, it was believed that the development and implementation of the current online environment exemplify a creative and engaging gamification initiative.

In addition, it is essential to recognize the importance of continuous research and development in this domain. Future efforts should focus on refining the gamification elements, exploring new technologies for immersive experiences, and adapting the approach to diverse cultural and educational contexts. Moreover, considerations for scalability, instructional training, and integration into formal curricula will be pivotal for ensuring the broader and sustained impact of gamified environmental education initiatives like the current digital escape room. As matter of fact, this study advocates for a paradigm shift in environmental education, moving forward the conventional classroom setting to embrace innovative and interactive approaches. By harnessing the power of gamification and technology, we have the potential to inspire a generation of environmentally conscious individuals who not only possess knowledge but actively engage in sustainable practices, contributing to the collective effort to protect the earth.

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