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Serious Game Design Integrating Design–Play–Experience Framework: Digital Interactive Experience Exploring Ecology of Palaeoloxodon †

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Abstract

In this study, we developed a game related to *Palaeoloxodon huaihoensis* to enhance public interest in learning about its ecology. The game integrates education and entertainment elements at four interactive levels "See Sea Bones," "Assembling Organs," "Bacterias Cleaner," and "Painting Elephant" to allow players to explore the fossil structure, internal organs, and historical background of *Palaeoloxodon huaihoensis*. In the design process, we incorporated the design–play–experience framework and the gameplay–purpose–scope (GPS) model to balance entertainment and education. To evaluate the effectiveness of the developed game, a questionnaire survey on a Likert scale was conducted with 180 participants visiting the National Museum of Natural Science, Taiwan. The results indicated that the majority of the players were satisfied with the game's design and content, particularly in terms of its ability to stimulate creativity. This research demonstrated the potential of games in museum education and provides insights for future optimization.

Keywords: *Palaeoloxodon huaihoensis*; serious games; education; computer games; GPS model; DPE framework

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1. Introduction

With the development of digital technology, computer games have become popular worldwide [1,2]. Although museum exhibitions attract many visitors, related knowledge is often not fully understood due to a lack of guidance and interaction. Visitors with limited background knowledge rely on assistance from parents, displays, or museum staff, but such support is not always available, leading to insufficient learning [3]. For example, the *Palaeoloxodon huaihoensis* fossil in the National Museum of Natural Science in Taichung, Taiwan, though visually appealing, is not fully appreciated by most visitors for its tens of thousands of years of ecological value. Modern museums recognize their limitations in static displays and the need for interactive ways to present scientific knowledge. Therefore, we designed an interactive game on personal computers (PCs) to transform scientific knowledge into accessible content. The game concept with entertainment elements enhances player engagement and interest in learning.

2. Related Works

2.1. Palaeoloxodon huaihoensis

Palaeoloxodon huaihoensis is a large mammal native to the Huai River basin in China, representing a key species of the Late Pleistocene. During this period, the global temperature dropped due to the effects of the Ice Age, causing sea levels to decline [4,5]. As a result, a land bridge formed in the Taiwan Strait, connecting mainland China with Taiwan. This geological change facilitated the southward migration of various land animals, including the Palaeoloxodon, eventually reaching the waters of the Penghu Channel [5].

Palaeoloxodon huaihoensis had a distinctive bony structure on its head resembling a cap, earning it the nickname "Ako," [6] symbolizing its unique appearance and physique. Fishermen in the Penghu area, China, accidentally discovered the fossil remains of this giant animal while fishing near the Penghu Channel [5,7].

2.2. Games Design

The development of computer games centers on two primary objectives: "education" and "entertainment" [8]. Serious or serious games enable game-based learning, edutainment, learning games, educational games, or goal-oriented games [9] beyond entertainment by incorporating diverse elements of education, training, and health promotion [10]. Their applications are not limited to in-school learning but extend to various learning environments outside traditional educational settings [11]. In designing the applied game, a balance between the "serious" (educational) objectives and the "game" (entertainment) elements is crucial. Caserman et al. emphasized that serious games are divided into "serious" and "game," and examined the balance between these two aspects [12]. In other words, the success of a serious game depends on its ability to establish a balance between knowledge transfer and player engagement, thereby achieving a dual benefit.

2.3. GPS Model

Feng et al. [13] noted that the gameplay–purpose–scope (GPS) model proposed by Djaouti et al. [14] provides a classification method for serious games, assisting developers in setting educational and entertainment objectives through the three dimensions. A serious game includes multiple levels with challenges designed for different learning goals, emphasizing immersion and interactivity. Activities such as fossil retrieval and organ assembly provide edutainment effects with a creative segment enhancing learning and enjoyment. The gameplay prioritizes structured learning content and goal-setting, covering knowledge points such as biological characteristics and geological changes, reflecting the purpose of the GPS model. According to Djaouti et al. [14], the scope refers to the target audience and usage context. A serious game is appropriate for museum visitors, students, and paleontology enthusiasts, with options to reflect the scope and promote knowledge dissemination.

2.4. DPE Framework

In the game design, we used the design, play, and experience (DPE) framework for systematic development. The DPE framework is a theoretical model widely applied in game design, covering five dimensions: learning, storytelling, gameplay, user experience, and technology [15]. The framework provides developers with a universal design language to effectively assist in analyzing game design [16]. The DPE framework emphasizes balancing engagement and interactivity in design while ensuring learning outcomes. The learning layer focuses on knowledge internalization; the storytelling layer emphasizes guidance through characters and narrative; the gameplay layer involves game mechanics design; the user experience layer centers on intuitive and immersive interface design; and the technology layer ensures that technical elements support learning and game objectives.

3. Materials and Methods

We designed and developed four game levels, namely "See Sea Bones," "Assembling Organs," "Bacterias Cleaner," and "Painting Elephant" as shown in Figure 1. Players play the game using a PC platform with a keyboard and mouse as the primary input tools. The game adopts a modern realistic style, featuring diverse settings such as the Penghu Channel, a laboratory, and an elephant vascular system. These varied designs enhance immersion and engagement, thereby increasing learning interest and knowledge retention (Figure 1a).



(**a**) The game 復甦古象 *Reviving the Ancient Elephant* features four different levels, with the main character, the professor, displayed at the center of the screen



(**b**) The main menu screen of *Reviving the Ancient Elephant*, showing the game logo at the top and various gameplay modes below, allowing players to start the full game or select specific levels

Figure 1. (**a**) the game features four different levels and (**b**) Main menu allowing players to start the full game or select specific levels.

3.1. Game Processes

The game's main interface shows an animation introducing the migration of *Palaeoloxodon huaihoensis*, integrating the learning and storytelling layers of the DEP framework. The animation illustrates the geographic and climatic changes of the Ice Age, enhancing players' understanding of background knowledge and immersion. Following the animation, the main menu provides two options: "Full Level Mode" and "Level Selection Mode." It combines the user experience and gameplay layers of the DEP framework, featuring sound adjustments and game introductions to ensure ease of use and engagement. This design seamlessly integrates learning, storytelling, and gameplay (Figure 1b).

3.2. Level Design

3.2.1. "See Sea Bones" Level

In the "See Sea Bones" level, a tutorial mode is set up to help players become familiar with controls and master submarine operation skills, guiding them to search for and recover the Palaeoloxodon fossils within a time limit, integrating the learning and gameplay layers of the DPE framework. The game interface provides features such as a mini-map, altimeter, and a 180 s time limit to enhance navigation and immersion, aligning with the User Experience layer. The fossil progress display and key prompts improve operational efficiency, supporting the technology layer and offering a smooth gaming experience, as shown in Figure 2.



(**a**) 操作方式 = Controls, 移動 = Move, 抬取 = Pick up, 加速 = Boost, 升高 = Ascend, 新手任務 = New player mission, 操控潛水艇，完成漢河古菱齒象化石收集 = Pilot the submersible to collect fossilized remains of *Palaeoloxodon huangheensis* (ancient river elephant)



(**b**) In-game interface during the fossil collection mission. The left side of the screen displays a depth gauge indicating the current underwater depth. The player pilots the submersible to explore and retrieve fossils, with controls shown at the bottom of the screen.

Figure 2. "See Sea Bones" level: (**a**)tutorial interface showing basic controls for submersible operation and fossil collection task. and (**b**) level screen.

3.2.2. "Assembling Organs" Level

In the "Assembling Organs" level, players choose the visual style of organs (cartoon or realistic) to enhance immersion and place six key organs back into the Palaeoloxodon, integrating the learning and gameplay layers of the DPE framework to improve anatomy knowledge and task engagement. The game provides organ descriptions and a 150 s limit, with prompts to help players complete the challenge. These designs offer real-time feedback in the technology layer, optimizing the user experience layer as shown in Figure 3.



(**a**) Style selection interface allowing players to choose between two visual styles: 寫實 **Realistic** or Q 版 **Cartoon**



(**b**) Players can pick up and examine organs in detail within the lab environment

Figure 3. "Assembling Organs" level: (**a**) Style selection interface offering two visual styles: realistic and cartoon (Q version) and (**b**) level screen.

3.2.3. "Bacterias Cleaner" Level

In the "Bacterias Cleaner" level, players can choose from three difficulty levels (easy, medium, hard), corresponding to different speeds, meeting challenge needs, and providing a multi-tiered experience. The health indicator and 30 s limit remind players to plan their steps, enhance time management, align with the user experience layer of the DPE framework, and improve immersion. Key prompts are provided to strengthen the technology layer's fluidity, and the gameplay layer offers diverse challenges to help players achieve their goals, as shown in Figure 4.



(**a**) 慢速 = Slow speed (Easy), 中等 = Medium speed (Normal), 快速 = Fast speed (Hard)



(**b**) HP（生命值）= Health Points, 滑鼠左鍵 = Left mouse button, 攻擊 = Strike

Figure 4. "Bacterias Cleaner" level: (**a**) difficulty selection interface with three levels: Easy, Medium, and Hard and (**b**) level screen.

3.2.4. "Painting Elephant" Level

In the "Painting Elephant" level, players can use the R and Q keys to select colors and textures, enabling personalized designs that integrate the learning and user experience layers of the DPE framework to enhance emotional connections. The photo mode allows players to adjust the camera angle using the G key, capture imageDjaouti et alDjaouti et alDjaouti et alDjaouti et als, and save their creations, strengthening the storytelling layer by providing means for documentation and sharing. Key prompts improve operational friendliness, enhancing the fluidity of the technology layer while deepening creative freedom and immersion as shown in Figure 5.



Figure 5. 'Painting Elephant' players can freely paint the mammoth in this level.

3.3. Questionnaire Survey

The participants in this study were visitors to the National Museum of Natural Science, ranging in age from 7 to over 40 years old, all of whom were first-time users of the game designed in this research. Convenience sampling [17] was employed to collect data between August 22 and 1 September 2024. The museum, with its extensive educational exhibits related to paleontology, provides an ideal learning environment and research setting for this study, enabling participants to interact within a real and concrete educational context. This setting enhanced the validity and applicability of the research findings.

4. Results

To evaluate player satisfaction, 180 valid questionnaires were collected, and the data were analyzed (Appendix A) [18–20]. The results of the analysis revealed that most items scored above 4.40 on average, with Q7 showing the highest score (4.64), indicating strong agreement on the game's design rationality. Several participants did not engage with certain levels, resulting in a final valid sample size of 164. Q9 scored 4.38 (standard deviation (SD) = 0.785), while Q10 scored 4.54 (SD = 0.686), reflecting positive feedback on creativity-

enhancing designs (Table 1). The results demonstrated the game's outstanding performance in design rationality and creativity stimulation successfully integrated education and entertainment in serious games.

Table 1. Questionnaire survey results.

Item	Sample (N)	Average Score	SD
Q 1	180	4.52	0.720
Q 2	180	4.56	0.644
Q 3	180	4.46	0.735
Q 4	180	4.41	0.864
Q 5	180	4.58	0.643
Q 6	180	4.44	0.778
Q 7	180	4.64	0.567
Q 8	180	N/A	N/A
Q 9	164	4.38	0.785
Q10	164	4.54	0.686
Q11	180	4.53	0.697
Q12	180	4.47	0.743
Q13	180	4.59	0.623

5. Conclusions

The PC interactive game developed in this study successfully combines educational and entertainment elements, providing players with a unique opportunity to learn paleontological knowledge. The questionnaire survey analysis results showed that most players appreciated the game's content, design, and controls, especially in the creative segment such as the "Painting Elephant" level, which effectively stimulated creativity. Although the "Assembling Organs" and "Painting Elephant" levels did not attract all players, overall feedback remains positive. The potential of game-based learning in museum education was verified in this study, emphasizing the importance of quality interactive design and real-time feedback in enhancing learning outcomes. Future research is necessary to include diverse audiences and optimize the game levels to better meet the needs and preferences of different players, thereby enhancing educational impact.

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Appendix A

Questionnaire

1. The learning process in the game is more engaging than traditional passive information reception.
2. The contextual design of the animation helped me learn about the Palaeoloxodon.

3. The real-time feedback in the game helped me understand my performance.
4. The controls were easy and straightforward.
5. The goal design in each level helped me stay focused.
6. The difficulty level of the game was appropriate.

The overall gameplay design was reasonable.

7. In the "Organ Reconstruction" level, my chosen style was:Stylized Organs ☐ Realistic Organs ☐ None (did not play)
8. The design of my chosen style in the "Organ Reconstruction" level suited my personal preferences.
9. The coloring process in the "Palaeoloxodon Painting" level enhanced my creativity.
10. The game interface was aesthetically pleasing.
11. The cutscenes between levels were smooth and engaging.
12. The feedback effects (such as click effects, success/failure indicators) were well-executed.

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