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Research paper

# Sustainable mobility education through escape rooms: A gender perspective

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ABSTRACT

This study explores the gender dimension in sustainable mobility, focusing on how interactive technologies and gamification, particularly Escape Rooms (ER), can promote awareness and behavioural changes. Despite the literature on sustainable mobility and gender, few studies analyse the intersection of these topics with gamification techniques. This research addresses this gap by examining how gender differences and ER modalities (physical and digital) influence learning, motivation, and satisfaction in sustainable mobility education. The study involved 388 students aged 10–13 who participated in a physical or digital ER experience designed to teach sustainable mobility concepts. The methodology included developing ER narratives and challenges and administering pre- and post-activity questionnaires to assess real and perceived learning acquisition, motivation, and satisfaction. Data analysis was conducted using confirmatory factor analysis and variance analysis to evaluate the impact of gender and ER modality. The results indicate no significant gender differences in learning outcomes on sustainable mobility and satisfaction with the ER experience, suggesting that ERs can be equitable educational tools. However, physical ERs showed higher motivation levels among boys than girls, highlighting the need for inclusive design considerations. This research contributes to understanding how gamified educational experiences can be designed, analysing how a balanced incorporation of intrinsic and extrinsic motivational elements could maintain the motivation of all children. These findings support ERs as effective and inclusive tools to raise awareness and encourage fostering sustainable behaviours among young learners. However, some caution should be taken in the design of their elements.

## 1. Introduction

Sustainable mobility is recognised for its environmental and social benefits in enhancing urban development and quality of life (Holden et al., 2019), necessitates the study of gender dimensions, as mobility patterns are significantly shaped by gender (Montero et al., 2023). In recent years, recognising their potential, there has been increased interest in the use of interactive technologies and gamification techniques to promote awareness, acquisition, and promotion of behaviours towards more sustainable mobility (Buchanan et al., 2018; Wang et al., 2022a). These two tools are particularly strong in their use of the motivational and persuasive influence of games through the integration of game concepts and elements to transform user behaviour (Zhang & Yu, 2022). Games can support and enhance the practice of behaviours and attitudes that may be challenging to experience in the real world, aiming to foster their acquisition and application in real-life contexts (Jacobs et al., 2017).

The Escape Room (ER), as a gamified experience that integrates interactive technology, has been consolidated in the educational field to promote the active participation of students and facilitate more dynamic and reflective learning on various topics (Yllana-Prieto F, 2021). The ERs can be categorised into two, according to the modality of the experience: physical ERs, which take place in designated physical spaces, and digital ERs, which are conducted through online platforms. According to Kuo et al. (2022), both types are effective and practical approaches that can be widely utilised to foster motivation and learning.

Although there is extensive literature on sustainable mobility and its relationship with gender, few studies explore the effect of gender and gamification techniques, specifically ER, on sustainable mobility to understand how to leverage these techniques to promote behavioural changes. This gap in the literature motivates our research, exploring how gender differences and the modality of ER (physical or digital) can influence the acquired learning about sustainable mobility, motivation, and satisfaction with the ER experience. Evaluating gender and ER

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modality differences in terms of motivation, satisfaction, and learning serves to design more inclusive and effective educational experiences that raise awareness among the new generation about the concepts and practical aspects of sustainable mobility.

To address this challenge, the article is structured as follows: after this introduction, a literature review is presented, addressing the most relevant studies on sustainable mobility, gamification, and ER and their intersection with gender, concluding with the formulation of the hypotheses to be addressed throughout the article. Next, the methodology used in the study is described, including the experimental design with the two ER modalities, the questionnaires used to evaluate acquired learning and satisfaction, and the statistical modelling strategy. The results are presented, followed by a critical discussion analysing the implications of the findings about gender, the modality of the activity, and educational objectives. Finally, the article concludes with the practical implications of the research and its limitations and proposes future lines of study in this field.

## 2. Literature review

The gender dimension within sustainable mobility is an area of growing interest, as it is recognised that gender can influence mobility patterns and choices. It has been demonstrated that women's travel behaviour is more aligned with sustainable practices than men's (González-Sánchez et al., 2021; Hanson, 2010). In the context of public transportation, perceptions of innovation and sustainability vary by gender: specifically, men seem to value technological development more, while women prioritise the sustainability that public transportation offers (Gómez-Ortega et al., 2023). Understanding these differences is, therefore, necessary to design mobility policies that are effective for everyone (Mejía-Dorantes et al., 2021), highlighting the need to expand the study framework by introducing aspects related to awareness and promoting gender-specific behaviours towards sustainable mobility to foster more inclusive practices.

In this direction, the use of gamification techniques to foster behavioural changes and promote learning has been the focus of recent literature in the area of transportation (Anagnostopoulou et al., 2018; Luger–Bazinger & Hornung–Prähauser, 2021; Pasca et al., 2021), where the use of interactive technologies and gamification techniques have proven to be effective tools for influencing individuals' attitudes and behaviours towards more sustainable transportation options. For example, gamification has been proven effective in promoting sustainable behaviours, demonstrating its ability to encourage more eco-friendly modes of transportation and improve road safety (El hafidy et al., 2021; Vlahogianni & Barmpounakis, 2017; Wang et al., 2022b; Yen et al., 2019). It has been used to improve the quality of mobility services, such as bike-sharing (Pasca et al., 2021), providing empirical evidence of the potential of gamification mechanics to address new challenges in quality management in sustainable mobility.

Additionally, gamification has been applied to stimulate sustainable behaviours in urban freight transport contexts, indicating its potential to foster stakeholder engagement and behaviour change in this area (Marcucci et al., 2018; Rubio et al., 2019). Likewise, gamification techniques are becoming increasingly popular in education for sustainable mobility, proving to be a valuable tool for influencing children's attitudes and mobility habits (Rogelj et al., 2024; Sipone et al., 2021). In all studies using gamification to convey concepts of sustainable mobility, the influence that gender can have on attitude changes or learning acquisition is not directly analysed. As far as the authors know, there needs to be more research in this regard.

Conversely, in the educational context, it has been observed that there are gender differences in students' opinions and perceptions of the use of gamification (Tamrin et al., 2022). Additionally, it has been shown that women tend to perceive these activities more positively than men (Hamari et al., 2014; Putz & Treiblmaier, 2019). However, these differences have not been thoroughly explored in the ER experiences. Nevertheless, gender differences in skills of great importance in an ER experience have been documented. In mathematics and problem-solving, women and men perform differently (Hyde et al., 1990; Sintema & Jita, 2022). Moreover, social factors amplify these gender gaps, especially in collaborative problem-solving, highlighting the importance of considering social contexts when analysing these differences (Borgonovi et al., 2023).

Despite these differences, results in the context of ER suggest that these activities can be inclusive and do not present gender biases. Several studies have explored participants' satisfaction with ER from a gender perspective, providing insights into their experiences. For example, some research shows that participants report high satisfaction, especially with ER's learning experience (Fuentes-Cabrera et al., 2020; Holland et al., 2023). Additionally, they highlight how women tend to be more motivated and show a higher level of anxiety about learning, reflecting a gender difference in the perception of the activity (Fuentes-Cabrera et al., 2020).

Regarding the effects of ER on learning, Ang et al. (2020) found that both physical in-person and digital ERs favour and motivate learning, suggesting a high level of satisfaction with this educational experience. However, Moula and Malafantis (2020) observed that male gender and prior experience with ER contribute to a more positive reception of the activity, indicating that there may be differences in satisfaction with ER based on gender. These findings suggest that the impact of ER may vary according to gender and prior experience, highlighting the importance of considering these factors when designing gamified educational experiences.

Understanding that gamification holds promise for promoting sustainable mobility, the role of gender in 10-13-year-olds' ER experiences is unclear in the literature; a more in-depth approach is needed to understand how this experience applied to sustainable mobility issues influences the learning, motivation and satisfaction of its participants. Therefore, the following hypotheses have been put forward:

**H1**. Gender influences the learning acquired and perceived due to ER on sustainable mobility.

- H1a: There are differences in learning acquisition between boys and girls after participating in the ER experience on sustainable mobility.
- H1b: There are differences in the perception of learning between boys and girls after participating in the ER experience on sustainable mobility.
- H1c: The modality of the ER (physical or digital) on sustainable mobility generates differences in learning acquisition between boys and girls.
- H1d: The modality of ER (physical or digital) on sustainable mobility generates differences in the perception of acquired learning between boys and girls.

**H2**. Gender influences the motivation and perceived satisfaction of ER on sustainable mobility.

- H2a: There are differences in satisfaction levels with the ER experience on sustainable mobility between boys and girls.
- H2b: There are differences in motivation levels with the ER experience on sustainable mobility between boys and girls.
- H2c: The modality of ER (physical or digital) on sustainable mobility generates differences in satisfaction levels with the experience between boys and girls.
- H2d: The modality of ER (physical or digital) on sustainable mobility generates differences in motivation levels for the experience between boys and girls.

## 3. Methodology

The methodology was structured in five phases (Fig. 1), designed to ensure a proper evaluation of the ER experiences and validation of the hypotheses. In Phase 1, the themes to be addressed in the ER tests were selected. In Phase 2, a narrative was developed, and tests were designed for both physical and digital ER. Phase 3 involved the creation of questionnaires to assess learning acquired and perceptions of the activity. Phase 4 consisted of conducting experiments and applying the questionnaires to evaluate concept acquisition and the perception questionnaire. Finally, phase 5 involved analysing the data to evaluate the study results.

### 3.1. ERs thematic

The proposed ER activities introduce five basic themes, including the concepts of sustainable mobility, considering their relevance, impact, and potential to raise awareness, make informed decisions, and encourage children of the age group involved in the experience (10–13 years old) to adopt more sustainable behavioural habits.

As foreseen in phase 1, the five macro-themes chosen were:

- **Active mobility.** This theme focuses on an alternative type of mobility. It refers to moving around using non-motorised means of transport, such as cycling, skateboarding, or walking, which promotes health and well-being by creating more sustainable places (Iamtrakul et al., 2024). Knowledge of this type of mobility represents awareness of a sustainable and healthy alternative to using motorised vehicles. It means a type of mobility that is very close to the age of the participants.
- **Sustainable and non-sustainable modes of transport.** The recognition and categorisation of modes of transport help us to understand the available alternatives and the consequent change of habits in the decision-making process when travelling. These concepts are at the basis of research that draws attention to the consequences that can be generated in mobility when implementing policies towards the use of sustainable modes of transport (Mazzulla, Bellizzi, Eboli, & Forciniti, 2021).
- **The Sustainable Mobility Pyramid.** This topic was intended to inform participants of the hierarchical model used as a reference when considering the different modes of transport and classifying them according to their effect from the point of view of efficiency, sustainability, health and economy.
- **Car sharing involves travelling with other people in a private vehicle.** This practice reduces the number of cars on the road, which reduces congestion and pollution (Cellina et al., 2024). Awareness of this practice could encourage students to change their carpooling arrangements with parents.
- **Organise and plan urban spaces.** Urban planning seeks to design and manage the growth of metropolitan areas sustainably and functionally (Ros-McDonnell et al., 2024). It includes aspects such as creating separate lanes for transport modes, preserving green spaces, ensuring accessibility, and creating liveable environments. Knowing how to distinguish and use the different spaces in a city makes citizens active agents in favour of more conscious, sustainable mobility.

### 3.2. Narrative design of ER, organisation and experimental procedure

ER are collaborative games where participants tackle challenges to achieve a mission within a set time frame and are designed for a specific audience with clear learning objectives. Like recreational ER, educational ER involves students playfully solving puzzles, challenges, and quizzes related to curricular content and skills. These ERs emphasize independent student work to address a real or fictional problem presented by the teacher (Nicholson, 2015). Students must collaboratively find a solution, fostering the development of skills and learning outcomes. In the second methodological phase of this research, as part of the design of the ER, a story was created that involved the students to be 'Guardians of Mobility'. Before solving the ER puzzles, a trailer was sent to each class as a teaser and a stimulus to start thinking about the mobility problems that cities must deal with. Two ER experiences were created, physical and digital, with the same themes and learning concepts. Once the experience started, the first part consisted of a video showing how engineers research and try to solve mobility problems in cities, encouraging students to solve the challenges of escaping from the room and learning how to be promoters of more sustainable mobility.

In the physical experience, the activities were organised in spaces of the University of Cantabria facilities, representing scenarios related to sustainable mobility, incorporating elements such as traffic cones, information signs, various modes of transport and reflective waistcoats (Fig. 2). In addition, before starting, participants have explained the scenario, the rules to be followed and the objective to be achieved to complete the ER. The tests were organised sequentially, as described by Wiemker et al. (2015). This type of procedure requires that the challenges be solved in a specific order to achieve the goal. This structure was used because of the type of evidence related to each other: knowledge discovered in previous challenges acted as reference points and helped to solve the subsequent challenges. This modality also helped them to have order and greater concentration in the group and not lose the activity's focus: learning new concepts. The tests were hidden in five envelopes that had to be found in the room and, according to the established rules, an envelope could not be opened if the previous one had not been solved. The ER lasted 50 min, and students were divided into groups of 5 or 6 members.

In the digital experience, the ER was designed on the Genially platform and could be executed online via a computer. Genially is a free, versatile, and dynamic tool for creating online activities. It was chosen for its various advantages, such as designing and modifying templates as needed, introducing animation elements, and adding motion, transitions, and transformations of text and images. The story's setting is

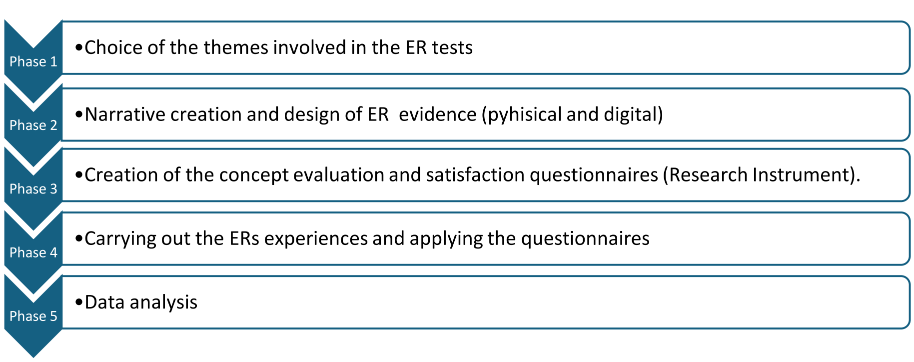


**Fig. 1.** Research structure.


**Fig. 2.** Physical ER experience.

represented in an office where the clues are hidden in various parts (Fig. 3). To solve the clues, an open structure was chosen for this version (Wiemker et al., 2015), allowing an open path without the need to follow a specific sequence. Students could investigate each part of the scenario and discover and solve the clues. The open structure for the digital ER was more functional as it allowed each student to organise their thinking and acting. Additionally, in this ER, the time available was 50 min to open a safe box, find a diploma, and exit the game. In the case of the digital ER, the introductory video represented the entrance to the office, maintaining the same content as the physical ER.

### 3.3. Research instrument

Two questionnaires were created, one for assessing the learning acquired from sustainable mobility concepts and one for analysing the perception of satisfaction, motivation, and perceived learning in the ER experience. The concept assessment questionnaire had questions related to the five macro-themes chosen for the design of the ERs and was provided before and after the activity. These questions were presented as a ranking following the model described by (Louviere et al., 2000). Students had to compare three definitions of sustainable mobility in each question and rank them according to their opinion and degree of learning acquired, from the most accurate to the least accurate. Using this type of question allowed for the assessment of the understanding and acquisition of concepts related to sustainable mobility through the experience of the ER. Appendix 1 shows the questions relating to learning acquisition as well as the correct order of answers according to the criteria established by various panels of university and school teachers to ensure their comprehensibility and usefulness in the context of this ER experiment.

The perception questionnaire asked students to indicate their opinions on the experience. Specifically, statements were made on three different issues: overall satisfaction with the experience, motivation to participate in the experience, and perception of the level of learning that the experience may have generated (Kinio et al., 2019) (Table 1). A 5-point Likert scale (Likert, 1932) was used to assess these dimensions, with three questions for each category. The Likert scale ranged from 1 to 5, where 1 indicated "very disagree" and 5 indicated "very agree". Therefore, each participant reported a degree of agreement for each statement. This is useful in latent perceptions questionnaires because it

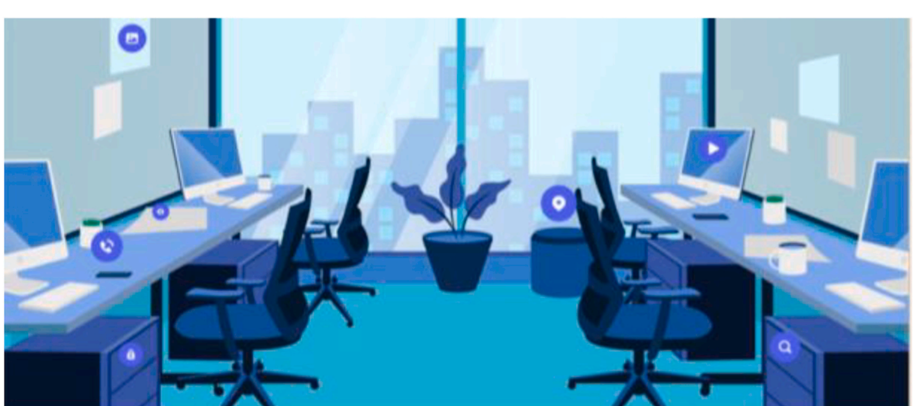

**Fig. 3.** Screenshot of digital ER.

**Table 1**
Statements of perceptions questionnaire.

| Aspect | Nomenclature | Indicator |
|---|---|---|
| Satisfaction (SAT) | sat1 | Overall, I liked this activity. |
| | sat2 | I would recommend this activity to other students. |
| | sat3 | The escape room has been well organized. |
| Motivation (MOT) | mot1 | This activity has increased my interest in sustainable mobility. |
| | mot2 | The difficulties of the tests and my skills were at a similar level. |
| | mot3 | Working in a group has helped me to solve the tests. |
| Perceived learning (APR) | apr1 | This activity has increased my general knowledge about sustainable mobility. |
| | apr2 | The escape room is a good way to learn sustainable mobility concepts. |
| | apr3 | I understood what they were explaining to me. |

allows for measuring attitudes and perceptions, capturing variations in agreement or disagreement with statements, and facilitating statistical interpretation of ordinal variables (Joshi et al., 2015).

### 3.4. Data collection

Phase 4 of the methodology, focused on data collection, was conducted before and after the ER experiences; parts of these data were included in Sipone et al. (2024). Before each ER, students were given questionnaires and time to fill them out. In the initial phase, data were gathered on the student's prior knowledge of sustainable mobility. Following the ER experience, whether physical or digital, data collection focused on assessing the learning acquired, students' perceptions of their learning, motivation and satisfaction with the experience. This study involved 388 students from different schools in Santander, Spain and nearby municipalities who carried out the ER between December 2022 and February 2023. Data were collected from 173 students who completed the physical experience and 215 students who completed the digital experience. Schools were selected to represent diverse socio-economic backgrounds, ensuring the study reflected the observed reality. Given the participants' age, ethical and legal standards were upheld by obtaining written consent from parents or guardians. All completed questionnaires were anonymised during data analysis to protect student privacy by removing personal identifiers and retaining only the information necessary for result evaluation.

Table 2 shows the characteristics of the students according to the type of experience: physical or digital.

**Table 2**
Characteristics of participants.

| Variable | Physical | Digital |
|---|---|---|
| Gender | | |
| Men | 50,29 % | 51,64 % |
| Woman | 49,71 % | 48,36 % |
| Residence | | |
| Village | 23,12 % | 53,95 % |
| City | 76,88 % | 46,05 % |
| Having a bike | | |
| Yes | 74,57 % | 83,57 % |
| No | 25,43 % | 16,43 % |
| Number of cars in house | | |
| 0 | 14,45 | 6,51 % |
| 1 | 38,73 % | 35,35 % |
| More | 46,82 % | 58,14 % |
| Frequency of public transport use | | |
| Sometime | | |
| Yes | 39,88 % | 40,93 % |
| No | 60,12 % | 59,07 % |
| A lot | | |
| Yes | 20,23 % | 22,54 % |
| No | 79,77 % | 77,46 % |

Fig. 4 shows the distribution of responses to the latent variables measured on a Likert scale. The chart presents the percentage of answers for each variable, with each bar representing the responses divided into different categories. Most responses are concentrated in the highest category (5), indicating a positive tendency among the participants.

### 3.5. Data analysis: indicators of perception and learning

The analysis of the results to test the hypotheses was carried out in different stages. The first stage involves a confirmatory factor analysis (CFA) (Hoyle, 2000) to examine the relationships between the latent variables of satisfaction, motivation, and learning with the observed indicators (see Table 1). The second stage includes applying the factor score technique, which provides the parameters necessary for understanding the relationship between the observed variables and the latent factors, thereby allowing inferences about their underlying relationships (Bollen, 1989). Once these parameters were obtained, the factors for each equation were standardised individually, which is necessary for analysing structural models to enable direct comparison of the effects of the different factors and eliminate scale differences between them. The third stage consisted of measuring participants' learning. For this purpose, the variable "Real Learning" (APRX) was calculated as the difference between the number of correct answers before and after the ER experience:

Real Learning (APRX) = # of correct responses after - # of correct responses before.

Fig. 5 shows the distribution of the generated variable APRX for the 388 observations for both physical and digital experience, as well as discretising by gender. As can be seen, in almost all cases, the learning derived from the experience is centred on 0, which implies that there is no knowledge acquisition. It is noteworthy that boys in the physical experience have a greater dispersion than girls, and in the digital experience, girls present a slightly higher variation.

For the analysis of the constructed indicators, an analysis of variance was performed to identify statistical differences between groups. The statistical experimental design provided a structured data collection approach, facilitating hypothesis validation (Lawson, 2014). Two statistical methods were used to analyse the differences between the groups: analysis of variance (ANOVA) and the Kruskal-Wallis test. ANOVA (Sthle & Wold, 1989) is a parametric method used to compare the means of three or more groups to determine if there are significant differences between them. This analysis assumes that the distributions of the groups are normal and that the variances are homogeneous. The literature recommends adherence to these assumptions to ensure a robust analysis (Delacre et al., 2019; McGuinness, 2002). However, some studies suggest that ANOVA remains valid with large samples even when these assumptions are unmet (Yabsley et al., 2019). On the other hand, the non-parametric Kruskal-Wallis test (KW) (Kruskal & Wallis, 1952) is presented as a suitable alternative to compare group variances without relying on the normality of the data comparing the medians of the groups (Lantz, 2013).

In this study, gender and the type of ER were considered as grouping variables, following the general hypotheses (H1 and H2), which propose that ER experiences may have differential effects according to these variables. The conditions of normality and homogeneity were assessed, and ANOVA and KW analyses were used according to the relevance of each case. The p-value obtained allowed the identification of whether significant variabilities existed between groups, providing information on the effect of ER activities in the context of sustainable mobility, gender differences and modality of experience.

## 4. Results

Table 3 presents the results of the confirmatory factor analysis (CFA) for the three latent variables: Satisfaction (SAT), Motivation (MOT), and

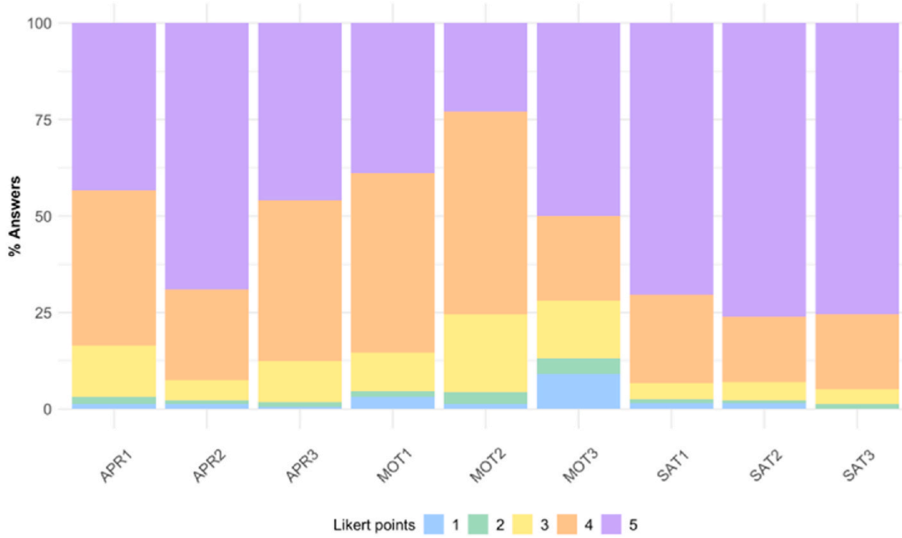


**Fig. 4.** Likert answers to the latent variables.

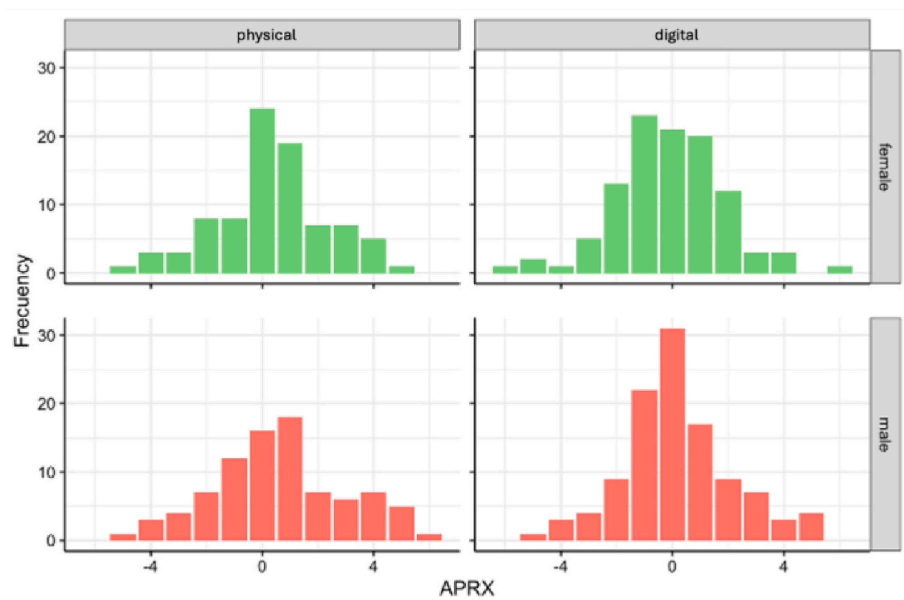


**Fig. 5.** APRX distribution.

**Table 3**
CFA join model output.

| Latent | Indicator | CFA Parameter | Std Error | Z value |
|---|---|---|---|---|
| | sat1 | 0.74[a] | 0.037 | 19.93 |
| SAT | sat2 | 0.89[a] | 0.036 | 24.4 |
| | sat3 | 0.67[a] | 0.048 | 13.93 |
| | mot1 | 0.56[a] | 0.062 | 8.98 |
| MOT | mot2 | 0.31[a] | 0.050 | 6.18 |
| | mot3 | 0.36[a] | 0.058 | 6.11 |
| | apr1 | 0.58[a] | 0.046 | 12.66 |
| APR | apr2 | 0.73[a] | 0.043 | 17.01 |
| | apr3 | 0.51[a] | 0.043 | 11.84 |

[a] Indicates the confidence level of the 95 % estimate.

Perceived Learning (APR). The CFA was performed using the Lavaan library in R (Rosseel, 2012). The latent variable Satisfaction (SAT), comprises three indicators (sat1, sat2, sat3), which present significant and high factor loadings, with estimates of 0.74, 0.89 and 0.67, respectively. These results indicate that the satisfaction derived from the experience is adequately represented by these indicators, with sat2 (*I would recommend this activity to other students*) being the one with the highest weight within the variable. The latent variable Motivation (MOT), measured through the indicators mot1, mot2 and mot3, also shows significant factor loadings, with estimates of 0.56, 0.31 and 0.36, respectively. This suggests that the main determinant of MOT is mot1 (*This activity has increased my interest in sustainable mobility*). Finally, in the latent variable Perceived Learning (PL), the indicators apr1, apr2 and apr3 present significant factor loadings of 0.58, 0.73 and 0.51, respectively. These values reflect an association between the experience of the activity and the participants' perceived learning, with apr2 (*The escape room is a good way to learn sustainable mobility concepts*) being the indicator with the highest factor loadings within this variable. The fit indicators of the model (CFI = 0.99, TLI = 0.99) are adequate, supporting the validity of the estimates to explain the relationships between the latent variables and the observed variables.

Table 4 presents the results of the estimated factor score parameters

**Table 4**
Factor score parameter.

| Indicator | Parameter | Std Error | Z value |
|---|---|---|---|
| λ1λ1 | 0.80* | 0.055 | 14.54 |
| λ2λ2 | 0.86* | 0.057 | 15.12 |
| λ3λ3 | 0.63* | 0.058 | 10.86 |
| λ4λ4 | 0.56* | 0.160 | 3.47 |
| λ5λ5 | 0.34* | 0.107 | 3.15 |
| λ6λ6 | 0.32* | 0.106 | 3.05 |
| λ7λ7 | 0.64* | 0.075 | 8.59 |
| λ8λ8 | 0.67* | 0.062 | 10.76 |
| λ9λ9 | 0.51* | 0.057 | 8.94 |

derived from the CFA (Table 3), allowing us to provide information on the construction of composite factors for the SAT, MOT, and APR variables within this study. These parameters serve to understand the underlying dimensions captured by the model. Each parameter λn signifies the strength and directionality of the relationship between the observed variables and the latent constructs. Likewise, the statistical parameter Z-value is always greater than 1.96, demonstrating a solid statistical significance with a confidence level of 95 %, and even 99 % in most cases. Specifically, parameters λ1 to λ3 have a strong load on the SAT factor, indicating that the observed variables associated with participant satisfaction are those that best represent this dimension. In this case, the three parameters are of similar importance, with values between 0.86 and 0.63. Similarly, λ4 to λ6 mainly load on the MOT factor, reflecting the underlying motivations of individuals, especially λ4, with a factor load on the latent variable much higher than the other two indicators of the same. Finally, λ7 to λ9 are linked to the APR factor, related to perceived learning, with relatively similar values in terms of factor loading, as in the case of satisfaction. The parameters λn correspond to the following equations:

$$SAT = \lambda1 * sat1 + \lambda2 * sat2 + \lambda3 * sat3 \quad (1)$$

$$MOT = \lambda4 * mot1 + \lambda5 * mot2 + \lambda6 * mot3 \quad (2)$$

$$APR = \lambda7 * apr1 + \lambda8 * apr2 + \lambda9 * apr3 \quad (3)$$

Table 5 presents the results of the homogeneity and normality tests performed on the data corresponding to the SAT, MOT, APR and APRX variables as a preliminary step to the analysis of variance. The homoscedasticity of the samples was evaluated using Bartlett's test, where the null hypothesis ($p > 0.05$) indicates homogeneity in the variances (Bartlett, 1950). This criterion was met for the MOT, APR and APRX variables, confirming the homogeneity of their samples. The normality of the data was analysed using the Shapiro-Wilk test (Shapiro & Wilk, 1965), which assesses whether data distribution within a sample follows a normal distribution under the null hypothesis ($p > 0.05$). In none of the cases analysed was this assumption of normality met. Consequently, the application of ANOVA was discarded, and an alternative test suitable for situations of non-normality was chosen, specifically the Kruskal-Wallis test (KW).

With the indicators constructed, variance tests can be carried out to test the hypotheses comparing the two groups: boys and girls. (Figs. 6-11). The $x^2$ *(1)* statistic represents the paired *t*-test (boys and girls) with one degree of freedom obtained through the Bonferroni test. A high $x^2$ *(1)* value indicates significant differences in the group distributions. The

**Table 5**
Homogeneity and normality test.

| Variable | P-Value Homogeneity | P-Value Normality |
|---|---|---|
| SAT | 0,01 | 0,00 |
| MOT | 0,34 | 0,00 |
| APR | 0,41 | 0,00 |
| APRX | 0,06 | 0,00 |

*p* corresponds to the p-value, allowing us to assess variances' differences, while n denotes the sample size considered in each analysis.

Figs. 7 and 8 show the variance analysis for the variables of perceived learning (APR) and real learning (APRX) first in an overall comparison including both experiences (physical and digital) and then in a separate analysis by modality. Fig. 6 shows the analysis of variance for APR and APRX for the overall sample without distinguishing between the modality of the experience. The results do not reveal statistically significant differences when comparing the variances between boys and girls for these variables in the overall sample. Therefore, it cannot be said that girls acquire more or less real or perceived learning than boys when participating in the ER experience on sustainable mobility (H1a and H1b).

Fig. 7 shows the differences in perceived learning by experience modality, demonstrating that it is not evident that the physical or digital modality has a differential effect on the perception of learning between boys and girls (H1d).

Fig. 8 provides the analysis of variance for real learning (APRX), comparing the variances between genders in both modalities. The results continue to indicate that there are no significant differences between genders, suggesting that gender does not differentially affect learning acquisition in ER experiences (H1c).

These results refute hypothesis H1, suggesting that neither gender nor the modality of ER (physical or digital) significantly influences the acquisition of real or perceived learning about sustainable mobility after participating in the gamified activity. Several factors could explain these results. Firstly, it is possible that gender differences in learning, commonly observed in other educational contexts (Putz & Treiblmaier, 2019; Sintema & Jita, 2022), do not manifest themselves in gamified activities due to the interactive and collaborative nature of these experiences. The structure of ER may encourage equal participation and minimise gender-related biases, which could equalise the learning levels achieved by both groups. Another factor is the specific content of the activity, focusing on sustainable mobility concepts, which does not seem to have an impact between genders as it appears to be associated with well-known issues for all (Fuentes-Cabrera et al., 2020), contributing to the absence of significant differences. Therefore, ER activities can promote an egalitarian learning environment, regardless of gender, which could minimise gender-related biases and encourage equal participation.

On the other hand, Figs. 9–11 focus on motivation (MOT) and satisfaction (SAT) with the ER experience. Fig. 9 shows the results of the variance analysis for the variables of motivation (MOT) and satisfaction (SAT) in the whole sample, comparing the responses between boys and girls. The results indicate that there are no statistically significant differences in motivation or satisfaction between the genders when analysing the variability of the sample. This suggests that, in general, both boys and girls show similar levels of motivation and satisfaction with the ER experience, regardless of gender, thus refuting hypotheses H2a and H2b.

However, if only physical experience is considered (Fig. 10), there is a significant difference in motivation between boys and girls at a 90 % confidence level (p-value = 0.058). Motivation, although not strictly dependent on gender (H2b), has an interaction between gender and modality (H2d). In this case, boys find greater motivation in physical experience compared to girls.

Finally, Fig. 11 reflects ER's capacity to generate similar satisfaction levels among participants, regardless of gender and modality of experience, underlining its potential as an inclusive tool in education. The results imply that satisfaction is not associated with gender or the modality of the experience (H2a and H2c). In this respect, our results align with many studies that analyse satisfaction with using ER for different learning activities (Dogu et al., 2025; Huang et al., 2020).

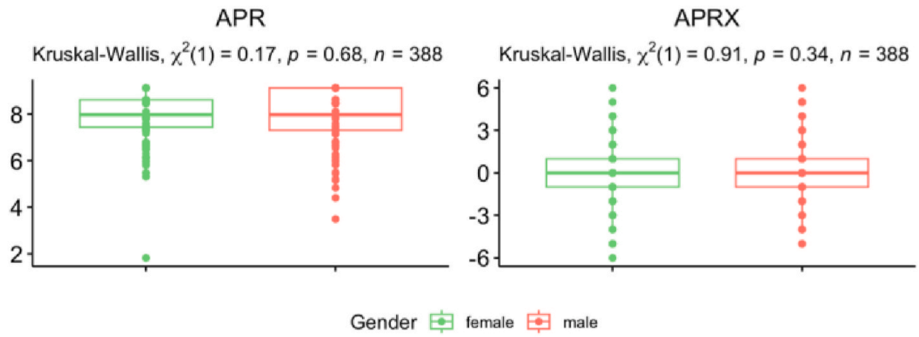


**Fig. 6.** KW for perceived learning (APR) and real learning (APRX) for the overall sample.

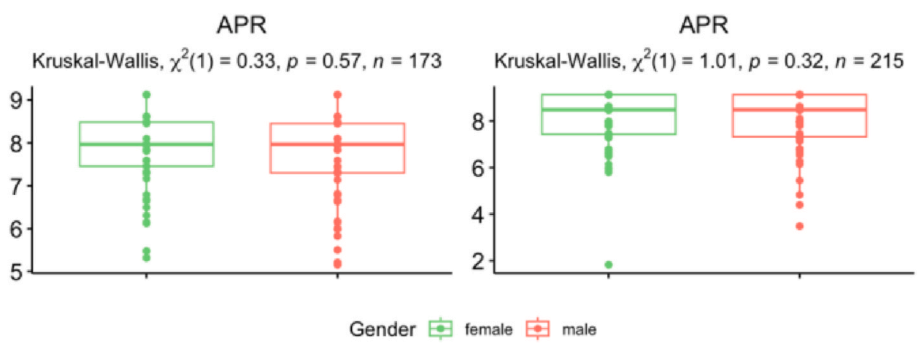


**Fig. 7.** KW for perceived learning (APR) of physical and digital experience.

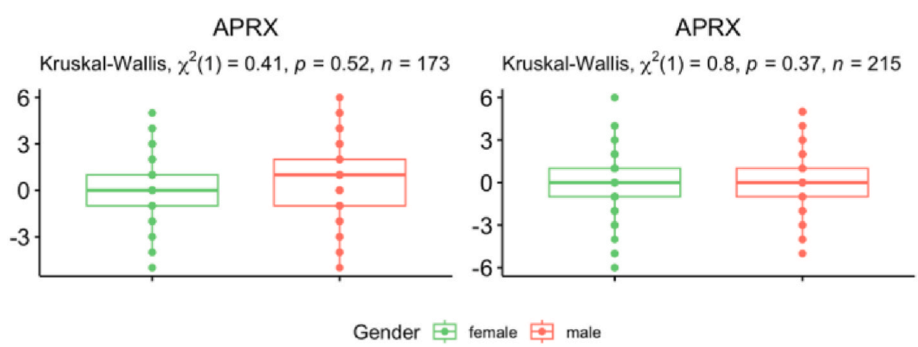


**Fig. 8.** KW for real learning (APRX) of physical and digital experience.

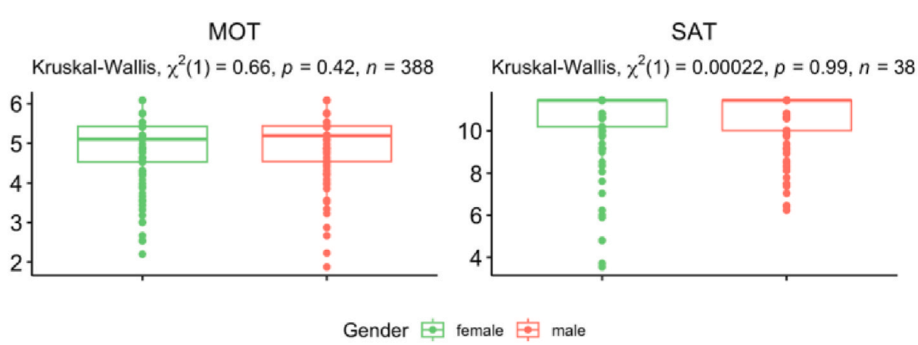


**Fig. 9.** KW for Motivation (MOT) and perceived satisfaction (SAT) for the overall sample.

## 5. Discussion

The results of this study allow us to establish the basis for the design of an ER from a gender perspective. On the one hand, it has been shown that there are no gender differences in satisfaction and perceived and real learning in the two modalities. Therefore, it is not decisive which mode is used to achieve the objective of educating about sustainable mobility and maintaining student satisfaction. On the other hand, it has

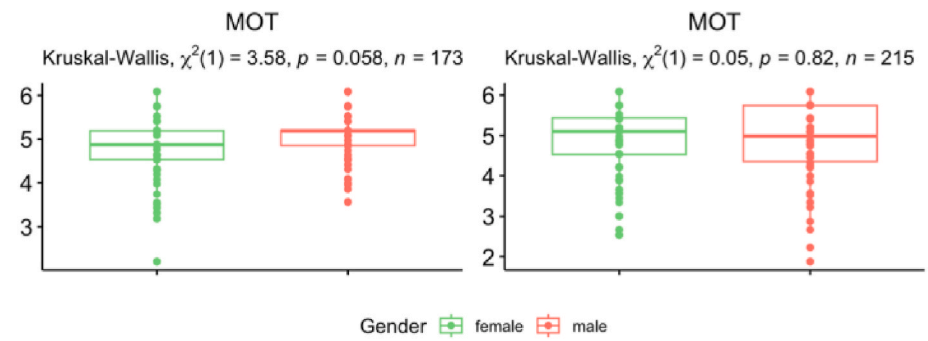


**Fig. 10.** KW for Motivation (MOT) from physical and digital experience.

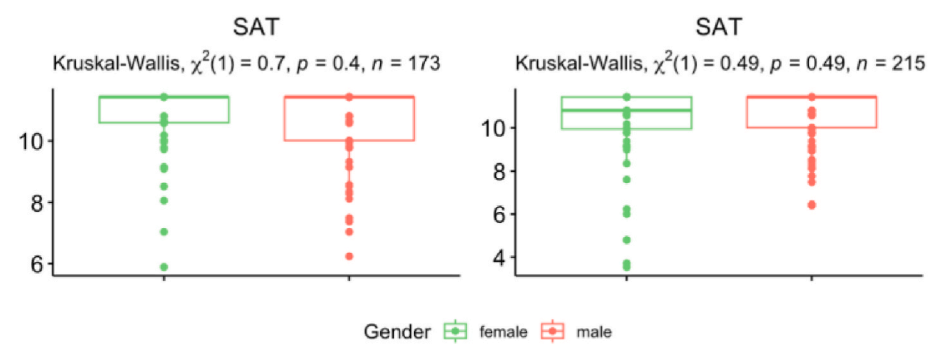


**Fig. 11.** KW for satisfaction (SAT) of physical and digital experience.

been shown that there is no gender difference in the motivation of students in the digital experience in line with recent research showing that the gap between males and females in the propensity to play videogames has closed, although it has been established that there are gender differences in what motivates them to participate in these games (Chou & Tsai, 2007; Nguyen et al., 2023). However, the gender difference observed in the physical ER is an insight into how the design of the experience may influence the expectations, preferences or perceptions of the participants.

This observation aligns with previous studies highlighting differences between men and women in terms of extrinsic and intrinsic motivation in learning environments. Extrinsic motivation is driven by external factors such as rewards, recognition or social pressure (Ryan & Deci, 2000). In the context of an ER, extrinsic motivation can manifest itself in different ways: for example, participants may be motivated to complete the game in order to win a prize, beat a record or demonstrate their competence to others. Some people may participate because their friends or colleagues organised the event, and they do not want to be left out. Others may be motivated to solve puzzles because of the promise of receiving a reward or avoiding a penalty. Intrinsic motivation, on the other hand, arises from an internal sense of enjoyment and personal satisfaction derived from participating in an activity without the need for external rewards (Ryan & Deci, 2000). In an ER environment, intrinsic motivation is the enjoyment of challenge and puzzle solving, the adrenaline rush experienced when tackling a challenging task, or the satisfaction of working collaboratively to unravel a mystery.

It is known that both genders respond positively to extrinsic motivators in gamified environments, i.e. the impact of external rewards seems to be similar for both, as both male and female learners show interest in reward systems that encourage autonomy and participation in learning activities (Torres-Toukoumidis, Carrera, Balcazar, & Balcazar, 2021). However, it must be considered when designing an ER that individuals do not determine their behaviour by extrinsic motivation but are primarily driven by intrinsic motivation (Deci & Ryan, 1985). Furthermore, although both types of motivation promote increased performance (Cerasoli, Nicklin, & Ford, 2014), intrinsic motivation is associated with higher quality of task effort, greater creativity, learning and psychological well-being (Mekler, Brühlmann, Tuch, & Opwis, 2017). Research indicates that students tend to show higher intrinsic motivation in non-playful learning environments (Luitel, 2024), which is in line with self-determination theory (Deci & Ryan, 1985). However, when elements of gamification are introduced, a dynamic shift occurs: male learners often report a greater sense of enjoyment and comfort with game-based tools compared to female learners (Mellado, Cubillos, Vicari, & Gasca-Hurtado, 2024; Rapp, Hopfgartner, Hamari, Linehan, & Cena, 2019).

ER designs should incorporate motivational elements that appeal to all participants, ensuring that both gender-specific intrinsic factors and cross-cutting extrinsic motivators are used effectively for all. This suggests that a balanced combination of game elements can be used to maximise participation, accommodate diverse preferences and create an inclusive learning experience. In educational settings, we have identified design features of gamification that tend to appeal to boys and girls differently, always considering that individual preferences may vary significantly from these tendencies. For example, male students tend to be more attracted to competitive elements such as leaderboards and achievement-oriented mechanics. This preference is associated with a greater appreciation of challenge, a sense of progress and recognition of performance. In this sense, the design of gamified environments that incorporate adjustable difficulty levels, continuous feedback and a visually stimulating interface could favour their motivation (Dele-Ajayi, Strachan, Pickard, & Sanderson, 2018; Nguyen et al., 2023; Piquer--Martinez, Valverde-Merino, Gomez-Guzman, & Zarzuelo, 2024). In contrast, female students respond more positively to challenging tasks, achievement badges, social incentives, narrative elements and personalised experiences. In addition, they value clarity of goals and opportunities for social interaction, suggesting that environments with well-defined goals and opportunities for collaboration can increase their level of active participation (Dele-Ajayi et al., 2018; Nguyen et al., 2023; Piquer-Martinezet al., 2024). At the same time, some universal elements of gamification, such as personalisation options, choice-based mechanics, progression systems (e.g. leveling up) and structured rewards, appear to be effective for all learners, regardless of gender (Piquer-Martinez et al., 2024; Torres-Toukoumidiset al., 2021).

## 6. Conclusions

This study presents the ERs as a valuable tool to prepare new generations to face the challenges of sustainability and equity in mobility. However, it was unclear whether these experiences had a differential effect on boys and girls. The results of the analysis of variance provide evidence that evaluates the hypotheses raised about the impact of gender and the modality of the ER experience on the variables of perceived learning (APR), actual learning (APRX), motivation (MOT) and satisfaction (SAT). Overall, the findings do not support most of the initial hypotheses, which invites reflection on possible factors that could alleviate the design and implementation factors of ERs without influencing the effectiveness of this gamified strategy in the context of sustainable mobility. The absence of significant differences in learning variables indicates that ERs can be equitable tools to foster learning on sustainability issues, providing consistent results across genders.

The differences in motivation within the physical experience suggest the need to design ERs that are attractive to both genders, incorporating elements that respond to diverse interests. However, since satisfaction does not seem to depend on gender or modality, ERs can be confidently implemented as educational strategies that foster positive experiences for all students. In addition, their use can help raise awareness of sustainable mobility among new generations. To achieve more inclusive and effective experiences, the design of ERs in educational settings should consider not only motivational differences by gender but also cognitive styles, learning preferences and previous experience with games. While elements such as competition, rewards and challenges may appeal to certain students, others may be more engaged through collaborative problem solving, immersive narratives and social interaction.

From a design perspective, it is recommended to combine intrinsic and extrinsic motivators, allowing both goal-oriented and experiential learners to participate fully. One possible strategy is the implementation of modular structures, where participants can choose between game paths focused on competition and speed or on exploration and teamwork. Furthermore, given that familiarity with digital games influences the level of engagement, it is suggested that processes of progressive adaptation be integrated to ensure accessibility to students with different levels of experience in gamified environments. Future studies could expand the sample size and include additional educational or cultural background variables. In addition, the implications of gender and modality of ER in contexts other than sustainable mobility could be explored and hypothesised in relation to the impact of these long-term experiences on learning and motivation or other age ranges of learners.

## CRediT authorship contribution statement

**Silvia Sipone:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis. **Andrés Rodríguez:** Writing – review & editing, Software, Methodology, Formal analysis, Data curation. **Maira Delgado-Lindeman:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **José Luis Moura:** Writing – review & editing, Resources, Project administration, Conceptualization.

## Data availability statements

The data used in this article have been obtained from surveys of study participants. Authors cannot share individual data but aggregate data included in the article tables.

## Declaration of competing interest

This research does not involve sensible and/or individual data regarding the human participants and does not involve the use of animals. The personal data in this paper are anonymous and/or presented in aggregate form. All the authors agree with the information provided and give their consent to the information provided.

## APPENDIX 1

This appendix presents the questionnaires used in the study, together with the answers ordered according to the criteria established for evaluating 'real learning' (APRX). The main criterion used to determine whether a response was correct was whether it was in the first or second position of the three possible options.

**Table A.1**
Mobility questions initial and final data in [brackets] (*) correct 1st option; (**) correct 2nd option; (***) correct 3rd option.

| Question | Response options |
|---|---|
| Do you know what bike lanes are for? | They are used to ensure road safety for bicycles, skateboards and roller skates. (*) |
| | They ensure that non-motorised means of transport do not travel on the road. (**) |
| | They are used by both pedestrians and cyclists. (***) |
| Do you know what pedestrian zones are for? | They serve to allow pedestrians to walk freely and safely. (**) |
| | They serve to restrict the movement of cars. (***) |
| | They serve to reduce noise pollution, reduce the use of motorised vehicles, improve pedestrian safety and increase public space (shopping areas, green parks, squares, etc.). (*) |
| Do you know what Low Emission Zones (LEZs) are for? | They serve to prohibit the circulation of all motor vehicles. (***) |
| | They create areas within cities where access to certain vehicles is restricted due to their emissions to improve air quality. (*) |
| | They are used to allow only public transport to circulate. (**) |
| Do you know what bus lanes are for? | They serve to prohibit the circulation of all motor vehicles. (***) |
| | They serve to create a space on the road reserved for bus traffic. (*) |
| | They are intended for use by public transport only. (**) |
| Do you know what car sharing is? | It consists of sharing a car with other people for a limited period of time. (**) |
| | It consists of sharing a car with other people, but only when I don't have my own car available. (***) |
| | It consists of sharing a car with other people to go to work, to school, to travel, etc. This practice can reduce congestion and pollution in cities reduce traffic congestion and pollution in cities. (*) |
| Do you know what Public Transport is? | It is a collective means of transport, because it is used by many people, and it is sustainable. (**) |

(continued on next page)

**Table A.1** (*continued*)

| Question | Response options |
|---|---|
| | It is a means of transport that has a timetable, established routes and can be used by purchasing a ticket. (*)<br>It is a means of transport used only by people who do not have their own car (***). |
| Do you know what Sustainable Mobility is? | It is to look for ways to reduce polluting gases from vehicles, by proposing different ways of getting around (**).<br>It is the set of actions to reduce environmental pollution, to promote equality between people in terms of travel and to bring economic benefits by reducing costs and to bring economic benefits by reducing costs (*).<br>It is to use only non-motorised means of transport such as bicycles and skateboards (***). |
| Do you know what Active Mobility is? | It is our ability to move around using non-motorised means (*).<br>It is our ability to move around using motorised means (***).<br>All modes of transport that will get to us soon (**) |
| Do you know why it is important to plan a city to make its mobility more sustainable? | Because it helps not to create traffic. (***)<br>Because it provides environmental and economic benefits and greater equality of mobility for all (*).<br>Because it creates more order in the city and a better quality of life (**). |
| Rank the following options in order of their degree of sustainability | Driving is the easiest way to get to school. (***)<br>Walking allows you to think on the way to school (**).<br>Going by bus allows you to get to school without help and with more people (*). |
| Put these means of transport in order according to which one you consider more sustainable. | Train (**)<br>Bicycle (*)<br>Motorbike (***) |
| Who should have mobility priority in a city that applies sustainable mobility? | Private cars and motorbikes (***)<br>Pedestrians (*)<br>All types of non-motorised transport (**) |
| What is considered most important when travelling in a sustainable mobility environment? | Go by bus and enjoy the scenery during the journey (**).<br>There should not be too many cars and it should not be dangerous to walk (*).<br>Not to get tired and to get to where I want to be quickly (***). |
| Which of these images best represents a sustainable city? |  (***)<br> (**)<br> (*) |

## Data availability

Data will be made available on request.

Dataset on Student Perceptions of Sustainable Mobility Pre- and Post Escape Room Intervention (Original data) (Mendeley Data)

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