On the Importance of Contextualizing an Educational Escape Room Activity

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Abstract: This paper describes the design and evaluation of "Enigma Bio", an educational escape room activity that aims to convey the abstract concept of biodiversity to children between 11 and 13 years of age, making them aware of the importance of climate change and its impact on biodiversity. The design of Enigma Bio is closely linked to the Biodiversity exhibition at the National Museum of Natural Sciences in Madrid, designed for a visit in groups of between 20 and 30 children, with an approximate duration of one hour, running on mobile devices and including augmented reality technology. The purpose of this research is to determine whether, in the case of educational escape room activities in museums with a limited time duration, it is more effective to have a pre-session introducing the topic. Our hypothesis is that without the context of the pre-explanation, the playful component of the game may be too powerful and may cause children not to pay enough attention to the message that the game intends to communicate, and even more so when dealing with a complex message such as the effect of climate change on biodiversity. To answer this research question, we follow an A/B testing experimental design involving two groups of children, one of which received an introductory talk on biodiversity and climate change before going to the museum and the other did not. The experimental design is completed with a pre-post evaluation of the children's environmental awareness by means of a previously validated questionnaire. The results of the experiment provide valuable insights into the effectiveness of the pre-session introduction in enhancing the learning outcomes of short educational escape room activities. Significant differences were observed between pre- and post-activity tests, indicating a moderate overall increase in awareness scores within both individual groups (A and B) as well as across the combined results. The findings suggest that the pre-session introduction indeed plays a role in enhancing students' awareness of the targeted message. These results represent a breakthrough in the e-learning practice that will be of value to other designers of educational escape rooms with a limited time duration.

Keywords: Educational escape room, Serious games, Games at museums, Augmented reality game

1. Introduction

Education is a major museum function, carried out by a dedicated staff and of concern to curators, exhibition designers, and other museum professionals. In large museums, the education staff, including part-time workers, docents, and occasional teachers, may represent up to 50 percent of all employees (Hein 2006). Museum educators engage in a broad range of activities, including tour programs, informal gallery learning programs, and family programs. Typically, educational activities involve some type of interaction with or around objects in the museum (Witcomb, 2006), which on many occasions may include some form of game (Beale, 2011). In the last few years, there have been a growing number of educational activities in museums using mobile devices to support interactive activities (Koutsabasis, 2017) and games (Paliokas and Sylaiou, 2016; Malegiannaki and Daradoumis, 2017).

The work presented here is motivated by several iterations in the design of the Enigma saga of games for museums developed by PadaOne Games as part of a growing number of initiatives incorporating augmented reality (AR) in exhibit-based informal science education settings (Goff, et al., 2018). The Enigma Bio game is conceived as a tool for educators guiding school groups on an approximately one-hour visit to the biodiversity exhibition at the National Museum of Natural Sciences in Madrid (MNCN, by its acronym in Spanish). The exhibition's content follows a thematic thread. It begins by introducing various forms of biodiversity, then links biodiversity to natural selection and adaptation to the environment, and finally addresses the threats to biodiversity, highlighting how human actions are impacting the climate and causing biodiversity loss.

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Climate change is a problem that the scientific community and the United Nations have been warning about through the yearly Climate Change Conferences held in the framework of the UNFCCC (United Nations Framework Convention on Climate Change) since 1992. Commercial video games such as “Alba: A Wildlife Adventure” by Ustwo Games (2020), "Beyond Blue" by E-Line Media (2021), and "Gibbon: Beyond the Trees" by Broken Rules (2024) are being used to raise awareness of the climate change problem among young people. The challenge for Enigma Bio is to achieve, in just one hour of play, a positive impact on the awareness of the participating children, taking advantage of the group experience in the physical space of the museum, the content of a specially designed exhibition, and the presence of an educator as a mediator of the experience.

Enigma games are treasure hunts designed specifically for museum settings, using image recognition and augmented reality (AR) on mobile devices to establish a link with the museum’s content. Image recognition guides players through the museum's exhibits, while AR offers clues and supplementary content about these items. However, based on our previous experience in designing this type of treasure hunt game (Camps-Ortueta, et al., 2019), it is very difficult to combine the fun of the game with the control of the interaction of the group of children with the educator. The solution we have found for Enigma Bio, as described in this paper, is to turn the treasure hunt into a form of escape room where the educator takes a central role in the game by controlling the gates.

Enigma Bio arose in response to a need detected at the museum by educators. While new technologies increase children's engagement with proposed tasks, the available applications often do not align with the museum's specific needs. The idea of using the escape room format arose from the need for educators to have a video game that stops the action at certain points so that educators can give their explanations.

Research has shown the effectiveness of using games to raise awareness about the consequences of climate change and the actions we can take to mitigate its effects. (Flood, et al., 2018) discuss two types of games: short ones that serve as motivators, and longer games that allow players to delve deeper into the complex relationships among the factors involved in the problem. Enigma Bio falls within the short game category, with the goal of improving our comprehension of the implications of climate change on species extinction and biodiversity loss.

The main purpose of this research is to determine whether, in the case of educational escape room activities in museums with a limited time duration, it is more effective to have a pre-session introducing the topic. Our hypothesis is that without the context of the pre-explanation, the playful component of the game may be too powerful and cause children not to pay enough attention to the message that the game aims to convey, especially when dealing with a complex message such as the effect of climate change on biodiversity. To answer this research question, we follow an A/B testing experimental design involving two groups of children: one of whom received an introductory talk on biodiversity and climate change before going to the museum, and one who did not. We complete the experimental design with a pre-post evaluation of the children's environmental awareness using a previously validated questionnaire. Our findings may be useful for other designers of educational escape room activities.

The rest of the paper runs as follows. In Section 2 we introduce educational escape rooms and describe how Enigma Bio fits within that framework. Section 3 describes the design and the main game mechanics of Enigma Bio. Section 4 details the experiment we conducted to evaluate the effectiveness of the game and the impact of having a pre-session introducing the topic. Section 5 presents and discusses the findings from the experiment. Finally, Section 6 addresses conclusions and future work.

2. Literature Review

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 achieve a specific goal, usually escaping from the room, within a limited amount of time (Nicholson 2015; Wiemker, Elumir and Clare, 2015). From the original mission of escaping from a locked room, many variants have emerged that are nowadays also considered escape room games, including: solving mysterious murders, opening locked boxes, or unraveling mysteries in order to avoid the end of the world (Veldkamp, et al., 2020). The genre has grown and proliferated in all major cities in recent times. Numerous escape rooms have opened, offering visitors a wide variety of experiences. Additionally, over time, alternative games have appeared, some with digital support and others with physical support that also echo the great success.

Escape room games have also begun to gain traction in academia (Fotaris and Mastoras, 2019). Many escape rooms designed for the classroom have been simplified to a group tabletop activity involving a series of locked boxes (Schaffhauser, 2017), as it is not feasible or even legal to lock a subset of a class in a room and wait until they puzzle their way out. When properly designed, these types of games provide a motivating and immersive experience for students, although they may lose the feeling of complete immersion that escape room experiences provide (Clarke, et al., 2017).

Previous versions of the Enigma saga games for museums developed by PadaOne Games took the form of treasure hunts (Ihamäki, 2014). As such, they consisted of a sequence of searches, clues and quizzes that ran through a museum exhibit and were played at the participants' own pace. Although they worked as games and managed to attract the children's attention to the objects in the museum, they left the educator in the background as he had no role in the game and typically the children did not interact with him except at the beginning and end of the game.

According to Veldkamp, et al. (2020) Enigma saga games already included the main activity of educational escape rooms, namely, cognitive puzzles that make use of the players' thinking skills and logic. Nevertheless, by incorporating additional escape room game design ideas into Enigma Bio we have managed to meaningfully incorporate the educator into the game, without compromising the fun. These are the main design elements added:

- Divide the museum exhibition space into zones, each of which acts as a room, so that you need to solve all the puzzles in one zone in order to leave it and move on to the next.
- Introduce randomness in the order of the puzzles in a room, given that there is a group of people trying to solve the game independently (typically the game is played in pairs, where each pair shares a mobile device). When puzzles are always tackled sequentially in the same order, some players end up leading others, which can be addressed by introducing an element of randomness.
- Position the educator at the end of the zone, serving as the guardian of the room. This arrangement ensures that the objective in each room is to discover a question to pose to the educator. The winner from each zone will have the privilege of being the first to present the correct question to the educator. This setup ensures that all players will reach the educator as they progress through the zone, where they will convene. The educator will then offer an explanation related to their recent discoveries within the museum.

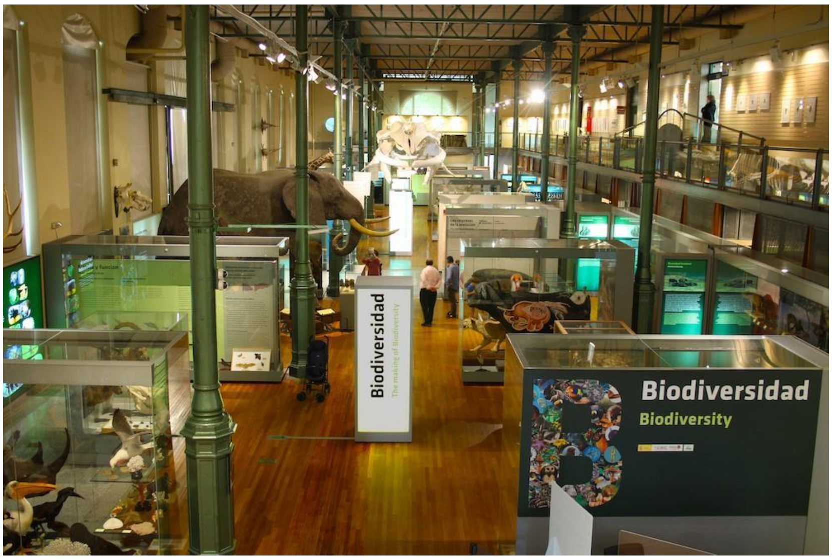
Next Section describes in detail the design of Enigma Bio.

3. Enigma Bio

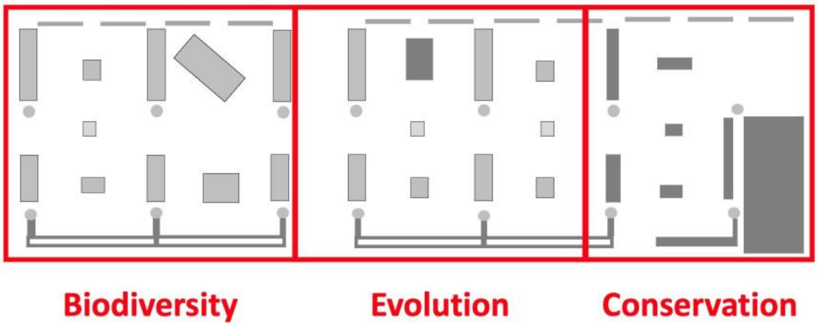
Enigma Bio is built around the biodiversity exhibition at MNCN. The concept of Biodiversity revolutionized the way we approach the study and conservation of nature by bringing together in a single concept the variety of species, their genetic variability, and their interrelationships with each other and with their environment. The exhibition, depicted in Figure 1a, attempts to answer these questions: What is Biodiversity? How has evolution shaped today's Biodiversity? How should Biodiversity be conserved? The exhibition is divided into three areas, as shown in Figure 1b: Biodiversity, Evolution and Conservation.

The first area of the exhibition explains what biodiversity is, how it is distributed in the different biomes of the world and how it manifests itself in the shapes, colors and relationships between the different organisms that make up ecosystems. Large collections of insects and mollusk shells then serve to explain the different levels at which we appreciate Biodiversity, from the gene to the ecosystem level. There is also a space to show how scientists try to order Biodiversity by classifying and naming living things.

The origin and the tree of life, whose branches link all living organisms evolutionarily, pave the way for the second area: "Biodiversity, the Fruit of Evolution." Here, the theory of evolution through natural and sexual selection is expounded upon, and its genetic basis is explained. Extinctions in the distant past, and more recent ones related to human activity, begin the area of "Conservation". This space not only reflects the direct causes of extinction and its victims, exhibiting extinct species such as the marsupial wolf, but also answers the questions of what, where and how to conserve.



(a) General view.



(b) Floor map.

Figure 1: Biodiversity exhibition at MNCN

As shown in Figure 1b, while the areas in the exhibitions are not physically separated, the display cases define spaces that can be perceived as connected, with "doors" enabling passage between zones. In Enigma Bio, each of these three "rooms" adhere to an open structure, allowing players to solve various puzzles simultaneously and without a specific order.

Enigma Bio's core game mechanic centers on using a mobile device's camera to search for artifacts, using image recognition technology. Players advance through a narrative adventure by following clues, answering questions, and engaging in different stages. Throughout these stages, participants encounter narrative elements, dialogues, artifact hunts, and blocks that regulate player advancement.

An artifact hunt prompts participants to use their device's camera to locate an object indicated by a game clue. Successfully identifying the artifact completes the search. Usually, an augmented reality image or text will overlay the object, offering hints or additional information for the game. To encourage students to read the content of the explanatory panels in the exhibition, many of the object searches in Enigma Bio refer to details on those panels, as shown in Figure 2 where several children try to find a detail on the panel "the shapes of biodiversity".

Figure 2: Interaction with the exhibition content

During a room stage, the participant has the freedom to interact with all the sub-sequences of artifact hunts and puzzles positioned within the room in any order they choose. To progress to the next stage from a room, the user must solve a final puzzle, which will only be possible to solve successfully after having completed the rest of the quests hidden in the room.

At the end of the room, the player will find a control stage in the game designed to prevent participants from progressing until they are given a keyword known only to the museum educator. This will allow to run the escape room in a synchronized manner for the group of participants, by allowing to wait until all participants have completed one room before granting passage to the next. And, more important, this will bring full attention of the children to the explanations of the museum educator, as shown in Figure 3.

Next, we describe the interface and more details about the main elements of gameplay in Enigma Bio. The complete game design, including the tutorial and three rooms associated with each of the three areas of the biodiversity exhibition, are described in (SPICE H2020 project, 2023).

Figure 3: Explanations of the educator

3.1 Enigma Bio Game Mechanics

The Narrative Screen (Figure 4) is a common resource in Enigma Bio. It consists of a character icon, character name, and a text box to communicate information and instructions to the player. Multiple narrative screens can be linked together, allowing for character changes, and creating interactive conversations.

Figure 4: Character and Text screen

The Scan screen used in the game for artifact hunts can be seen in Figures 5a and 5b. By using the device's camera, it can track any image. Once the player finds the correct image, the overlay will change from "Searching" to "found" and the compass shown in the interface will change color to show that´s the correct image. Typically, in Enigma Bio a text or an image will be shown on top of a tracked image, as shown in Figure 5c where the image tracked is the puffer fish and the overlay indicates to search for the "shapes of biodiversity panel".

Since players will usually not be familiar with this mechanic, the main goal of the tutorial phase in Enigma Bio is help the player to learn how to use this tool, so that later she can use it in the escape room.

The Escape Room Screen, shown in Figure 6a serves as the central hub for every room in the game, featuring a total of 5 puzzle blocks. While four of these blocks are accessible at any time and in any order, the central block can only be accessed upon completing the other four.

(a) Scan Screen.

(b) Scan Screen in action.

(c) AR Overlay.

Figure 5: Artifact search

Once a block in the room is successfully completed, the player will receive a piece, as the one shown in Figure 6b, needed to solve the final puzzle in the room, and it will no longer be possible to re-enter that block. Completed items will undergo a color change to visually indicate their status as finished, accompanied by a new image display. As illustrated in Figure 6c, completed blocks exhibit puzzle pieces instead of the icons featured in Figure 6a. Notably, the central button is highlighted, signaling to the player that access to the final block has been unlocked.

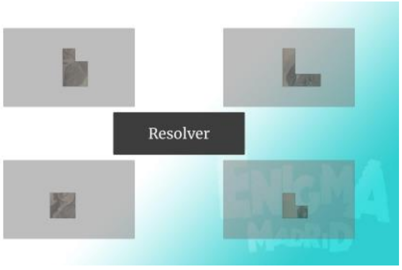
The final block in every room is a puzzle to be assembled with the pieces obtained in the room, and possibly, some others, as shown in 7. The solved puzzle will provide a clue for the next artifact to find, as, for example, in Figure 7, where there is a picture of Carl Linnaeus, which tells the player to find that same image for answering the next questions.

The game is interspersed with different types of questions that usually refer to the content of the exhibition panels. The idea is to alternate search phases with question phases, so that first we make sure that the player is in front of a certain panel and then we ask them a question whose answer is on that panel.

The basic type of question in Enigma Bio is a multiple-choice question as the one depicted in Figure 8a, that may have one or more correct answers. Upon providing a correct answer, a green checkmark will be displayed, or, in the case of an incorrect answer, the screen will exhibit a red cross (as shown in Figure 8b) and will also reveal the correct answer for reference. These are non-blocking questions since the player can proceed the game even with a wrong answer, but the number of right answers will be displayed at the end of the game and players will compete to obtain the highest score.

(a) Escape Room Screen.

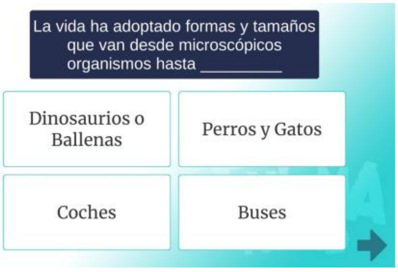
(b) Puzzle piece obtained.



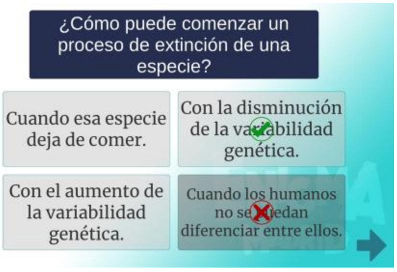
(c) Escape Room Completed.

Figure 6: Escape Room Screen

Figure 7: Puzzle Screen



(a) Question.



(b) Incorrect answer.

Figure 8: Multiple choice questions

There is also a question type that involves specifying a specific four-digit number. This format is particularly suitable for inquiries that require a numerical year as the answer. For instance, in Figure 9a, the question presented is: "In what year was the term 'Biodiversity' first used?" with the correct response being: 1988. These are blocking questions because the game cannot proceed unless the correct answer is provided, thus forcing the player to find it.

Finally, there is also an open question type that entails a multiple-choice format without a designated correct answer. This type of question can serve various purposes, such as gathering insights about the player or functioning as a questionnaire at the conclusion of each level.

(a) Four-digit question. (b) Open question.

Figure 9: Questions

Every room in Enigma Bio finishes with an "Introduce Room Code" stage as the one shown in Figure 10a. This screen prompts players to input a code for advancement. The code will be provided by the museum educator, once the correct question is posed to him. The last piece of information in every room is a question that must be posed to the educator. In order to promote competition, the educator will distinguish the first players to find the question, making them stand by him while providing the answer to the group, as shown in Figure 10b.

(a) Introduce room code. (b) Museum Educator's explanation.

Figure 10: Room exit

4. Research Design and Method

In this experiment, first, we would like to assess whether playing Enigma Bio raises children's awareness of the threats posed by climate change. In addition, we would also like to answer the question of whether, in the case of short games in museums, it is more effective to have a pre-session introducing the topic. Our hypothesis is that without the context of the pre-explanation, the playful component of the game is too powerful, and the child does not pay enough attention to the message that the game intends to communicate. In addition, as this activity is aimed at primary school children, aged 11-13, our hypothesis was that the concept of biodiversity and its relation to climate change may be too complex in general for these children to grasp just from the museum activity.

In this experiment we had the participation of 57 children in 5th grade of primary school (ages between 11 and 13) who visited the National Museum of Natural Sciences on November 22, 2022. The children were randomly assigned to one of two groups, experimental group (29 children) and control group (28 children).

With a pre/post measures design, we attempt to address the hypothesis at hand: a pre-talk is necessary to develop greater awareness of threats to biodiversity related to climate change. The evaluation is carried out by means of a validated questionnaire on environmental awareness (van Valkengoed, Steg and Perlaviciute, 2021). The questionnaire, included in Appendix A consists of 5 factors that reflect the 5 most common perceptions regarding climate change: people's perceptions of the reality and causes of climate change, and the perceived valence, spatial distance, and temporal distance of the consequences of climate change.

The validated questionnaire provided by van Valkengoed, Steg and Perlaviciute (2021) consists of 7-point Likert scale responses to the questions posed where 1 is "strongly disagree" and 7 is "strongly agree". This type of response can be a problem for children of early age (Mellor and Moore, 2013). Therefore, we chose to simplify the questionnaire and offer students only 2 possible answers: "I agree" or "I disagree". With this modification the scores we will obtain are altered since the items only offer dichotomous scores (0 and 1) and each of the 5 factors offers a maximum score of 5 points if the subject is fully aware of the environmental impact of the factor in question.

The experimental setup involves two groups, both of which were given the validated questionnaire on environmental awareness at the beginning (pre). However, one group was also given a 30-minute lecture on Biodiversity and climate change before the museum activity, while the other was not. Both the initial questionnaire and the lecture took place at their school one week before the visit to the museum.

Both groups visited the museum and carried out the activity in the Biodiversity exhibition which consists of 50 minutes playing Enigma Bio with the active participation of an educator. Finally, one week after the visit to the museum, back at school both groups took again the environmental awareness questionnaire (post).

5. Findings

The results obtained demonstrate encouraging outcomes. Significant differences were observed between pre- and post-activity tests, with overall scores showing a moderate increase after performing the activity, both within each individual group (A/B) and across the combined results of the groups. This tendency can be seen visually in Figure 11, where the clustered distributions of the student scores before and after the activity are represented via a box plot.

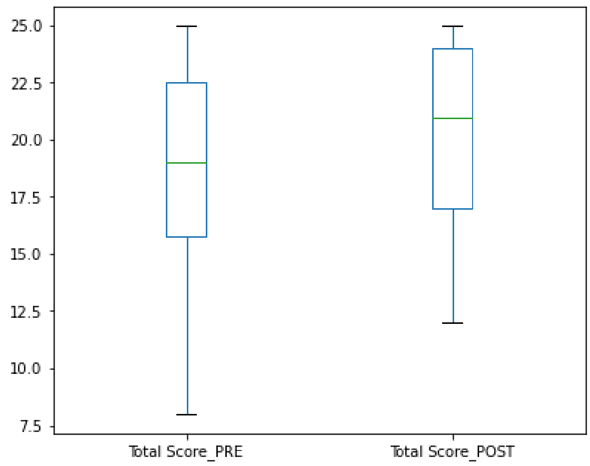


Figure 11: Box plot of the total score distribution (clustered samples)

After conducting the Wilcoxon signed-rank test for paired samples ($\alpha = 0.05$), we observed a clear and significant trend of score improvement among the students (refer to Table 1). The trend is evident and statistically significant in 3 out of the 5 factors assessed in the test, as well as in the overall total score. This test, however, only allows us to establish that there are significant differences at the individual level between test administrations, but by itself does not provide evidence of the direction of the changes.

Table 1: Clustered results of the validated environmental awareness test van Valkengoed, Steg and Perlaviciute (2021) (mean scores and significance of the Wilcoxon test for paired samples, N = 57)

	Reality	Causes	Conse-quences	Spatial Distance	Temporal Distance	Total Score
Pre	4.47	3.18	3.29	3.93	3.58	18.45
Post	4.62	3.83	3.94	3.83	3.63	19.85
p-value	0.0052	0.0020	0.0004	0.0028	0.0579	0.0013
Sig.	**	**	***	**	–	**

To address this concern, we can refer to the data on the proportion of students who improve their total test score, which amounts to 55% of the sample. When looking at individual factors, the proportion of improving students ranges between 16 and 33%, with a good number of participants whose scores in that factor remain unchanged between tests. In fact, if we analyze the number of factors in which students report better scores, we obtain an average of 1.16 factors ($\sigma = 1.02$, not accounting for the total). Consequently, we can confidently state that the activity significantly enhances the students' general awareness, regardless of whether they received the lecture or not, although this improvement is generally focused on a small subset of awareness factors per student.

The hypothesis aimed at validating the need to include a talk prior to the museum visit to reinforce awareness of the causes threatening biodiversity, particularly the role of climate change as a threat, was moderately supported by this experiment.

After the initial administration of the questionnaire, a Mann Whitney U test was conducted to assess whether the factor-to-factor and total scores' distributions of control and experimental groups before the activity were similar. The results indicated no significant evidence to reject the null hypothesis of similarity of populations in all comparisons (for the total score, p-value = 0.44). In other words, both randomly chosen groups exhibited similar behavior before the activity, a crucial factor in avoiding bias in the experiment.

As shown in Tables 2 and 3, the students assigned to the experimental group exhibit marked and positively trending significant differences in their individual behavior concerning 2 out of 5 considered factors, as well as in the overall score. On the other hand, the control group does not perceive statistically significant differences in the total score of the questionnaire, although it does show moderately significant positive changes in 2 out of 5 factors. Both groups seem to display a subtle negative trend in the spatial distance factor, although the difference in the mean is not particularly high in either case.

Table 2: Control Group (no presentation before)

	Reality	Causes	Conse-quences	Spatial Distance	Temporal Distance	Total Score
Pre	4.50	3.36	3.46	3.86	3.86	19.04
Post	4.74	3.59	4.11	3.78	3.89	20.11
p-value	0.0103	0.1797	0.0177	0.0378	0.1638	0.0845
Sig.	*	–	*	*	–	–

Table 3: Experimental Group (with presentation before)

	Reality	Causes	Conse-quences	Spatial Distance	Temporal Distance	Total Score
Pre	4.44	3.00	3.11	4.00	3.30	17.85
Post	4.48	4.08	3.76	3.88	3.36	19.56
p-value	0.1342	0.0050	0.0086	0.0369	0.0964	0.0059
Sig.	–	**	**	*	–	**

In summary of the results collected from the group analysis, the following points of interest can be established:

- The experimental group shows a statistically significant and positive individual trend in their overall awareness level, while in the control group, there is not enough evidence to confidently establish a similar result. However, in the latter group, the p-value falls below 0.1, and the pre- and post-experiment means are separated by about one point, indicating that the differences in trends between groups are not as pronounced as initially perceived.
- The experimental group appears to have a markedly positive effect on the students' awareness concerning the factors of causes and consequences. The improvement in consequences also extends to the control group, which shows significant improvement in this aspect as well.
- The control group exhibits a statistically significant and positive difference in the reality factor, although the group's mean remains close to the original.
- Both groups display a moderate negative trend in the spatial distance factor, although the differences in the means are not particularly pronounced.

5.1 Discussion

The main aim of an educational game is to use the playful experience as a vehicle for introducing significant learning (Djaouti, et al., 2011). If the design of games is already an activity that requires large doses of creativity and knowledge (Fullerton, 2008), the design of educational games also requires finding a balance between learning and fun that makes it especially demanding (Shute, et al., 2020), and even more so when dealing with a complex message such as the effect of climate change on biodiversity. Nonetheless, others have demonstrated the effectiveness of using games as a means to raise awareness and educate on biodiversity-related issues such as climate change (Reckien and Eisenack, 2013; Flood, et al., 2018) or sustainability (Fabricatore and Lopez, 2012; Nordby, et al., 2016; Mercer, et al., 2017). Enigma Bio faces additional challenges targeting primary school children aged 11-13, who may find it difficult to understand certain abstract concepts, and even more so if the experience is restricted to the short duration of a school visit to a museum (Camps-Ortueta, et al., 2023). The solution we propose to add an introductory session prior to the game in the museum is in line with Markmlund and Taylor (2016), who states that is not only the game but also the context that matters when we talk about educational games.

The results of the experiment provide valuable insights into the effectiveness of the pre-session introduction in enhancing the learning outcomes of short educational games. Our hypothesis, which posited that without the context of a pre-explanation, the playful element of the game might overshadow the intended message, was moderately supported by the findings. Significant differences were observed between pre- and post-activity tests, indicating a moderate overall increase in awareness scores within both individual groups (A and B) as well as across the combined results. This trend can be visually observed in Figure 11, depicting the distributions of student scores before and after the activity.

Nonetheless, there are differences in the factors that van Valkengoed, Steg and Perlaviciute (2021) refers to as “climate change perceptions”: upon closer examination, it is evident that the activity contributed to a statistically significant and positive individual trend in the overall awareness level of the experimental group. However, the control group did not exhibit strong enough evidence to confidently establish a similar result. Although the control group displayed a lower p-value and a noticeable separation between pre- and post-experiment means, differences in trends between the two groups were not as pronounced as initially anticipated.

The findings suggest that the pre-session introduction indeed played a role in enhancing the students’ awareness of the targeted message, though further experiments would be required to reinforce this claim on a more general basis. The experimental group displayed marked improvements in understanding the factors related to causes and consequences of biodiversity loss, with the control group experiencing subtler enhancements in these aspects. This implies that the introductory context helped students better comprehend the nuanced relationships presented in the game that were related to these factors.

On another note, the results regarding spatial and temporal distance perceptions yielded unexpected findings. Contrary to our anticipation, students either slightly regressed in these aspects or exhibited insignificant changes post experiment. This surprising outcome prompts a closer look at the complexity of these concepts for young learners.

The intricate nature of spatial and temporal dimensions, especially when connected with the abstract concept of climate change, might pose challenges for primary school children’s cognitive understanding. These complex interrelationships may demand a more advanced cognitive development level to be fully grasped.

Considering that spatial and temporal concepts are often challenging even for individuals of various ages, the difficulty could be magnified for children in the primary school age group. The gradual and subtle nature of climate change effects over time and space could require tailored teaching approaches that bridge these abstract notions with the students’ real-world experiences.

6. Conclusions and Future Work

In this study, we have introduced Enigma Bio as an enhanced version of the enigma saga’s treasure hunt games, infused with escape room elements to enrich the puzzle-solving experience. By incorporating educators into the gameplay mechanics, we have transformed the game into a valuable tool for engaging students.

Our initial findings shed light on the game’s effectiveness, even within its brief duration, a result that could be attributed to the immersive museum setting. Interestingly, initial outcomes also suggest that prior exposure to relevant concepts, such as biodiversity, could amplify the game’s impact. Notably, the experiment highlighted the positive influence of a pre-session introduction on the efficacy of short educational games in helping primary school children understand complex concepts. While both groups showed increased awareness, the experimental group, armed with contextual introductions, demonstrated more substantial improvements, particularly in comprehending the intricate relationship between biodiversity and climate change, especially regarding climate change's effects and consequences on biodiversity. These findings underscore the crucial role of well-designed instructional strategies in facilitating young learners' grasp of intricate subjects and fostering a stronger connection to real-world challenges.

Looking ahead, our research will expand into more comprehensive experiments to provide conclusive insights into the effectiveness of our approach. Further exploration into optimizing learning outcomes for young students will involve refining the timing, content, and delivery of pre-session introductions. Additionally, considering the unexpected trends in spatial and temporal distance perceptions, we propose investigating the cognitive development trajectory of young learners in understanding complex environmental concepts. Innovative pedagogical strategies and gamifications aimed at making these abstract notions more relatable could prove vital in nurturing a more accurate and comprehensive understanding of climate change and its significance in the lives of primary school children.

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Appendix: The Questionnaire

Reality

1.	I believe that climate change is real.
2.	Climate change is NOT occurring.
3.	The world's climate is changing.
4.	I do NOT believe that climate change is real.
5.	Climate change is happening.

Causes

1.	Human activities are a major cause of climate change.
2.	Climate change is mainly due to natural causes.
3.	Climate change is mostly caused by human activity.
4.	The main causes of climate change are human activities.
5.	Climate change is caused entirely by natural processes.

Valence of consequences

1.	Overall, climate change will bring more negative than positive consequences to the world.
2.	Climate change will mostly have positive consequences.
3.	Climate change will bring about serious negative consequences.
4.	The consequences of climate change will be very serious.
5.	There will be mostly positive consequences of climate change.

Spatial distance

1.	My local area will be influenced by climate change.
2.	Climate change only influences locations far away from me.

3.	The region where I live will experience the consequences of climate change.
4.	The consequences of climate change will only take place in distant locations.
5.	Climate change will also influence the place where I live.

Temporal distance

1.	The consequences of climate change are visible now.
2.	It will be a long time before the consequences of climate change are felt.
3.	Only future generations will experience the consequences of climate change.
4.	The consequences of climate change will only be experienced in the far future.
5.	The effects of climate change will be felt very soon.

