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# Analysis of factors influencing the acquisition of sustainable mobility through immersive experience in primary school children

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Gamification and Escape Rooms (ER) have emerged as effective tools for fostering attitudinal and behavioural shifts and enhancing learning. While their application in sustainable mobility remains limited, it is predominantly associated with digital games and mobile applications tailored towards an adult audience. This study explores the potential of these tools in cultivating an understanding of sustainable mobility principles among children aged 10 to 13. Through an immersive experience involving problem-solving and puzzles, 174 participating students were immersed in a playful setting conductive to assimilating knowledge about sustainable mobility. Pre- and post-experience questionnaires were administered to assess the extent of learning, and their results were categorised based on student characteristics, such as gender and mobility patterns. Using multinomial logit models to analyse the questionnaire data helped identify variables that affect the likelihood of giving correct answers before and after the experience. The results indicate that gender, bicycle usage, dependence on public transportation, and the number of cars in the household significantly impact awareness of mobility issues. Moreover, the ER experience has been found to cause a small yet noticeable change in understanding sustainable mobility concepts.

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## Introduction

The incorporation of the UN Sustainable Development Goals (SDGs) and, consequently, the concept of sustainable mobility into educational curricula is increasingly prevalent.

Sustainable mobility encompasses environmental considerations and intertwines with the three pillars of social, economic, and environmental sustainability (Ranjbari et al. 2021). Regrettably, these dimensions are frequently overlooked, primarily due to a deficiency in understanding. Outreach and education initiatives can drive behavioural changes towards sustainable mobility solutions, extending beyond environmental aspects and filling these gaps. In recent years, there has been a surge in interest in leveraging gamification strategies to integrate, disseminate, and reinforce the core tenets of the SDGs among individuals. This trend primarily revolves around digital games and mobile applications and is predominantly tailored for an adult audience (Poslad et al. 2015).

Gamification is widely recognised as a potent persuasive tool and has evolved into a pervasive phenomenon in contemporary society. Various definitions in the literature converge on the understanding that gamification entails the application of game design elements in non-game contexts (Larson 2020) to engender interest and gratification and, most significantly, to instigate behavioural transformation (Andersson et al. 2018). In recent years, the adoption of gamification techniques, integrating gaming elements to encourage voluntary behavioural modifications, has gained prominence across diverse academic domains (Gentry et al. 2019; Wang et al. 2022).

Wang et al. (2022) conducted a comprehensive review of the literature on the use of gamification in transport and found several areas of interest. These encompass examining traveller behaviours, promoting sustainable modes of travel, advocating for safe driving practices, and endeavours to mitigate carbon dioxide emissions and energy consumption. Notably, successful instances exist wherein gamification has been harnessed to cultivate sustainable lifestyles among children and parents (Ferron et al. 2019).

Despite the valuable contributions of these studies to the field, research focusing on the dissemination and assimilation of knowledge regarding sustainable mobility among children appears to be scarce (Sipone et al. 2021).

Amidst the myriad gamification techniques that facilitate knowledge acquisition, engender engagement, and promote positive behaviours, a novel approach has garnered increasing attention from researchers: the utilisation of Escape Rooms (ER) (Bassanelli et al. 2022). In the domain of sustainable mobility, the application and scholarly investigations of ER remain limited (Sipone et al. 2024a).

This study explores the potential of ER as a catalyst for fostering the comprehension of sustainable mobility concepts among children aged 10 to 13 by creating an ER with multiple challenges. To this end, both pre- and post-experience questionnaires have been devised and administered to the 174 students. The primary objective is to discern the factors influencing the acquisition of these concepts and evaluate the ER activity's efficacy in this regard.

The analysis of the survey results offers novel insights into the pedagogical efficacy of employing educational escape rooms and the associations between mobility patterns and knowledge acquisition regarding sustainable mobility among children. Additionally, this work provides a comprehensive account of the entire experience, aiming to facilitate the development of impactful educational escape rooms for imparting an understanding of sustainable mobility concepts.

Other important contributions of our study are the practical implications that our study brings to research: applying multinomial logit models (MNL) to analyse the questionnaire data provides a robust methodology for assessing the impact of ER on learning, allowing us to identify the variables that influence knowledge acquisition. The study demonstrates that ER can bring about a perceptible change in students' knowledge, suggesting its potential as an educational tool. The use of pre- and post-experience questionnaires and analysis using multinomial logit models provides a solid basis for assessing the impact of ER on student learning. Unlike most gamification and ER applications that focus on adults, this study focuses on children, which opens up new possibilities for sustainability education from an early age. This can help design more effective educational interventions.

After an introduction, the next section reviews ER literature and its educational uses. The following part details the experience and methodology. The fourth section analyses the results, leading to study conclusions in the fifth section.

## Literature review

ERs are interactive team-based games wherein participants are tasked with overcoming challenges to accomplish a mission within a constrained timeframe (Nicholson 2015). Despite being a relatively new concept, ERs have become immensely popular. They were first used in Japan in 2007 and have grown rapidly in recent years. Karageorgiou et al., (2019) posits that educational ER represents an innovative pedagogical approach within the gamification framework.

The burgeoning popularity of ERs as a sought-after leisure pursuit has prompted their integration into educational settings, offering a novel avenue to engage students in their learning environment (Kinio et al. 2019). Their appeal lies in their potential to enrich student learning through immersive experiences, applicable across diverse subject areas and educational levels (Fotaris and Mastoras 2019; Sanchez and Plumettaz-Sieber 2019). ER serves as an active learning strategy, transforming learners from passive observers to active participants. Brown et al., (2019) assert that ER is a highly effective and efficient learning modality, enabling students to retain and apply acquired knowledge. Furthermore, it serves as a motivational tool, fostering a fun and collaborative learning environment.

Educational ERs are tailored for specific target groups with clearly defined learning objectives. Like recreational ERs, educational ERs task students with solving puzzles, challenges, and quizzes linked to curricular content and skills, employing a playful approach.

Educational ER hinges on students' autonomous efforts to collaboratively resolve real or hypothetical problems posed by educators, thereby fostering skill acquisition and learning outcomes (Wynn and Okie 2017).

Given its novelty, research on ER as an educational tool is rapidly evolving. Various studies have detailed the utilisation of ERs across a wide array of disciplines, including medicine (Guckian et al. 2020), computer networks (Ho 2018), mathematics (Fuentes-Cabrera et al. 2020), and the cultivation of generic skills (Craig et al. 2020). These studies have furnished compelling empirical evidence demonstrating the positive impact of educational ERs on student engagement (Jambhekar et al. 2020) and learning outcomes (Huang et al. 2020).

While ER has been used to address climate change (Ouariachi and Wim 2020) and sustainability (Ceccarini and Prandi 2022) with children, there is a paucity of literature in the transport field that addresses sustainable mobility education for both children and adults.

## Methodology

**Creation of the ER and related issues**. The development of an educational ER needs adherence to specific procedures. Our investigation devised an ER with a primary emphasis on resolving problems, overcoming challenges, and engaging in puzzle-like activities centred on sustainable mobility themes. The challenges were structured sequentially, as outlined by Wiemker et al. (2015). This sequential structure entails that the resolution of the puzzles follows a predetermined sequence to attain the objective. Wiemker et al. (2015) also delineate two alternative structures for ER creation: the open structure, where there is no prescribed order for puzzle resolution, and the multilinear structure, which amalgamates sequential and non-sequential puzzles and quizzes. The selection of the sequential structure was predicated on the interrelated nature of the tests: concepts uncovered in preceding tests served as reference points and aids for resolving subsequent challenges.

Critical elements in the design of an educational ER include incorporating a narrative that provides context for the knowledge and skills required for its resolution (Subhash and Cudney 2018). A narrative was crafted to envelop the tests, and the ER areas were set up within the classrooms and halls of the University, featuring scenarios related to sustainable mobility, such as the use of traffic cones, illustrative posters, various modes of transport, and reflective traffic waistcoats. The storyline engaged the students as "Mobility Guardians," guiding them through quizzes to uncover the fundamental principles of sustainable mobility, empowering them to make informed decisions and embrace more sustainable behavioural practices.

The assessments were tailored for students aged 10 to 13, focussing on five fundamental mobility topics. The puzzles were devised to require all team members' involvement and communication to accomplish the activity. Table 1 and Fig. 1 show the five proposed macro-themes, the related specific concepts, and the ER puzzles and tasks.

The choice of the five macro-themes was based on the selection of the basic mobility concepts. The preliminary study on the existing literature on sustainable mobility (Cellina et al. 2024; Iamtrakul et al. 2024; Ros-McDonnell et al. 2024) issues has allowed us to select the proposed topics for their relevance, impact, potential to raise awareness, to make informed decisions and to adopt more sustainable behavioural habits in children of the age group involved in the experience.

Before starting the ER, the students were presented with a video describing the situation and the final objective of the game. To exit the ER, the students, in small groups of 5 or 6 members, had to stop a timer by entering a numerical code. The groups that had to overcome the challenges were predetermined by the professors of each participating centre, respecting the criteria of heterogeneity (balance between men and women, academic level). The ER experience could be proposed simultaneously in five prepared spaces at the university. The total number of groups was set at five or six units, depending on the number of students in the participating class.

To stop the timer, they had a maximum time of 50 min.

At the same time, all the rules of the game were made clear: they should not cheat, spoil the material, make noise and raise their voices, cooperate, and ask for help by putting on a traffic waistcoat.

**Participants**. For the experiment, 174 students from diverse schools of a city in north of Spain (Santander), from the 5th grade of primary school to the 1st year of Compulsory Secondary Education, were chosen.

The selection of schools aimed to ensure a comprehensive representation of various socio-economic backgrounds, accurately reflecting the observed reality. Considering the participants' age, written consent was diligently obtained from parents or guardians to uphold the ethical and legal standards of the study. Subsequently, in the data analysis phase, the completed questionnaires were anonymised to safeguard the students' privacy, retaining solely the pertinent information essential for result analysis.

**Creation of the data collection questionnaire**. Prior to commencing the ER, students were presented with a questionnaire comprising two sections. The first segment encompassed 8 inquiries about social characterisation (gender, family

**Table 1 Organisation of the Escape Room themes.**

| Track | Macro theme | Concepts | Playing tests |
|---|---|---|---|
| 1. | Active mobility | • Non-motorised vehicles: skateboards, bicycles, skates, skateboards.<br>• Walking and running. | • Search an alphabet soup for various ways to actively move around;<br>• Find the code to decipher the secret message and the first number to unlock the countdown. |
| 2 | Means of transport | • Analysis of the different means of transport about their impact on the economic, environmental and social components.<br>• Public transport and its characteristics. | • Search the room for various types of means of transport;<br>• Divide the means found into two groups according to the definition of sustainable and non-sustainable and solve the riddle formula: S-NS = C (code). |
| 3 | Mobility pyramid | • Analysis of the hierarchy of priority for travel in the city.<br>• Pedestrians, bicycles, public transport, freight transport, cars and motorbikes. | • A Snote (a secret message in a picture with a hidden text) forces players to watch a video that will help them answer some questions. |
| 4 | Carpooling to reduce traffic congestion | • Traffic jams: the causes and the problems that generate them.<br>• The solution: making the same journey by carpooling. | • Read a newspaper story and, using a cut-out template, find out the message to obtain the secret code number through a mathematical operation;<br>• Solve the maths puzzles in the newspaper to get the numbers to include in the formula found in the news message. |
| 5 | Organisation and planning of a city's spaces | • Recognition and definition of different types of space in the city to create solutions towards more sustainable mobility: bicycle lanes, bus lanes, pedestrian zones, low emission zones. | • Find out the name of some areas of the road or city written with code red using glasses with red lenses;<br>• Find the secret number written in invisible ink on the test using a UV light. |


**Fig. 1** Practical experience.

composition, place of residence) and mobility patterns (number of family vehicles, bus usage, cycling). In the second segment, 14 questions related to mobility issues were asked following the themes in Table 1. The questions in the latter part were structured as ranking questions, formulated in accordance with the model delineated by Louviere et al. (2000). For each query, students were tasked with comparing three definitions related to sustainable mobility issues and ranking them based on their understanding and opinion, from the most accurate to the least accurate.

The outcomes were withheld from the students before the activity to prevent independent research on sustainable mobility, thereby preserving the integrity of the research. Utilising these question types facilitates the assessment of the comprehension and assimilation of sustainable mobility concepts before and after the gamification experience through the ER. The subsequent questionnaire, administered post-experience, replicated the 14 mobility-related questions from the initial questionnaire.

In this study, we will exclusively correlate the outcomes of the characterisation questions with the initial and final responses about sustainable mobility topics. To ascertain the efficacy of learning, both a pre-test and a post-test were employed. The pre-test was conducted immediately before the students engaged in the ER, while the post-test was administered after the debriefing session. The test results were subsequently scrutinised using a multinomial logit model to gauge the extent of learning (Hensher et al. 2015).

**Multinomial Logit models**. When considering the incorporation of the UN Sustainable Development Goals (SDGs) and the concept of sustainable mobility in educational curricula, it is important to recognise the factors that influence students' knowledge and attitudes, to this end, a series of Multinomial Logit models (MNL) are presented below, following the methodology of (McFadden 2001).

This technique is widely used in fields such as econometric analysis or transport to analyse discrete decisions and allows modelling of choice between alternatives (Coppola et al. 2021; Rodríguez et al. 2022; dell'Olio et al. 2023; Rodríguez et al. 2023). It represents a novelty in comparing results in extension studies with respect to the usual statistical techniques.

In MNL (McFadden 2001), students' behaviour when choosing an option is modelled through a utility function. The utility associated with the choice of alternative i for individual n is given by the formula:

$$U_{in} = V_{in} + \epsilon_{in}$$

Where:

- $U_{in}$ is the total utility of alternative i for individual $n$,
- $V_{in}$ is the utility, a linear function of the observable attributes of alternative $i$,
- $\epsilon_{in}$ is the random error term that captures unobservable or unpredictable factors affecting the individual's decision.

The utility $V_{in}$ is defined as:

$$V_{in} = \beta_1 X_{1in} + \beta_2 X_{2in} + \ldots + \beta_k X_{kin}$$

Where:

- $X_{1in}, X_{2in}, \ldots, X_{kin}$ are the observable attributes of the alternative $i$ for the individual $n$,
- $\beta_1, \beta_2, \ldots, \beta_k$ are the coefficients that measure the impact of each attribute on the utility of the alternative.

The random error term $\epsilon_{in}$ serves to capture the errors or incorrect responses of the students, as it represents the part of the decision that cannot be fully explained by the observable attributes.

The MNL model assumes that individuals choose the alternative with the highest perceived utility. Since there is a random component in the utility, the probability that an individual $n$ chooses alternative $i$ is given by the following expression:

$$P_{in} = \frac{\exp(V_{in})}{\sum_{j=1}^{J} \exp(V_{jn})}$$

Where:

- $J$ is the set of possible alternatives.

The proposed models aim to capture the influence of various variables on decisions (gender, family size, available modes of transport, etc.), which is intended to understand the students' responses in our questionnaires. Several models have been created

to evaluate learning outcomes independently and collectively, allowing us to explore different dependent variable categories. We analyse both individual choices (RESPI for the initial questionnaire and RESPF for the post-activity questionnaire) and the independent variables derived from these questionnaires. We aim to understand the factors influencing students'correct or incorrect responses.

This approach was used to estimate the bivariate logit model because students' responses could be clearly classified into two categories: correct or incorrect, based on whether the top two positions in the response ranking were correct or not. However, the model considered multiple independent variables simultaneously, as these variables do not act in isolation; their influence on students' decisions is joint.

In these models, the dependent variable corresponds to the individual choice (RESPI for the initial questionnaire and RESPF for the final questionnaire). In contrast, the independent variables encompass the characteristics of the alternatives that influence this decision. These independent variables can be considered individually or grouped in some cases. Thus, the MNL model allows us to understand correct or incorrect choices and how the characteristics of the alternatives and random factors influence students' behaviour.

## Result and discussion

Following the methodology described in the previous section, an ex-ante form was administered to 173 individuals, collecting data twice for each participant. This generated 4844 choice scenarios (between the two questionnaires per individual), which were used for the subsequent analysis. The questionnaire was designed to address both social characterisation and mobility patterns. The data collected were analysed separately: on the one hand, questions related to social characterisation and mobility patterns, and on the other hand, questions linked to the concepts of sustainable mobility, which allowed a differentiated assessment of these two aspects.

From the characterisation and mobility patterns, we can analyse different data referring to the place where they live, the number of family members, how many cars the family owns, whether the children have a bicycle and why they use it: whether it is for playing, going places, or both options. They are also asked whether they use public transport and how often: less than once a week or more than once a week. Table 2 illustrates the frequencies and proportions of their responses.

The answers concerning sustainable mobility concepts have been analysed to explain that ER activities have led to changes in the student's knowledge about sustainable mobility issues. Secondly, to see if some mobility behaviours, habits, or social situations can affect the acquisition and change of conduct regarding sustainable mobility. A complete description of the data set method, in addition to the raw database, has been published in (Sipone et al. 2024b). From these data, MNL modelling has been conducted to assess how these social situations influence students' choices. In this modelling, utility functions are formulated for correct choices (when the first two options were correctly ranked) and incorrect choices, allowing for a comparative analysis of students' choices concerning sustainable mobility. This generates a binary system of correct and incorrect choices. Since the knowledge questions were structured as ranking questions, it is important to note that, for each question, the first two positions in the ranking are considered correct, while the last one is considered incorrect.

As for the answers concerning sustainable mobility concepts, Table 3 illustrates the participant responses across the initial and final questionnaires.

**Table 2 Socio-economic characteristics of participants and mobility habits.**

| Variable | Options | Frequency | % |
|---|---|---|---|
| **Gender (SEX)** | Boy | 87 | 50,29% |
| | Girl | 86 | 49,71% |
| **Residency (RES)** | Village | 40 | 23,12% |
| | City | 133 | 76,88% |
| **Family size (TFAM)** | 2 | 5 | 2,89% |
| | 3 | 35 | 20,23% |
| | 4 | 92 | 53,18% |
| | 5 | 27 | 15,61% |
| | 6 | 5 | 2,89% |
| | More | 9 | 5,20% |
| **Own a bike (BIKE)** | Yes | 129 | 74,57% |
| | No | 44 | 25,43% |
| **Using bike to play (UBIKP)** | Yes | 94 | 54,34% |
| | No | 79 | 45,66% |
| **Using the bike to get around (UBIKG)** | Yes | 82 | 47,40% |
| | No | 91 | 52,60% |
| **Number of cars in household (NCAR)** | 0 | 25 | 14,45% |
| | 1 | 67 | 38,73% |
| | 2 | 69 | 39,88% |
| | More | 12 | 6,94% |
| **Use of public transport (PT)** | Yes | 112 | 64,74% |
| | No | 61 | 35,26% |
| **Frequency of public transport use Occasionally (UTPS)** | Yes | 69 | 39,88% |
| | No | 104 | 60,12% |
| **Much (UPTL)** | Yes | 35 | 20,23% |
| | No | 138 | 79,77% |

**Table 3 Participant responses across the initial and final questionnaires.**

| | Correct | Wrong |
|---|---|---|
| **Initial questionnaire** | 1907 (78,74%) | 515 (21,26%) |
| **Final questionnaire** | 1990 (82,16%) | 432 (17,84%) |

From a statistical perspective, according to the data from Table 3, students who engaged in the activity demonstrated an overall improvement of roughly 4%. Notably, the initial levels of knowledge were already quite high, with roughly four over five individuals presenting familiarity with the concepts before engaging in the experience. This tendency suggests that future research should explore incorporating more complex or specific concepts into the ER activity in order to measure the evolution of learning.

Concerning the results obtained from the sustainable mobility questionnaire, the 14 questions included in the evaluation (Table 3) were weighted equally, as each addresses homogeneous aspects for understanding this concept. The decision to give equal weight to all questions reflects the interest in capturing a general understanding of the different topics related to sustainable mobility. According to the data presented in Table 3, the students who participated in the activity showed an overall improvement of 3–4% in the final questionnaire compared to the initial one. Although this margin of improvement may seem modest, it is important to highlight that the initial knowledge levels were already high, with approximately 79% correct answers in the initial questionnaire. This high level of prior knowledge limits the margin for improvement, but the increase to 82% of correct answers in the final questionnaire represents a positive change.

**Table 4 Effect of gender on initial and final responses.**

| | Model 1 (initial) | | Model 2 (final) | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **z** | **Coefficient** | **z** |
| $\beta_{SEX}$ | 0.36344 | 7.46 | 0.19779 | 4.11 |
| $\beta_0$ | −0.18827 | −5.27 | −0.18716 | −5.21 |
| N | 2422 | | 2422 | |
| L-Likelihood | −4278.20 | | −4306.25 | |

**Table 5 Effect of place of residence on initial and final responses.**

| | Model 1 (initial) | | Model 2 (final) | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **z** | **Coefficient** | **z** |
| $\beta_{RES}$ | 0.36253 | 8.90 | 0.31718 | 7.83 |
| $\beta_0$ | −0.13734 | −3.68 | −0.11359 | −3.03 |
| N | 2422 | | 2422 | |
| L-Likelihood | −4266.23 | | −4283.90 | |

**Table 6 Effect of family size on initial and final responses.**

| | Model 1 (initial) | | Model 2 (final) | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **z** | **Coefficient** | **z** |
| $\beta_{TFAM}$ | 0.08106 | 9.68 | 0.06378 | 7.67 |
| $\beta_0$ | −0.10852 | −2.85 | −0.10140 | −2.64 |
| N | 2422 | | 2422 | |
| L-Likelihood | −4258.40 | | −4285.02 | |

**Table 7 Relationship between modes of transport and knowledge of sustainable mobility.**

| | Model 1 (initial) | | Model 2 (final) | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **z** | **Coefficient** | **z** |
| $\beta_0$ | −0.26637 | −3.84 | −0.26818 | −3.85 |
| $\beta_{PT}$ | 0.14658 | 2.53 | 0.11036 | 1.95 |
| $\beta_{BIKE}$ | 0.24740 | 4.51 | 0.21611 | 4.01 |
| $\beta_{NCAR}$ | 0.09389 | 2.23 | 0.10803 | 2.54 |
| N | 2422 | | 2422 | |
| L-Likelihood | −4267.40 | | −4286.61 | |

In the first of the MNL models, the effect of gender on students' responses was assessed by summarising in a table the values relative to the initial and final questionnaire results (Table 4). Before the experiment, females (gender = 1) showed a higher probability of answering correctly, with a significant coefficient (> 99%) of 0.36, reflecting the trend observed in other educational contexts (Polo-Peña et al. 2021) where girls show a prior interest and demonstrate higher competence in sustainability issues. Likewise, in the post-activity questionnaire, the value of the gender coefficient, while maintaining its high level of significance, substantially reduces the parameter with which it is represented (33%), which can be interpreted as the effectiveness of the ER activity in instilling the concepts of sustainable mobility in the other gender. Especially in the case of men, a knowledge gap is closed, helping to address the inequalities detected in the responses to the previous questionnaire.

The second model relates the initial and final learning outcomes to the student's place of residence. Specifically, we considered, on the one hand, those whose residences were in urban areas (city) (RES = 1) and, on the other hand, those whose residences were in rural areas (village) (RES = 0). Modelling the results (Table 5), we note that the impact of place of residence on sustainable mobility knowledge was also significant. Students from urban areas showed higher prior knowledge, possibly due to greater exposure to sustainable mobility concepts in these environments. However, as reflected by the evolution of the residence parameter, the escape room's realisation proved to be an equaliser, slightly reducing the knowledge gap between urban and rural students. In all cases, the models yielded coefficients with a statistical significance above 99%, validating their use in this comparison.

The following model, developed to analyse and compare the results obtained in the questionnaires before and after the experiences related to sustainable mobility, was conducted considering the household size. Like the previous models, two specific models were implemented to examine the correct answers before and after the experience (Table 6).

In this case, the results were statistically significant (> 99%), with coefficients indicating a direct correlation between family size and higher prior knowledge of sustainable mobility. This decrease in the coefficient value for the number of family members, together with the drop in statistical significance (still remaining well above 99%), suggests that the practical educational experiences are effective since, after the experience, belonging to a very large family has a softening effect on the probability of answering the questionnaire right or wrong (e.g. for a family of 10 members, the probability of not answering the questionnaire right decreases by 5%). In other words, the escape room experience levelled the knowledge of sustainable mobility between pupils of different family sizes, reducing the influence of this factor on correct answers.

However, most interestingly, after the ER experience, the coefficients of these variables decreased significantly (Table 6). This suggests that practical educational experiences are effective, as it does not now account for the direct influence that belonging to a larger family size may have on a higher number of correct answers in the questionnaire. In other words, the escape room experience levelled the knowledge of sustainable mobility among students of different family sizes, reducing the influence of this factor on correct answers.

After analysing these 3 factors individually, the combined relationship between transport modes and sustainable mobility knowledge was investigated, both before and after the educational experiences. For this purpose, a model was developed in which bicycle ownership and public transport use were related to the probability of answering correctly and the number of cars answering incorrectly.

The results revealed that bicycle ownership and use of bicycles were positively associated with higher knowledge in this domain to a greater extent than the use of public transport. However, it was significant and positive in both cases (> 95%). This suggests that students who have access to and use bicycles as a means of transport tend to be more familiar with sustainable mobility concepts. Cycling, as a sustainable mode of transport, can foster greater awareness and understanding of these issues.

Conversely, a higher number of cars in the household is correlated with a tendency towards incorrect answers, possibly reflecting a lower exposure or perceived need to seek sustainable transport alternatives. This implies that pupils whose families have more cars may be less interested in learning about sustainable mobility, as they have access to several motorised vehicles. Moreover, this coefficient, as evident by comparing the information in Table 7, hardly changes before or after the escape room. In other words, this type of student does not improve their

**Table 8 MNL result considering different variables.**

| | Model 1 (initial) | | Model 2 (final) | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **z** | **Coefficient** | **z** |
| $\beta_0$ | −0.23434 | −3.39 | −0.07189 | −1.85 |
| $\beta_{UBIKE}$ | 0.12920 | 2.07 | | |
| $\beta_{TFAM}$ | 0.05767 | 4.84 | 0.01889 | 1.98 |
| $\beta_{SEX}$ | 0.10592 | 1.70 | | |
| $\beta_{NCAR}$ | 0.09592 | 2.31 | | |
| $\beta_{CHOICEI}$ | | | 0.64754 | 9.73 |
| N | 2422 | | 2422 | |
| L-Likelihood | −4252.34 | | −4237.20 | |

understanding and knowledge of the concepts during the experience.

In the final analysis of our research, we have tried to establish relationships between some of the concepts we have previously studied individually in the models we developed earlier and the different modes of transport to provide greater validity to our conclusions. Their results are shown in Table 8, both for the pre-experience phase and post-experience phase.

These models considered the influence of variables such as bicycle use, family size, gender and number of cars, and the results obtained were again statistically significant ( > 95% or >99%, depending on the variable) and consistent in terms of signs with the previous models and with what would be expected from known behaviour.

Specifically, it is observed that cycling, larger family size and female gender, as we have previously shown individually, increase the likelihood of students having prior knowledge before undertaking the educational experience, with the greatest weight, in this case, being that of cycling for commuting, although very similar to that of students' gender.

These results support the idea that previous experience, the cultural environment in which we live, and exposure to certain factors can influence the level of knowledge about sustainable mobility prior to the educational activity concerned.

On the other hand, as shown in the previous model (Table 7), it is confirmed that the number of cars in the family negatively influences prior knowledge, increasing the possibility of incorrect answers quite significantly with respect to the other parameters. Several cars in the household environment may decrease awareness and knowledge about sustainable mobility.

Finally, in Table 8, we can also consider the model's results on the probability of responding correctly after the ER. In this case, the aim was to evaluate the previous response's effect to better understand the data in the table (Table 3). In this Table it was quantitatively stated that there was an improvement of slightly more than 4% after the experiment, and this final model also explains this slight improvement. The highest coefficient is supported by the $Beta_{choice\ i}$ affects the variable that is activated when the initial answer is correct and also has a very high significance and superior to the rest of the variables that were chosen in this model (family size and intercept). This result, therefore, ratifies that there is learning through experience in the ER that the previous response cannot explain.

## Conclusion

This article describes an ER to raise comprehension and increase knowledge of sustainable mobility.

The results analysis uncovers fresh insights into how effective educational escape rooms are and how mobility patterns correlate with children's grasp of sustainable mobility. Additionally, this study offers an overview of the experience, aiming to aid in developing educational escape rooms that teach concepts of sustainable mobility.

We sought to determine if the experience promoted sustainable mobility knowledge and how specific factors might influence this process. The results suggest that initial responses are influenced by a variety of factors, including participant gender, the number of cars in the household, bicycle use, family size, and public transport usage. These elements enhance the understanding of these concepts.

When analysing each question for the knowledge acquisition part of the ER, it was detected that most of the students responded correctly, even before the activity. Similar outcomes were observed in a sustainability-focused research study, (Ceccarini and Prandi 2022), underlining the prevalence of sustainable development concerns in contemporary society. Younger generations show an increased awareness of sustainability issues, particularly in sustainable mobility.

Despite this similarity with previous studies, the essence of our research has led us to provide further explanations for this result. The gap in the current literature has been to try to find out whether social factors (such as gender, family size, and place of residence) or mobility habits (such as bicycle ownership and use; use of public transport or number of cars in a family) have any weight in the predisposition to acquire sustainable mobility notion and whether the use of ER activity could have any relevance and influence.

Using MNL models, following the methodology developed by McFadden (2001), a series of models have been made, both individual models of some of the variables and global models, comprising several of them. These models have tried to explain how various factors affect knowledge acquisition in the sustainable mobility sector among students.

Our models suggest that the answer to an initial question and the specific parameter of the incorrect segment are essential in accurately compiling the final survey. Our research shows that early responses are influenced by several factors, including participant gender, the number of cars in the household, bicycle usage, family size, and public transportation use. These elements enhance the understanding of the concepts. However, it appears that the ER experience levels the students' knowledge of sustainable mobility concepts by minimizing the impact of all these factors in their final responses.

## Limitations and future research

Despite the promising results, the study has several limitations. Firstly, while substantial, the sample size of 174 students may not be representative of the broader student population. Future research should aim to include a larger and more diverse sample to enhance the generalisability of the findings.

Future research should also explore introducing more advanced and complex concepts within the ER activity to challenge students further and deepen their understanding. Investigating the impact of different ER designs and themes on learning outcomes could provide valuable insights into optimising this educational tool.

Moreover, examining the role of additional variables, such as socio-economic status and cultural background, could offer a more comprehensive understanding of the factors influencing sustainable mobility education.

Finally, in the next step, we intend to explore further the data obtained from this experience to establish correlations between additional variables and student learning in ER, thus refining and validating the efficacy of this technique.

## Data availability

The data used in this article have been obtained from surveys of study participants. Data are available in the following repository: Sipone, Silvia; Rodriguez, Andres; Rojo, Marta; MOURA, JOSE LUIS (2024), "Dataset on Student Perceptions of Sustainable Mobility Pre- and Post Escape Room Intervention", Mendeley Data, V3, https://doi.org/10.17632/ft64w7cckx.3.

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## Author contributions

Silvia Sipone: conceptualization, investigation, writing original draft, methodology, visualization; Andrés Rodríguez Gutiérrez: data curation, formal analysis, visualization; methodology; José Luis Moura: resources, reviewing and supervision; Marta Rojo: reviewing and supervision.

## Competing interests
The authors declare no competing interests.

## Ethical approval
The authors of this manuscript declare that no formal ethical approval was obtained for this study because, according to Universidad de Cantabria's ethical compliance guidelines for research and innovation projects, ethical review is not required for studies involving anonymized data. 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 in accordance with the recommendations of the Organic Law BOE-A-2021-8806 7/2021, of 26 May, on the Spanish General Data Protection Regulation (RGPD). In addition, the following relevant laws have been complied with:• Organic Law 3/2018, of 5 December, on the Protection of Personal Data and the guarantee of digital rights.• Organic Law 1/1996, of 15 January, on the Legal Protection of Minors.• Organic Law 8/2015, of 22 July, and Law 26/2015, of 28 July, both refer to the modification of the system for the protection of children and adolescents.The study adhered to these principles by ensuring all data were fully anonymized, participants' confidentiality was protected, and their involvement was voluntary. Given the minimal risk posed by the study's activities, ethical approval was unnecessary under these institutional guidelines.

## Informed consent
We affirm that informed consent was obtained from all parents and legal guardians of the participants. All participants were fully informed that their anonymity was assured, why the research was being conducted, how their data would be utilised and if there were any risks to their participation. Voluntary participation was ensured. Data privacy and confidentiality were maintained during each step of data collection, adhering to standard practices and protocols.

## Additional information
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