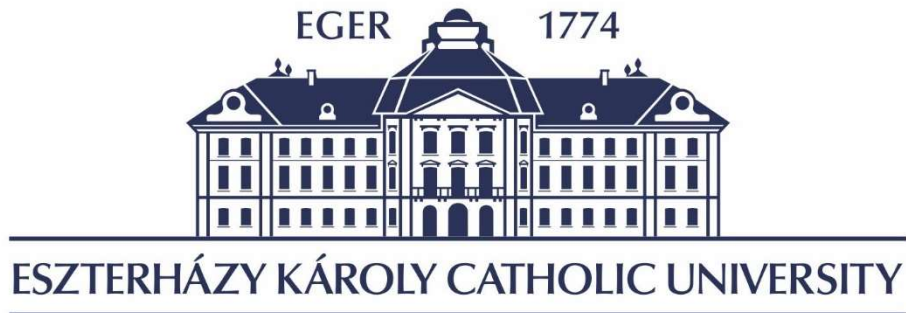


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Complex Effects Analysis of Escape Games in the Field of Environmental Education

Theses of the doctoral (PhD) dissertation

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1. Introduction

At the age of 18, I began volunteering with children: I co-organized camps for various organizations and led children's and youth groups at the local parish. During my undergraduate studies in environmental engineering, I also became a group leader at the Szentjánosbogár [firefly] Association's camps. While participating in their leadership training, I became more familiar with game-based pedagogy for the first time, since these programs are predominantly based on this approach; here I realized I wanted to pursue education as a career, because I missed playing with children during the school year. One of the main motivations for my doctoral dissertation is therefore the idea that playing is great even in school.

Games are closely linked to education, both in the history of education and from a theoretical perspective. The Roman orator Quintilian already argued that learning must be playful throughout the entire educational process, until the end of adolescence, so that the child does not come to hate the sciences for life (Mészáros et al., 2005). Besides, two examples from biological and psychological theories:

- Bruner (1995) describes play as a low-risk learning opportunity.
- Grastyán (1985) argues that play is a place of discovery which creates opportunities to search for alternative solutions.

I was therefore interested in the question of how, and with the help of what kinds of games, one can teach effectively; thus, I created my first escape game for a science class, and later my advisor suggested that I could even write a doctoral dissertation on its applicability. The aim of my thesis is thus to demonstrate that the goals of environmental education can be achieved through escape games, primarily the shaping of environmental attitudes, but also the support of knowledge construction.

The significance of this thesis lies primarily in the fact that very few experimental studies have been conducted on the use of this game type, and those that have used both pre- and post-tests have led to diffuse results (Veldkamp et al., 2020). Furthermore, the number of studies on the use of games in environmental education has only begun to rise over the past fifteen years. (Hallinger et al., 2020)

2. Research questions, hypotheses

Educational escape games have already been used to shape environmental attitudes, but no significant difference could be detected between pre- and post-test results (Chang, 2019; Pater, 2020). In my research on attitudes, I aimed to achieve a heterogeneous sample, as the authors of these studies suspected that the improvement was not significant in their cases due to an overly homogeneous sample.

At the same time, as I mentioned in the introduction, the question remained open as to whether it is possible to acquire new knowledge through this game (Lathwesen & Belova, 2021; Veldkamp et al., 2020). The main reason for these uncertainties is that this game type is very difficult to study, as only 3–6 people can play simultaneously. This means that even a large number of play occasions results in only a relatively small sample. The situation is further complicated by the one-time nature of the game and its relatively short duration, which makes examining its effects difficult. (Fotaris & Mastoras, 2019)

Therefore, the first research question is whether escape games can be used for the purposes of environmental education. The hypotheses formulated in connection with the first research question (Q1) are given below:

H1. Attitudes toward environmental pollution can be improved through educational escape games.

H2. Participation in educational escape games helps players acquire interdisciplinary knowledge.

H3. Group play enables more effective knowledge acquisition than individual play.

H4. Participation in educational escape games leads to lasting knowledge acquisition.

H5. Participation in educational escape games facilitates conceptual change among players.

Moreover, the method used to examine conceptual change appeared suitable for analyzing the different ways of understanding the concepts used as keywords, which raises a second research question (Q2): In what different ways do students interpret the concepts used as buzzwords in the conceptual change study when asked to respond as experts in the field of environmental science?

3. Theoretical background of the research

3.1. Escape rooms in education

According to Nicholson (2015, 1.), “Escape rooms are 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.”

The first English-language publications about usage of this game type for educational purposes appeared around 2015. They were already used for a variety of pedagogical purposes during the first two to three years (Kovács, 2024), such as vocational orientation (Bassford et al., 2016), increasing motivation (Borrego et al., 2017; Dominek & Turcsán, 2017; Rouse, 2017), enhancing different soft skills, or for acquiring curricular knowledge (Borrego et al., 2017; Boysen-Osborn et al., 2018, 2018; Eukel et al., 2017; Vörös & Sárközi, 2017)

The wide range of applications has been made possible by the creative use of the many different game mechanics found in escape rooms. For example, the story of the game can be used to introduce new concepts and engage players (Bassford et al., 2016; Clarke et al., 2017). The tasks and puzzles can be tailored to the curriculum requirements (Borrego et al., 2017) and set to an optimal difficulty level (Clarke et al., 2017; Dominek & Turcsán, 2017; Ouvrard-Prettol & Linden, 2018), offering opportunities for differentiation. Solving the puzzles requires finding various clues, which can also provide a new way of introducing new concepts. (Ouvrard-Prettol & Linden, 2018).

In addition, the costs of the game are easily scalable, and expensive commercial solutions can be readily replaced with cheaper digital tools (Dietrich, 2018). Furthermore, escape card games, board games, books, comics, and apps are also available on the market now.

3.2. Environmental education

In 2015, the United Nations specified the seventeen Sustainable Development Goals (SDGs) for the period up to 2030. Goal 4, which relates to education, calls for making quality education accessible to all and creating opportunities for lifelong learning. (United Nations, 2015) Besides, six other goals

explicitly mention education as a necessary prerequisite for achieving the given goal. (Mika & Kiss, 2018)

Environmental education thus plays a key role in achieving SDGs. Kárász defines environmental education as follows: “a process through which people (regardless of age, but within the framework of their own age-specific characteristics) gain an understanding of their environment and learn to consciously take care of its sustainability.” (2015, 47.) The importance of this definition for my thesis lies in the fact that it draws attention to the role of age-specific characteristics in education. It can thus be further linked to constructivist learning theory, which emphasizes the importance of individual characteristics in the learning process.

Although it is true that real-life experiences in the natural environment – due to their influence on the development of emotions and attitudes – have an exceptional importance in environmental education (Havas, 1999), it may be worthwhile to incorporate constructivist learning theories into environmental education (Nahalka, 2010), because they help to establish the everyday work that takes place indoors (in schools, museums, etc.).

3.3. Constructivism and environmental education

Regarding the learning-theoretical foundations of educational escape games, Nicholson (2018) emphasizes constructivism, more specifically the approach called socio-constructivism in my dissertation. Through a constructivist-based approach, the world of escape games can be linked to environmental education. Next, let us examine the relationship between this learning theory and environmental education.

Piaget (e.g. 1964) was the first who named the processes that occur during learning “construction,” a term that refers to the fact that learners actively build their own knowledge. as “construction,” which refers to the fact that learners actively build their own knowledge. When someone perceives a stimulus, they interpret it based on their prior knowledge, and if their current knowledge does not fit with the newly acquired facts, this can cause tension within them. We call this tension “cognitive conflict”. If the learner is able to resolve this, a so-called “conceptual change” may occur, during which the learner develops alternatives to their current internal theory and begins to use a new, more adaptive one. (Nahalka, 2022) Within this framework, socio-constructivism is the approach that emphasizes the role of social interactions

and conflicts in the process, e.g. it considers debate as one of the main sources of cognitive conflict. (Bélanger, 2011)

However, it is common in environmental education that students encounter the concepts and models used in this field for the first time in their lives during the activity; thus, the challenge often lies not in achieving conceptual change, but in helping students integrate their existing concepts into new theories. (e.g. Robertson, 1994)

3.4. Escape games and environmental education

From a constructivist perspective, escape games may be suitable for environmental education. In fact, their effectiveness had already been confirmed in certain areas before this research began, Chang (2019) found that the attitude-behavior gap can be significantly reduced with the help of escape games, though no significant results were obtained regarding environmental attitudes alone.

Furthermore, it is worth noting that this game is a popular pastime among all age groups – from teenagers to seniors – and is often played as a family activity. (Nicholson, 2015) This means that confirmation of my hypotheses also implies that escape games can support lifelong learning, which has been an important goal in environmental education from the beginning. Moreover, since younger and older age groups can participate in this activity together, the conditions for intergenerational learning are also met (Newman & Hatton-Yeo, 2008, 32.).

4. Methodology

4.1. Attitude and knowledge measurement

I used the definition of the attitude provided by Hunyadyné (1979, 91.), who described attitude as an “emotional-cognitive approach interwoven with evaluation”; this fits well with the theoretical background of the attitude scale used.

Based on this, environmental attitudes can be defined in several ways: on the one hand, as an approach to a specific, well-defined element of the environment; on the other hand, as a relationship to the environment understood as a multidimensional concept derived from organizing the environment’s various elements into hierarchical structures (Cruz & Manata, 2020).

In my dissertation, I examined one dimension of this multidimensional structure to test the hypothesis regarding changes in environmental attitudes using a 5-point Likert-scale questionnaire (Uzun et al., 2019). This is a 16-item questionnaire measuring emotions related to the natural environment.

I analyzed the results using Andrich's rating scale model with conditional maximum likelihood (CML) estimation, as this does not require a representative sample. After fitting the model, I analyzed the participants' ability scores before and after the game using paired sample t-test.

From a research methodology perspective, however, I also found it interesting to compare the results provided by item response theory with those provided by classical test theory using real data, as similar simulations can be found in the literature, e.g., the comparison of the Wilcoxon test and the t-test (de Winter & Dodou, 2010). I analyzed the ordinal data using the Friedman test.

4.2. Traditional test

In addition to attitudes, I also examined the extent to which escape games facilitate the acquisition of new knowledge. I measured this chronologically first with a test modeled after a classic pop quiz, and then using a word association method. Although the latter was the primary method, it is important to use other methods alongside it, as it does not assess whether the participant understands the word written as the answer.

In addition to attitude, I also examined the effectiveness of escape games in facilitating the acquisition of new knowledge. In chronological order first, I measured this using a classic quiz-style test and then through a word association test. Although the latter was the primary method, it is important to use other methods alongside it, since it does not measure whether the participant understands the word written as the answer. (Jonassen et al., 1993, citing Stewart as cited by Nagy).

Since, according to the Tbilisi Declaration (United Nations, 1978), environmental education is by nature interdisciplinary – which means it should involve multiple scientific fields – I used games and selected test questions in both experiments that covered multiple disciplines or explored the connections between different scientific fields.

I evaluated the results of the traditional test using the Friedman test and the Kruskal-Wallis test, since the test had not been validated; therefore, it is more appropriate to treat the total scores obtained as a rank scale.

4.3. Word association tests and their analysis

By using the word association test, I aimed to understand some parts of the students' semantic lexicon and how it changes. The semantic lexicon is a mental network in long-term memory, with individual concepts at its nodes and edges indicating whether there is a connection between their meanings. According to Shavelson (1972), the meaning of a given concept is the list of nodes with which that concept is semantically related. If a change occurs in the meaning, then the connections also change.

During the word association tests, students were given buzzwords and then had 1 minute to write down whatever associations came to their mind regarding that word. To evaluate the relationship of the call words, I used the relationship coefficient (RC) developed by Garskof and Houston (1963), and then compared the results from the pre-test with those from the post-test one week later using a t-test. The one-week interval was necessary to measure changes in the long-term memory.

In relation to the second research question, I also conducted a qualitative analysis of the word association tests, with the aim of exploring the research participants' understanding of certain phenomena, analogous to a phenomenographic analysis (Hajar, 2021). I organized the categories resulting from the analysis into a hierarchical order and then represented them in a diagram. This analysis also helps to uncover typical conceptual learning pathways and any misconceptions.

4.4. Samples

In all cases, the research was conducted using convenience sampling. In the traditional test-based study, participants were 9th-graders from a religious high school in the capital. The two classes solved the same puzzles in different formats. The members of the eight-grade high school class played the game individually and could only move on to the next task after successfully solving the previous one; however, thanks to this format, they received more feedback from the game than

the other group. This sub-sample contained $N_i = 31$ students. The four-grade high school class played in teams of three, but they were given all four tasks at once. One of these tasks required the solutions of the others, which provoked discussion and the sharing of what the group members had learned. This sub-sample consisted of $N_g = 34$ students.

The word association tests were conducted in two grade levels: in the 7th grade, the sample contained $N_7 = 68$ students, while in the 9th grade, it consisted of $N_9 = 98$ students. The participants in the attitude surveys were primarily selected from the visitors of the Eszterházy Károly Catholic University Observatory and Science Experience Center. In addition, I took the game to various schools to make my sample more heterogeneous, since in the case of a science museum, it was likely that the environmental attitudes of most visitors were already homogeneous and positive.

There was a total of 131 participants who were able to solve at least one puzzle and completed both the pre- and post-tests. Eight questionnaires were incomplete, which made them unusable for the Friedman test, so the sample consisted of $N_w = 123$ individuals. Two participants selected “strongly agree” for every item on at least one of the tests; since they could not be evaluated using the CML, after their exclusion, the sample used for the RSM contained $N_R = 129$ players.

5. 5. Theses and answers to research questions

Q1 Is it possible to use escape games for environmental education purposes?

Attitudes toward environmental pollution can be developed using educational escape games designed for this purpose.

Hypothesis H1 was confirmed. Using Andrich’s rating scale model, I assigned ability scores to each participant such that every response (both pre- and post-test) was used for the calculations and then paired the participants’ scores from the pre- and post-tests. I performed the paired t-test calculation based on the hypothesis that results improved from the pre-test to the post-test, and the test showed a significant increase ($t = -4.3215$, $p < 0.001$).

I also found significant changes in the results of the Friedman test for several questions. The most important of these is Item 1, namely, "I am angry with people who cause environmental pollution" ($X^2= 10.5263$, $p=0.001$). Since the median scores increased from 3 to 4, we can speak of an improvement. This item plays a particularly important role because the theme of the escape game used was waste management, thus reinforcing the assumption that the change was caused by the game.

A significant change is also observed in the total score based on the Friedman test ($X^2= 16.9798$, $p<0.001$), and since the median increased in this case as well (from 48 to 49), we can also speak of an increase here.

Participation in the educational escape game designed for this purpose helps players acquire interdisciplinary knowledge.

Hypothesis H2 was confirmed. A total of 65 participants took part in the traditional, multiple-choice survey, and the median total score increased from 6 on the pre-test to 8 on both the post-test and the re-measurement. Calculations performed for the pre-test and post-test showed a significant change ($X^2= 43.1034$, $p < 0.001$), as did those for the pre-test and the re-measurement ($X^2= 33.9231$, $p < 0.001$). Since the median increased, this can be considered a significant increase.

When using educational escape games, group play enables more effective knowledge acquisition than individual play.

Hypothesis H3 was confirmed. Comparing the different subsamples I found that, according to the Kruskal-Wallis test, there was a significant difference in pre-game scores between the two groups in favor of the students in the eight-grade high school ($X^2=3.9292$, $p=0.0475$); however, such a difference was no longer detectable in the results of either the post-test ($X^2 =1.1454$, $p=0.2845$) or the re-measurement ($X^2 =0.1568$, $p=0.6921$).

I also determined the significance level of the difference in score changes. In the post-test, the results of the players in groups ($median_g = 3$) showed a significantly greater increase than those of the players who played individually ($median_i = 1$), according to the Kruskal-Wallis test ($X^2= 4.0715$, $p = 0.0436$). Based on the Kruskal-Wallis test, there was no significant difference between the re-measurement and the

pre-test ($\text{median}_{\text{team}} = 2$, $\text{median}_{\text{individual}} = 1$, $\chi^2 = 3.8030$, $p = 0.0512$), although this result is very close to being significant, too.

Participation in educational escape games leads to lasting knowledge acquisition.

Hypothesis H4 was confirmed. The previously presented calculation results showed that students performed significantly better on the 1-month re-measurement than on the pre-test. The experiment was conducted such that students were not given homework on the topic, and during this one-month period, the game's content was not introduced in any way during class, so that I could measure the game's effect exclusively. The experience described in connection with the following hypothesis also supports the acquisition of lasting knowledge, as I used a post-test filled one week later in that case.

Participation in educational escape games facilitates a conceptual shift among players.

Hypothesis H5 was confirmed. Regarding the word association tests, I found that the Garskof-Houston coefficient calculated from the responses of both the 7th and 9th grade groups changed significantly for certain concept pairs. This means that the meaning associated with those concepts in the classroom has changed.

For the 7th grade, the change in the stimulus pairs "mixture" and "compound" ($t = -4.2403$, $p < 0.001$) and "mixture" and "wastewater" ($t = -2.3395$, $p = 0.0223$) was significant. For 9th grade, the changes in the terms "precipitation-liquid" ($t = -2.0586$, $p = 0.042$), "precipitation-water cycle" ($t = 4.9479$, $p < 0.001$), the "liquid-rain" ($t = -3.3560$, $p = 0.001$), and the "rain- water cycle" ($t = -2.6636$, $p = 0.009$) keyword pairs showed significant changes.

Q2 Different forms of understanding of the concepts used as keywords

Due to space limitations in this theses book, I present here only two diagrams related to concepts closely linked to environmental education. For 7th graders, I organized the levels of conceptual development along two dimensions in relation to wastewater. [Figure 5.1] One dimension relates to wastewater treatment, with the first level consisting of responses that only state that wastewater is polluted; at the

next level, this source of danger is disappeared (e.g., drain, sewer); and at the third level, the need for treatment emerges (e.g., water treatment). The fourth and highest level is when the respondent understands wastewater as a complex system of substances (e.g., a mixture). The other dimension relates to the origin of wastewater. In this case, the first-level interpretation mentions households, while the second level includes industry as well.

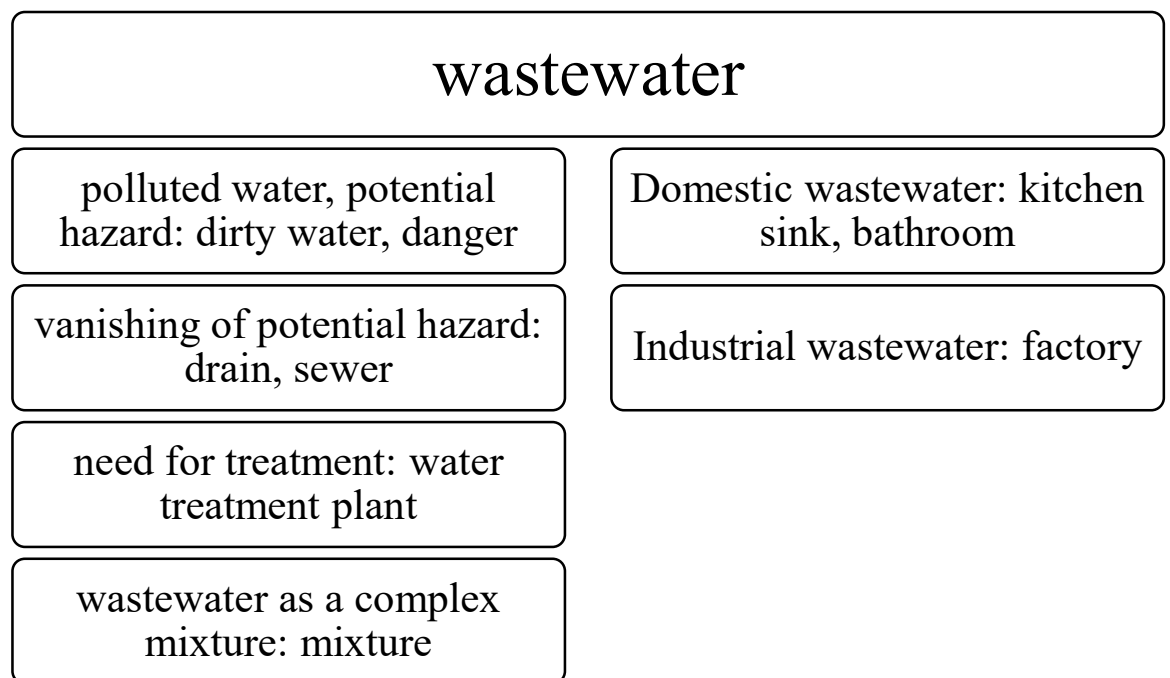


Figure 5.1 Levels of conceptual development based on the analysis of wastewater

I identified a potential misconception regarding wastewater within the field of biology. Bacteria and viruses were identified exclusively as pathogens among the associations, even though certain bacterial phyla play a huge role in wastewater treatment.

For 9th graders, the water cycle is an interesting example of the graduality principle, which was observable in connection with most call words. [Figure 5.2] Here, two paths of learning are identifiable. The first level of understanding involved connecting the concept to everyday terms (e.g., rain, cloud), followed by recognizing the steps (e.g., rises, falls, storage, absorption). The response space then split into two: in one direction, students were able to describe the entire process using everyday terms, while in the other, they used precise, scientific terms to name the individual steps (e.g., evaporation, condensation). Finally, the highest level was represented by responses indicating a complex understanding of the process (e.g.,

due to heat, solar energy). This allowed for the identification of two additional levels compared to what Kosztin (2010) observed in younger children.

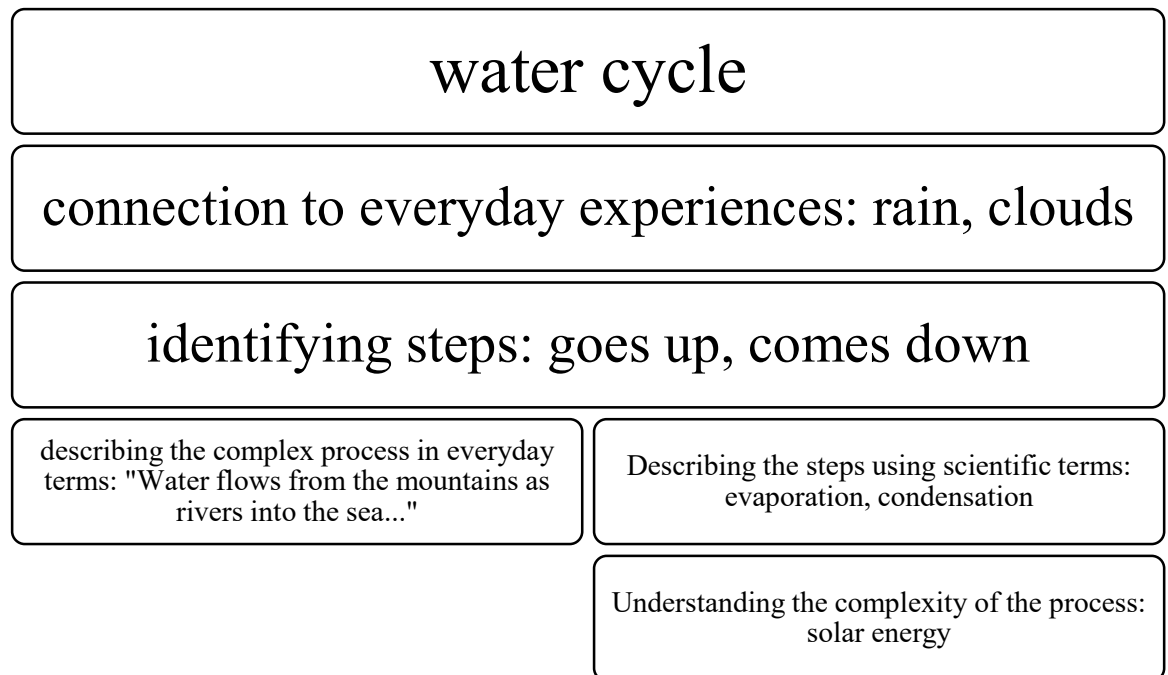


Figure 5.2 Levels of conceptual development based on the analysis of water cycle

6. Summary

Based on the results of the knowledge test presented in my thesis, players can integrate new knowledge through educational escape games; moreover, based on the word association tests, the use of this type of game supports the formation of new concepts or even conceptual shifts. I conducted these studies in school classrooms and thus found escape games to be effective in environmental education during class time.

Based on both knowledge and attitude assessments, this type of game can influence not only players' knowledge but also certain emotional dimensions, as people of different age groups play together in an environment designed for learning. This means that the conditions for so-called intergenerational education are also met in such situations (Newman & Hatton-Yeo, 2008). This arises from the fact that the difficulty of the game type can be adapted to the age group in several ways, for example, by developing riddles of varying difficulty levels for the same story of the game (e.g. Clarke et al., 2017), or by modifying the time limit (e.g. Bassford et al., 2016).

Escape games can therefore be effective and popular methods even in settings where environmental education work takes place with age-diverse groups, or where activities must be conducted for homogeneous groups formed from different age groups. In the case of the studies presented here, such a place was the Observatory and Science Experience Center.

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