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An escape game in a museum as an opportunity to enhance visitors' environmental attitudes

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Abstract

Museums are places for informal education. The Observatory and Science Experience Centre in Eger, Hungary, has been using different entertaining methods for this purpose for some time. Recently, however, curators identified the need for a new game to enhance visitors' environmental attitudes and awareness. They decided to address this issue using an escape game. This game type has the advantage of being a popular form of entertainment for both younger and older people, and even for whole families – a good fit for the Observatory's visitor structure. Research has shown that escape games lead to a promising, albeit statistically not significant increase in players' environmental attitude scores. In light of these considerations, the aim of the study presented here was to examine whether the escape game designed for the Observatory's purposes would be effective in improving visitors' environmental attitudes. To answer this question, the author used the environmental emotion sub-scale (EESS) from the "Environmental Attitude" questionnaire developed in 2019 by Naim Uzun, Kenneth L. Gilbertson, Ozgul Keles and İlkka Ratinen. The 131 participant players in the study sample (83 female, 48 male) voluntarily filled out the survey form both before and after playing the game. Both analyses of the results, one applying the Wilcoxon signed-rank test to the attitude scores and the other using the rating scale model (RSM) with paired sample *t*-test, showed that the players' environmental attitudes had indeed improved significantly ($p < .001$).

Keywords Environmental education · Escape game · Intergenerational learning · Museum pedagogy · Informal learning environment · Hungary

Résumé

Le potentiel d'un escape game dans un musée pour améliorer les comportements environnementaux des visiteurs – Les musées sont des lieux d'éducation informelle. L'Observatoire et centre d'expérience scientifique d'Eger, en Hongrie, recourt

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pour cela depuis un certain temps à différentes méthodes divertissantes. Récemment, toutefois, les conservateurs ont déterminé qu'il était nécessaire de créer un nouveau jeu pour renforcer les comportements environnementaux des visiteurs et leur sensibilisation en la matière. Ils ont décidé d'aborder la question au moyen d'un escape game, un format présentant l'avantage d'être une forme de divertissement populaire, pour les jeunes et les moins jeunes, voire pour toute la famille, ce qui correspond à la structure des visiteurs de l'Observatoire. Des recherches ont montré que les escape games entraînent une augmentation prometteuse, bien que statistiquement non significative, des scores des joueurs en matière de comportement environnemental. À la lumière de ces considérations, l'objectif de l'étude présentée ici consistait à examiner si l'escape game conçu pour les besoins de l'Observatoire serait efficace pour améliorer les comportements environnementaux des visiteurs. Pour répondre à cette question, l'auteur a utilisé la sous-échelle des émotions environnementales du questionnaire « Comportement environnemental », développé en 2019 par Naim Uzun, Kenneth L. Gilbertson, Ozgul Keles et İlkka Ratinen. Les 131 participants à l'étude (83 femmes/filles, 48 hommes/garçons) ont rempli volontairement le formulaire d'enquête avant et après avoir participé à l'escape game. Les analyses des résultats, l'une appliquant le test des rangs signés de Wilcoxon aux scores en matière de comportement environnemental et l'autre utilisant le modèle d'échelle de notation avec un test *t* sur échantillons appariés, ont toutes deux révélé que les comportements environnementaux des joueurs s'étaient effectivement améliorés de manière significative ($p < 0{,}001$).

Introduction

The Observatory and Science Experience Centre in Eger, Hungary, is a small museum. Its building functioned as an observatory in the 18th century. It has a room dedicated to astronomy, a planetarium, a camera obscura constructed for entertainment purposes by the founders, a history of optics exhibition, and two rooms offering gamified programme possibilities. The study presented here is based on Karl Kapp's definition of gamification:

> a careful and considered application of game thinking to solving problems and encouraging learning using all the elements of games that are appropriate (Kapp 2012, p. 15).

Toys and games implemented for educational purposes should therefore be understood following the rubric of gamification.

One of the gamified exhibitions in the Observatory is the science experience room, where guests can conduct various experiments in a playful environment. The other, a so-called "scientific playhouse", opens only on special occasions such as holidays. It offers visitors the opportunity to play with gadgets which introduce important scientific and mathematical concepts. However, the Observatory was keen for environmental education to play a more significant role in its gamified

programme possibilities. A new game was therefore planned to enhance visitors' awareness of environmental degradation and pollution.

Description of the game

The theme of the game was waste management (reduce, reuse, recycle). It was designed as an escape game (EG) for groups with 3 to 6 members. Pairs could also play if they wanted to and could not find a third player, but none in the study sample succeeded in completing the game. The goal of the game was to open a briefcase and a money box, both of which featured number locks.

The players' first task was to solve an introductory puzzle involving numbers in a short poem which replaced certain corresponding letters. Upon successful completion of this task, they were rewarded with a code with which they could open the briefcase. They then had a limited amount of time to open the money box.

In the briefcase, the players would find many items of waste, an experience designed to shock them and influence their attitudes. They then had to find and solve three parallel puzzles. Finally, they had to solve a meta-puzzle using the results of the three previous puzzles in order to open the money box and win the game.

One of the puzzles was about recycling. An encrypted text directed players to select recyclable PET flasks. They had to exclude one polluted bottle, allowing the code number to be derived from the Roman numerals on the others. Another puzzle was about reducing waste. Players had to count how many lines could be deleted from a shopping list based on instructions on a hidden piece of paper. In the remaining puzzle, players had to find a sentence by jumping like a knight in chess through a table full of words. They were directed to count the number of dangerous waste items in the briefcase (medicines, electrical devices and a container of dye).

In the meta-puzzle, the players had to determine the order in which the numbers occurred in the code. Every exercise featured a small logo with the motto "reduce, reuse, recycle". Players had to follow the previous concepts in order of importance to enable them to get the code. The role of this exercise was to provoke discussion, even in those groups whose members would have solved the first three puzzles individually.

Since the museum's visitors include children, retired people, school classes and families, it was important to adjust the puzzles' difficulty level to the players' knowledge. Playing time was therefore tailored to the age of the players: 5th to 8th graders (aged 10–14)[1] had 25 minutes to open the money box, whilst older players had only 20 minutes. The players could also get verbal hints if they needed them.

[1] In Hungary, children join kindergarten (compulsory) at age three and enter primary school (Grades 1–8) when they are six, or with a special permit when they are seven years old. They can progress to different types of secondary schools (Grades 5–12, 7–12, 9–12, or 9–13) when they are 10, 12, or 14 years old respectively, and sit the final school leaving exam at the end. If they attend a school where they can also take their high school graduation exams, passing it entitles them to enter a university.

Literature overview

The most important reason behind the Observatory's desire for greater emphasis on environmental education in its gamified programme possibilities relates to the United Nations (UN 2015) Sustainable Development Goals (SDGs). Whilst only the fourth goal (SDG 4) is explicitly about education, János Mika (2017) argues that every goal has either implicit or explicit educational requirements to reach it. Furthermore, the Belgrade Charter's second guiding principle states that: "Environmental education should be a continuous life-long process, both in-school and out-of-school" (UNEP 1975, p. 4, section V.2.). Since museums and similar institutions are among the most important places for informal education (Stocklmayer et al. 2010), it would seem that they have a duty to participate in this mission (Wang and Chiou 2018). This is especially true for the Observatory, in its capacity as a museum of science and astronomy.

Escape games in museums

Escape games offer various advantages for the purposes of the Observatory's "scientific playhouse". Scott Nicholson defines EGs as

> live-action team-based games where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal (usually escaping from the room) in a limited amount of time (Nicholson 2015, p. 1).

The properties of this game type make it suitable for museums' purposes, and indeed some have already tried it (Antoniou et al. 2019; Nicholson 2015). The first advantage is that EGs are economically scalable. Escape board and card games, apps, books and comics are now on the market, some of which can even be played alone. This is a crucial factor for developing a new programme, especially for smaller museums like the Observatory, as Beata Bieszk-Stolorz et al. (2021) emphasise. The game presented in this study fits into a suitcase.

Second, this game type is also popular with various age groups, and even whole families play them frequently (Nicholson 2015). If such games achieve their educational goals, they support intergenerational learning, as realised "within programs specifically designed to bring together young people and older people in shared meaningful activities" (Newman and Hatton-Yeo 2008, p. 32).

Third, Rosemary Logan and Glenn Sutter (2012) suggest that museums should apply current learning theories and methods. So far, several research projects have been planned in this spirit, such as dioramas (Scheersoi 2021), drama and art workshops (Abacı and Kamaraj 2009), and other endeavours. EGs can also be a tool for this approach, since they are connected to *socio-constructivism* (Nicholson 2018), a learning theory that posits that learners actively build their own knowledge during social interactions and conflicts. Socio-constructivism suggests that the key moment in learning is when present knowledge does not fit new facts. This leads to a tension termed *cognitive conflict.* However, if the challenge seems too great for the students,

it can discourage the learning process (Bélanger 2011, Nahalka 2022). According to Lev Vigotszkij (2000 [1934]), puzzles should be in the players' *zone of proximal development*, i.e., challenging but not unachievable. It is this learning theory which informed the design of the Observatory's meta-puzzle. Geared to stimulate discussion, the game's adjustment of difficulty to the players' age enabled them to experience a sense of achievement.

Escape games in environmental education

Gamification, including EGs, seems to offer considerable potential for environmental education. Researchers have successfully tried out gamified apps and board games for this purpose, in some cases in collaboration with museums (e.g., Appel et al. 2019; Douglas and Brauer 2021; Kotsopoulos et al. 2019; Morganti et al. 2017). EGs have also generated promising results. Both Ho-Ying Helena Chang (2019) and Emmy Pater (2020) showed an increase in players' environmental attitude scores after completing an EG, but the change was not significant. The reason for this might be that participants' attitude scores were already high at the start of the game. However, Chang (2019) claims that the EG in her study successfully decreased the *value–action gap*; "the dissonance between individuals' values and their actions" (ibid., p. 1), which is "grounded in a lack of sense of agency" (ibid., p. 2).

Based on these findings, the hypothesis *(H1)* of my own research was:

> *H1* Escape rooms planned for environmental education purposes can improve players' environmental attitudes.

Methods and sample

This study defines *attitudes* according to Györgyné Hunyady (1979): as emotional-cognitive relations interwoven with evaluation. Based on this definition, *environmental attitudes* can be described as the intensity of positive or negative emotional-cognitive relations surrounding a particular environmental topic. Relations to smaller topics can be ordered into a hierarchical attitude system, a multidimensional structure which can also be called "environmental attitudes" (Cruz and Manata 2020). My research set out to examine both positive and negative attitude changes. I therefore adapted the instrument to a one-dimensional form, since the positive-negative concepts only make sense in this case.

The scale I chose was the environmental emotion sub-scale (EESS) from the "Environmental Attitude" questionnaire developed in Turkish by Naim Uzun et al. (2019). They tested this scale on secondary school and high school pupils and undergraduate students. The questionnaire may be understood as a one-dimensional instrument based on factor analysis. Uzun et al. (ibid.) suggest that the EESS can also be used on its own, not just as a part of their survey. Testing their questionnaire in English and Finnish as well, they discovered that translation does not influence its usability, so it was possible to adapt the test to Hungarian for my own research. This

was a key factor, since there was no other validated scale available for such a wide age range in Hungarian. When adapting the questionnaire, I changed only one word. The original questionnaire contained the phrase: "Natural disasters such as tsunamis are extremely worrying". Since there are no tsunamis in the Carpathian Basin, "earthquake" seemed like a more appropriate choice, as most tsunamis are caused by them.

Participants (details of the sample are provided in the next section) filled out the test anonymously before and after the game. Usually there was a short discussion about the puzzles between the game and the post-game test. Participants were instructed to fill in the post-game test with a fresh mind, without trying to remember their first answers. The pre- and post-game tests were immediately paired after players had finished them and marked with the same number.

The EESS is a 5-point Likert-scale type questionnaire. It contains 16 items to measure players' attitudes towards the natural environment. Participants are asked to choose which answer best fits their level of agreement. Since the values form an ordinal scale, the Wilcoxon signed-rank test for the participants' total score seemed the right choice to compare and evaluate paired samples. However, according to the research of Joost de Winter and Dimitra Dodou (2010) applying the *t*-test to this scale type should lead to similar results. The one-dimensionality of the EESS also made it possible to evaluate it using a polytomous Rasch model, namely Andrich's rating scale model (RSM), and to calculate the paired sample *t*-test to the ability scores (theta) of the participants (Zerényi 2016).

Therefore, my original hypothesis *(H1)* could be reformulated in two ways:

H1a There is a significant difference between the attitude scores on the pre- and post-game tests in the Wilcoxon test.
H1b There is a significant difference between the ability scores calculated from the pre- and post-game tests.

To understand more deeply what happened in the samples' smaller parts, I also analysed different groups (sub-samples varied according to sex and age) with the Wilcoxon and the Kruskal–Wallis tests, using a new variable which contained the difference between the post- and pre-game test's ability scores. The sub-samples were too small for more robust tests like *t*-test and ANOVA.

The sample

Previous research about the usage of EGs for enhancing environmental attitudes encountered the problem that participants' initial attitude scores were too high. The goal of my own research was therefore to work with a more diverse sample. Participants were selected based on convenience sampling; most of them were visitors to the museum, but more students were included from a Catholic and a private secondary school in a large city, and from a Catholic university in a smaller city. The museum's guests tend to be very interested in the sciences and might therefore be expected to achieve relatively high initial scores on environmental attitude scales.

Table 1 Demographic description of the sample (N = 131)

Sex (n)	School type (n)	Age (n)
Female (83)	Primary school, 5th–8th grade (66)	Below 10 (1)
Male (48)	Secondary school, 9th–12th grade (15)	10–20 (83)
	University, tertiary education (50)	20–30 (24)
		30–40 (9)
		40–50 (8)
		Above 50 (5)
		NAs (1)

Notes: NAs = not specified

Table 2 Descriptives of the participants' age

	Min	Mean	Median	Max	*SD*	*n*	NAs
Age	9	20.3	15	56	11.5	130	1

Notes: SD= standard deviation, *NAs*= not specified

However, the presence of whole classes from both rural and urban, primary and secondary schools served to make the sample more diverse.

Some players had to be excluded. The attitude scale was only validated for school attendees, so when whole families played, only those players could be included who were in education at that time. The results of teams who did not succeed in solving any of the four puzzles in the briefcase were also omitted, since they tended not to fill in the post-game test honestly due to their frustration.

Incomplete tests also had to be excluded, but only during the calculation of the Wilcoxon test. These participants' ability scores could still be calculated using RSM with the conditional maximum likelihood (CML) estimation. The CML also has the advantage that samples do not have to be representative, which was true for this study. On the other hand, it cannot estimate the ability scores of those who achieve maximum scores on either test, which was true for two participants, neither of whose results worsened in the post-game test.

The number of participants who filled out both questionnaires was 131, which required about 100 games. Eight of them were incomplete, so the remaining sample contained 123 members ($N_W = 123$) in the case of the Wilcoxon test and 129 members ($N_R = 129$) in the case of RSM. Achieving large sample sizes is a common difficulty in research on EGs, as only one small group plays at a time (see e.g. Fotaris and Mastoras 2019; Grande-de-Prado et al. 2021; Pater 2020). My own relatively small sample is therefore nevertheless quite a large one in the context of this particular field.

As Table 1 shows, there were more female players in the sample than male ones, and most participants attended primary school ($n = 66$). The median age of the sample was 15 years, while the most common age was 14, and the mean was 20.3 ± 11.5 years (Table 2). The youngest participant was a 9-year-old who was on

Table 3 Descriptive statistics of the pre- and post-game tests

	Min	Median	Max
Total score of pre-tests	18	48	64
Total score of post-tests	17	49	64

Table 4 Results of the Wilcoxon test for each item

	V	*p*-value
I am angry with people who cause environmental pollution.	144	< 0.001
Natural disasters such as earthquakes are extremely worrying.	376	0.7728
I worry about global environmental issues.	461	0.0800
I get angry if anybody damages any live plants or animals.	242.5	0.2332
Environmental pollution caused by wars angers me.	532	0.4599
If I didn't warn people who damage the habitat of animals, I would regret it.	607.5	0.0509
I feel anxious because of deforestation.	252	< 0.001
I feel guilty when I do harm to the environment.	400.5	0.1167
Hiking in natural areas gives me peace of mind.	282.5	0.2779
I get excited when I participate in any activity in nature.	324	< 0.001
Generally, I would be proud of myself because of my sensitivity to the environment.	393	0.0144
I would be happy doing nature-based sports such as hiking.	360	0.8010
I am curious about the changes in nature.	410	0.5000
I would be satisfied if we had more environmental lessons in school.	282	0.1269
Outdoor activities give me more pleasure than shopping.	272	0.3209
Being alone in nature relaxes me.	259.5	0.0163

Note: V = The result of the paired sample Wilcoxon test calculations

holiday before entering 5th grade. The oldest student was 56, a mature undergraduate enrolled in a distance-learning university course.

Results

The Wilcoxon test

In the Wilcoxon test, I used the open source programme BlueSky Statistics 10.3.2 for every calculation of the total scores of both the pre- and post-game tests, with the hypothesis that a difference < 0 represented significant improvement ($V = 1{,}275$, $p < 0.001$; descriptives are provided in Table 3). None of the Wilcoxon test results for individual items showed a significant decrease, but some showed a significant increase, as Table 4 shows.

Table 5 Item fit statistics

	Outfit *MS*	Infit *MS*
I am angry with people who cause environmental pollution.	1.0920	1.0560
Natural disasters such as earthquakes are extremely worrying.	1.4820	1.2780
I worry about global environmental issues.	0.9640	0.9510
I get angry if anybody damages any live plants or animals.	1.0490	0.9520
Environmental pollution caused by wars angers me.	1.0560	1.0830
If I didn't warn the people who damage the habitat of animals, I would regret it.	0.9350	0.9400
I feel anxious because of deforestation.	0.7600	0.7350
I feel guilty when I do harm to the environment.	1.0030	0.9570
Hiking in natural areas gives me peace of mind.	0.8740	0.9280
I get excited when I participate in any activity in nature.	0.7400	0.7300
Generally, I would be proud of myself because of my sensitivity to the environment.	0.7180	0.6420
I would be happy doing nature based sports such as hiking.	1.0450	1.1190
I am curious about the changes in nature.	0.7030	0.7610
I would be satisfied if we had more environmental lessons in school.	0.9640	1.0050
Outdoor activities give me more pleasure than shopping.	1.1110	1.1410
Being alone in nature relaxes me.	1.0250	1.0780

Notes: MS = mean square

Table 6 Descriptive statistics of the ability scores

Stats	Ability scores	Post ability scores
Mean	2.1045	2.2601
Median	2.0711	2.2439
Standard deviation	0.8694	0.8979
Pearson's second coefficient	0.1153	0.0541

The rating scale model and the *t*-test

The RSM fit the pre- and post-game tests quite well. As Table 5 shows, the only item in which outlier-sensitive fit (outfit) value was outside the range of 0.6–1.4 was the one related to worries about natural disasters (1.4820). Moreover, except for the information-weighted fit (infit) value of the item related to pride about environmental sensitivity, which was 0.6420, none were outside the range of 0.7–1.3. Finally, 5.0193% of the participants misfitted (their Chi-square based *Z*-value was above 1.96).

Based on the Anderson-Darling test, only the post-scores' normality test's *p*-value was above 0.05 ($A_{pre\text{-}test}$ = 1.4329, $p_{pre\text{-}test}$ = 0.001; $A_{post\text{-}test}$ = 0.5688, $p_{post\text{-}test}$ = 0.1377), however, the deviation was relatively small. Pearson's second coefficients were 0.1153 on the pre-game test and 0.0541 on the post-game tests (Table 6). Therefore, the paired sample *t*-test can be used for the ability scores of pre- and

post-game tests with the hypothesis that difference < 0, since $N_R > 50$ based on Ratcliffe's simulations (Ratcliffe 1968). The test showed significant change ($t = 4.3215$, $p < 0.001$; descriptives are provided in Table 6).

The independent sample Wilcoxon test for the change in abilities (= abilities calculated from post-game test – abilities calculated from pre-game test) did not show a significant difference between male and female players ($W = 1887.5$, $p = 0.8482$). However, the Kruskal–Wallis test showed significant differences among the different age groups ($X^2 = 10.2143$, $p = 0.0061$). The pairwise test showed that undergraduates' ability scores increased significantly more than those of 5th to 8th graders ($p = 0.0085$).

Discussion

The literature shows some uncertainty as to whether EGs enhance players' environmental attitudes (Chang 2019; Pater 2020). However, in the present study, both the Wilcoxon test and the RSM with the *t*-test showed a significant increase (in both cases $p < 0.001$). The latter is the more reliable, since the RSM with the CML estimation decreases the effect of convenience sampling. The Kruskal–Wallis test showed that undergraduates' ability scores increased significantly more than those of 5th to 8th graders. Presumably, the simple increase of playing time was not enough help for the younger players, since some of the puzzles were beyond their proximal development zone and they could not improve as much during the game. Nonetheless, there were no significant differences between male and female players.

Based on these calculations, we can accept the hypotheses of this study in both forms: there is a significant difference between the attitude scores on the pre- and post-game test in the Wilcoxon test (*H1a*), and there is a significant difference between the ability scores calculated from the pre- and post-game tests (*H1b*). Furthermore, the Wilcoxon test showed that the scores on the first item, "I am angry with people who cause environmental pollution", changed significantly. This also confirms the hypotheses and shows that previous tests were not false positives, since the theme of the EG was waste, to which this item is closely related.

Based on these considerations, the suggestions of both Chang (2019) and Pater (2020) have led to the expected conclusion: on a more diverse sample, with lower initial environmental attitude scores, it is possible to detect significant improvement. In fact, this study was still rather homogenous, as the majority of the sample was selected from visitors to the museum with supposedly higher initial scores. This also strengthens the hypotheses.

However, the calculations showed significant change when it came to the phrases "I feel anxious because of deforestation" and "I worry about global environmental issues". The latter phrase also had quite a low *p*-value ($p = 0.0800$). The possibility of increasing anxiety levels may need further examination. It might be caused by the nature of this game type, as other research has observed players' frustration sometimes intensifying into anxiety due to the constant time pressure (Hermanns et al. 2017).

In connection with the attitude scale I used, the calculations related to RSM led to an outfit value above 1.4 for the item about natural disasters. This also merits further investigation. It may be caused by the fact that such events are extremely rare in the Carpathian Basin, suggesting that either this question type should be avoided in questionnaires made for such regions in future, or that an example other than earthquakes should have been chosen for this research.

Conclusion

This study has found that gamified educational escape rooms can be used as a tool to enhance museum visitors' awareness of and attitudes towards nature and the environment. This was proved by both the Wilcoxon test and the RSM with the *t*-test with $p < 0.001$. The significant increase in scores on the item about pollution also strengthened these results.

This game type relates to social learning theory and socio-constructivism, which hold that players learn not only together, but also from each other. This has been emphasised as an important characteristic of intergenerational learning by Seyedeh Zahra Aemmi and Hossein Karimi Moonaghi (2017), particularly when the learners are from different age groups. The game in my study reached its goals based on the tests and calculations, and the participants were between the ages of 9 and 56 years, in many cases with complete families forming the groups. The game therefore seems to be a good tool for this purpose, too. However, this may require further investigation with exclusively heterogeneous groups.

Jan Packer and Roy Ballantyne (2005) have highlighted that museums need to address the learning experience of both individual and group visitors. Individual visitors tend to be more motivated, so it is particularly important to note that in this research an engaging team game proved to be effective. Moreover, the game was cost-effective to assemble, requiring only some number-locked gadgets, waste materials, paper and a free desk. With some creativity, EGs are economically well scalable and therefore present an effective opportunity even for smaller museums to gamify offline programmes with the purpose of environmental education. In larger museums, whole rooms can be turned into games of this type, as some literature has suggested (Nicholson 2015).

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Declarations

Conflict of interest The author did not receive support from any organisation for the submitted work. The author has no relevant financial or non-financial interests to disclose.

Ethical approval This study was approved by the Research Ethics committee of the Eszterházy Károly Catholic University (Ethics approval number: RK/203/2024).

Author's note I already presented this game and some of the research results with my colleague at the 12th International Methodological Conference in 2023 (Kovács and Murányi 2024). However, I have narrowed this article to the aspect of changes in environmental attitude, which was my part in that research, and the

sample presented here is much more extensive, as the theme of the conference was teacher training, so only part of the data collected earlier could be used, and I also expanded the sample after the conference. Therefore, in this article I have written only about my own results, but the description of the game and part of the literature review is reused from the conference paper.

Participants' informed consent All participants were informed about the research and gave their consent to participate in the research, and in the case of children, their guardians also gave their consent.

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