GAMIFIED HISTORIC BUILDING INFORMATION MODELING (G-HBIM) EXPERIENCE: A COMPARATIVE ANALYSIS
تحليل مقارن: (G-HBIM) تجربة نمذجة المباني التاريخية عبر الالعاب

Mohamed W. Fareed [1], Prof. Dr. **Yasser Sakr** [2], Prof. Dr. **Ahmed Radwan** [3]
Department of Architecture, The Higher Institute of Engineering- Elshorouk City, Egypt [(1)]
Department of Architecture, Faculty of Fine Arts, Helwan University, Egypt [(2, 3)]

محمد وحيد فريد [١]، **ياسر حسنى صقر** [٢]، **احمد حسنى رضوان** [٣]
قسم العمارة – المعهد العالى للهندسة – اكاديمية الشروق، مصر [١]
قسم العمارة – كلية الفنون الجميلة – جامعة حلوان، مصر [(٢،٣)]

mw.fareed@gmail.com[1] - yasser.sakr@hq.helwan.edu.eg[2] - ahosney@gmail.com[3]

ABSTRACT

This paper presents a comparative analysis of four case studies that used gamification t o educate people about cultural heritage, specifically through Gamified Historic Building Information Modeling (G-HBIM). The main goal of the case studies was to raise awareness among users of all ages, genders, and expertise levels regarding heritage/history. Edutainment, training, and virtual tourism were common themes. The paper analyzes and compares the different techniques and game engines used the types of information presented, and the usability/memorability of the games. The Octalysis framework of gamification was used to evaluate the games, with core drives 3, 5, and 7 being the most used. The paper suggests that future GHBIM experiments and case studies should consider using all core drives, including 1, 4, 6, and 8, and notes that there is potential to "heritigize" these drives for cultural heritage purposes. The paper concludes that gamification can be an effective tool for learning architectural cultural heritage, and that GHBIM guidelines could be developed from the case studies analyzed.

KEYWORDS

Digital Heritage ; Gamification; Architectural Heritage; Historic Building Information Modeling (HBIM)

الملخص

تقدم هذه الورقة تحليلاً مقارنًا لأربع دراسات حالة استخدمت التحول اللعبة كوسيلة لتثقيف الأفراد حول التراث الثقافي، وتحديداً من خلال استخدام نمذجة المعلومات المبنية للمباني التاريخية المحسّنة بالألعاب (G-HBIM). الهدف الأساسي لهذه الدراسات كان تعزيز الوعي بين المستخدمين من مختلف الفئات العمرية والأجناس ومستويات الخبرة فيما يتعلق بالتراث والتاريخ. وشملت المواضيع السائدة الملاحظة عبر الدراسات التوعية والتدريب والسياحة الافتراضية.

تحلل الورقة وتقارن بين تقنيات ومحركات الألعاب المختلفة المستخدمة في هذه الدراسات، مفحّصة أنواع المعلومات المقدّمة وتقييم قابلية الاستخدام والذاكرة في الألعاب. لتقييم جوانب التحويل اللعبة، تم استخدام إطار عمل أوكتاليسيس، حيث تبيّن أن الدوافع الأساسية ٣ و ٥ و ٧ هي الأكثر استخدامًا بشكل متكرر. ومع ذلك، تشير الورقة إلى أن التجارب ودراسات الحالة المستقبلية لـ G-HBIM يجب أن تدمج جميع الدوافع الأساسية، بما في ذلك ١ و ٤ و ٦ و ٨. علاوة على ذلك، تلاحظ الورقة إمكانية تكييف ودمج هذه الدوافع بطريقة تتوافق مع أهداف التراث الثقافي، مما يجعلها "تراثية" بشكل فعّال لهذا الغرض.

ويتوصل الباحثون في الورقة إلى استنتاج أن استعمال اللعبة يمكن أن يكون أداة فعّالة لتسهيل تعلم التراث الثقافي المعماري. بالإضافة إلى ذلك، تقترح الورقة تطوير مبادئ توجيهية لـ G-HBIM استنادًا إلى الأفكار المستخلصة من دراسات الحالة المحللة. من خلال دمج مجموعة أوسع من الدوافع الأساسية وتوسيع عناصر التحول اللعبة، يمكن للمشروعات المستقبلية لـ G-HBIM تعزيز تأثيرها التعليمي بشكل أكبر.

في الخلاصة، تقدم هذه الورقة البحثية فحصًا شاملاً لتطبيق التحول اللعبة في تثقيف الأفراد حول التراث الثقافي من خلال G-HBIM. تسلط النتائج الضوء على فعالية التحول اللعبة في زيادة الوعي وتعزيز عملية التعلم في مجال التراث الثقافي المعماري. كما تقدم الورقة توصيات قيمة للدراسات المستقبلية وتطوير مبادئ توجيهية لتحسين الإمكانات التعليمية لـ G-HBIM .

الكلمات المفتاحية

التراث الرقمي؛ التراث المعماري؛ نمذجة المعلومات للمباني التاريخية

1. INTRODUCTION

Historic buildings hold immense cultural significance, and it is crucial to preserve their legacy by learning. Traditional methods of learning, such as lectures and textbooks, can be dry and unengaging, leading to poor retention of information. Gamification, on the other hand, has emerged as a popular approach to engage users and improve learning outcomes. One such approach is Gamified Historic Building Information Modeling (G-HBIM), which combines historic building information modeling with gamification elements to create an immersive learning experience.

While G-HBIM has potential benefits, there is limited research on its effectiveness compared to traditional learning methods. Therefore, this study aims to analyze and compare the effectiveness of G-HBIM and traditional methods in learning about historic buildings. The study will explore the impact of G-HBIM on learning outcomes and user experience, identify the factors that influence the effectiveness of G-HBIM, and determine its potential to engage users and improve their interest in learning about historic buildings. The research will utilize Octalysis, a popular gamification framework, to analyze and evaluate G-HBIM's effectiveness as a learning tool.The findings of this study could have significant implications for creating more ef-fective and engaging learning tools for historic buildings. Additionally, this research can contribute to the growing body of knowledge on gamification and its potential to enhance the learning experience. By utilizing the techniques and information discussed, designers can create immersive gaming experiences that promote cultural heritage awareness and encourage user participation.

Research questions:

- -How does Gamified Historic Building Information Modeling (G-HBIM) compare to traditional methods?
- -What are the aspects that have significant impact of G-HBIM as a learning tool about historic buildings?

Research goals:

- -To explore the impact of G-HBIM on learning outcomes of users.
- -To investigate the user experience of G-HBIM as compared to traditional methods of learning about historic buildings.

Research hypotheses

- -G-HBIM experience will have a positive impact on the learning outcomes of users as compared to traditional methods of learning about historic buildings.
- Research Methodology

A literature review was conducted to find recent examples of gamification being used in the field of architectural heritage. The search was done on Scopus and Web of Science using keywords such as "Gamified heritage BIM" and "GAMIFICATION of cultural heritage," which initially returned 48 and 50 results, respectively. The search was then refined to include only case studies published in English within the last five years (2018-2023) and that used H-BIM explicitly throughout the entire process. The final sample consisted of 11 papers, which were examined for relevance, and only those that focused on the application of gamification in the heritage sector were selected. Commercial games were excluded, and only games with educational purposes were considered. As a result, four case studies were chosen for analysis and then compared according to the following parameters:

- Game overview and purposes:
- A short brief about the main goals, justification and aims of the game.
- Adopted workflow:
- The framework and HBIM process adopted by the game.

- Communicated types of information (Factual and Tacit information):
- Review of the communicated information through the selected games divided into:
  - Factual information: Information that deals solely with facts. Mostly they are considered as Explicit Knowledge that is easy to articulate, write down, and share, Such as: Architectural features, Artistic and aesthetic features, Spatial dimensions, and Scientific fact (Komova, 2017).
  - Tacit information: Information and knowledge that is garnered from personal ex-perience and context. It is the information that, if asked, would be the most difficult to write down, articulate, or present in a tangible form, e.g., Intangible heritage, historic events, Folklore, social context, traditional knowledge, and historical narratives (Medina et al, 2011).

- Engagement process

- **Usability:** refers to how effectively, efficiently, and successfully a particular user can utilize a product or design in a certain situation. It may contain these elements: (Schwoerer, 2022)
- **Effectiveness:** It supports users in completing actions accurately.
- **Efficiency:** Users can perform tasks quickly through the easiest process.
- **Engagement:** Users find it pleasant to use and appropriate for its topic.
- **Ease of Learning**: New users can accomplish goals easily.
- **Curiosity:** Four categories of users can be distinguished by their levels of curiosity: the Artist, who seeks to understand and communicate human experience through creative expression; the Inventor, who challenges the status quo to develop new and improved tools and technologies; the Explorer, who is interested in discovering other people, cultures, and ways of life; and the Scientist, who observes and studies to better understand the mechanisms (Britannica, 2019).

- **Age related differences:** Serious Games are primarily designed for users aged 18 to 34, who are interested in "edutainment." However, the target age group may vary depending on the specific case and requirements. (Bagnoloet al, 2021).

- **Gamification elements and mechanics:** Every case study is reviewed according to the above mentioned Octalysis framework.a popular framework used in gamification to analyze and design engaging experiences. The framework consists of eight core drives, which are motivators that influence people's behavior. The eight core drives can be explained as follows:

- **Epic Meaning & Calling:** People are motivated by a sense of purpose, a feeling that they are part of something bigger than themselves.
- **Development & Accomplishment:** People are motivated by a sense of progress and achievement, by seeing tangible results and improving their skills.
- **Empowerment of Creativity & Feedback:** People are motivated by the ability to express themselves, to be creative, and to receive feedback on their efforts.
- **Ownership & Possession:** People are motivated by the feeling of ownership and control over something, whether it's a virtual object or a real-world item.
- **Social Influence & Relatedness:** People are motivated by the desire to connect with others, to belong to a group, and to be recognized by their peers.
- **Scarcity & Impatience:** People are motivated by the fear of missing out, by the desire for something that is rare or hard to obtain.
- **Unpredictability & Curiosity:** People are motivated by the desire to explore and discover, to solve puzzles and unlock hidden secrets.
- **Loss & Avoidance:** People are motivated by the fear of losing something valuable, whether it is time, money, or status.

2. BIM AND HERITAGE DOCUMENTATION

Building information modeling (BIM) is a process that involves the use of computerized object-oriented information to design, construct, or operate a building or infrastructure asset. It is a digital representation of the physical and functional aspects of a facility and is considered a shared knowledge tool that contains data about a facility. This data can be used as a foundation for making decisions throughout the life cycle of the facility, which includes initial conceptualization and ends with demolition. BIM is an important tool in modern construction and building management, as it allows for greater accuracy, efficiency, and collaboration among all parties involved in the process. (M. Alizadeh et al., 2016)

BIM is clearly distinct from CAD and 3D modeling software, which are primarily limited to the digital representation of geometric data. In BIM, simulation takes priority over visualization. Thanks to the data connected to the numerous construction components of a structure, a BIM model serves as a digital depiction of how the actual building is anticipated to operate. (Osello et al., 2015).The use of BIM for the documentation of cultural heritage is covered in a variety of publications and research initiatives. The necessity of cross-disciplinary cooperation, the inclusion of diverse data, geometric interoperability, and data-transfer protocols are among the major difficulties (Hussein, 2020).By combining historical architectural information with digital survey data, HBIM is a novel method for producing intelligent 3D models of historicbuildings. HBIM is based on a parametric library of historical building components that follow the principles of classical architecture and pattern books from the 19th century. In other words, it uses a collection of standardized, customizable design elements that are based on historical architectural styles and can be modified to fit specific projects.

3. GAMING IN THE ARCHITECTURE AND URBAN PLANNING DISCIPLINES

Architects are already familiar with computational design in academic settings for architecture appears to make it easier to include gaming in education. This facilitates the use of video games to spread knowledge about architecture and to promote its critical interpretations. Several prestigious universities throughout the globe, including University College London, have incorporated video games into their courses. However, games aren't yet seen as a useful tool in developing countries. (Brković Dodig, 2019).Numerous studies show that the desire to highlight game play in the architectural context supports gaming as a teaching tool and the goal to create "gameful" environments that compromise the real world and the virtual environment. The visual aesthetic design, for example, includes visual elements like the general aesthetic and a range of specific explanatory elements including narrative context, rules, goals, incentives, multisensory signals, and interaction, which are crucial topromote desired learning outcomes. Despite the extensive scientific literature and the significant role that architecture plays in the development of "virtual" video games, it is difficult to pinpoint a specific architectural methodology to design a video game that supports the historicist, pedagogical, and ICT approaches (Kazman, 2020).

4. POTENTIALS OF GAMIFICATION IN ARCHITECTURAL HERITAGE DOMAIN

Gamification can be a powerful tool in the architectural heritage domain for both educational and preservation purposes. Through interactive games and quizzes, users can learn about the history, architecture, and cultural significance of buildings and landmarks. Gamification can also be used to create virtual tours of architectural heritage sites, and to explore these sites while learning about their history and significance (Gombault et al ,2020).It can also help to encourage people to preserve architectural heritage sites. Games can be developed where users must repair and maintain virtual heritage sites, teaching people about the importance of preservation and encouraging them to act in

the real world. Gamification can be used to engage people with heritage sites through scavenger hunt games or other interactive experiences (Elbaz et al, 2020).

Figure (1): The main facade of the cathedral as seen in Assassin's Creed Unity, Source: (Ubisoft,2014).

Another significant potential of gamification potentials is using game models for disaster recovery of architectural heritage. A critical example was the use of a game's model to restore the Notre-Dame Cathedral in Paris in the aftermath of the devastating fire that destroyed a significant portion of it in April 2019. Gamification is the process of applying game design principles, mechanics, and elements to solve real-world problems and engage people .One company that exemplified this approach was Ubisoft, the developer of the video game Assassin's Creed: Unity, which features a detailed and accurate depiction of the Notre-Dame Cathedral. It is worth to mention that Assassin's Creed Unity is set during the French Revolution and includes a recreation of Paris from the late 18th century, featuring numerous iconic landmarks. The game's designers and programmers made significant efforts to ensure that the Paris depicted in the game was faithful to the city that existed in 1789, working with historians and using over 150 maps to ensure accuracy. The game's detailed an accurate 3D models proved to be a valuable tool for the restoration team, providing them with access to precise information about the cathedral's design and structure (Mochocki et al, 2021).Using gamification in disaster recovery of cultural heritage has multiple advantages. Firstly, it can increase awareness and appreciation of historical landmarks and artifacts among the public. Secondly, it can help preserve and document cultural heritage, providing a reference for future generations. Lastly, it can create immersive experiences that promote education and cultural exchange (Ávila et al ,2020).

5. CASE STUDIES

5.1. Case study 1: The religious complex of Santa Maria della Pace, Italy

Figure (2): Santa Maria Della Pace, near to piazza Navona, Rome in Italy, Source: Researcher, 2022

Game overview and purposes:

The Santa Maria della Pace religious complex is an architectural masterpiece that features a unique blend of different architectural styles. The church, which is the main building in the complex, was built in the Baroque style, which was prevalent in the 16th and 17th centuries. Its façade is a striking

example of Baroque architecture, characterized by its ornate decoration, curvilinear shapes, and dramatic use of light and shadow. The interior of the church is equally impressive, with its intricate frescoes, altarpieces, and marble sculptures. One of the most notable features of the interior is the dome, which is adorned with frescoes depicting scenes from the life of the Virgin Mary.
The courtyard building, on the other hand, is an example of Renaissance architecture, which was popular in the 15th and 16th centuries. Its façade features a classic Renaissance portico, with columns and arches that create a sense of harmony and proportion. The complex also features a number of architectural elements that are unique to the region. For example, the church's bell tower is topped by a distinctive onion dome, which is a common feature of Neapolitan architecture. The courtyard building also features a series of balconies and terraces, which offer stunning views of the city. Despite the complex's long history and multiple uses, many of its architectural features have been preserved, thanks to the efforts of conservationists and historians. The Gaming-HBIM model, which was created to share the complex's historical and architectural value with a wider audience, is a testament to this ongoing commitment to preservation and restoration. By providing both technical knowledge and information for non-technical users, the model ensures that the complex's unique architecture will continue to be appreciated for generations to come (D'agostino et al, 2022).

Adopted workflow:

A virtual model of a historical building was constructed using a combination of digital survey and integrated information representation. The sources of information were extensive investigation, critical examination of technical publications, archival and iconographic records. Various reality-based techniques were used for the digital survey, including terrestrial and aerial photogrammetry. However, due to the small dimensions of the adjacent spaces in the historical center, optimal terrestrial photographic coverage of the external fronts was not possible. (Ibid)

Communicated types of information (Factual and Tacit information):

The Gaming-HBIM model of the Santa Maria della Pace religious complex is designed to provide users with a comprehensive understanding of the building's historical and architectural features. To achieve this goal, the model communicates information in six different categories, which are further subcategorized according to the needs of different user groups.
One of the key categories of information is architectural features. This category includes detailed information about the building's design, construction, and ornamentation, as well as its unique spatial dimensions. For experts and technicians, this information may include technical data about the current state of building conservation, such as the condition of the building's structural elements or the materials used in its construction. They may also include a point cloud model of the building, which allows them to explore the building's spatial dimensions in detail.
For virtual tourists, the information provided in this category is more simplified and focused on the building's historical and cultural significance. They may be given information about the architectural styles used in the building's construction, as well as the cultural and social context in which it was built. They may also be given information about the building's most notable architectural features, such as the dome, frescoes, and altarpieces in the church (Ibid).

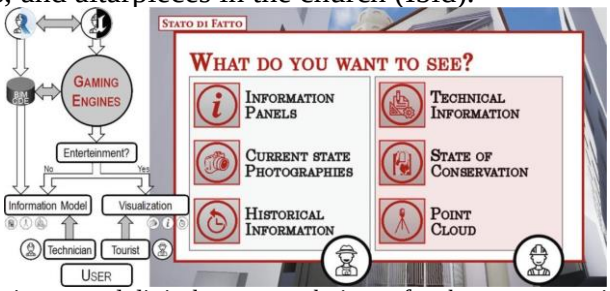

Figure (3): Description of the integrated digital survey techniques for the reconstruction of theexperimentation site, Source: (d'agostino et al, 2022)

Engagement process:

The game, designed using Historical Building Information Modeling (HBIM), provides users with categorized information related to the historic building complex, including technical data accessible through Autodesk A360. The game is user-friendly and can be used by experts, technicians, and virtual tourists. The game focuses on spatiotemporal changes to the complex over the last two centuries and uses this as the main topic of exploration. (Ibid).

Gamification elements and mechanics:

This case study illustrates the application of gamification core drives in the development of a game that combines BIM models with game engines to create an immersive virtual experience.The game aims to appeal to both specialized professionals and average consumers, while also restoring value and accessibility to neglected or deteriorated cultural assets. The core drive of

Empowerment of Creativity & Feedback (Core drive 3) is evident in the game's integration of technical data with entertainment features to encourage direct community participation. In addition, the game's future development plans include implementing interoperability with social network platforms to further enhance Social Influence & Relatedness (Core drive 5) and potentially introduce specialized roles like the BIM Gamer. The game's ability to offer a free, immersive virtual tour that allows for interaction with Cloud-BIM historical-informative parametric elements embodies Unpredictability & Curiosity (Core drive 7). This feature enables better management and utilization of the property, protecting its historical record and allowing fora better understanding of the spatiality and nature of the architectural work.

5.2. Case study 2: The Cloister of the Saint-Jean church the Evangelist of Liege,Belgium.

Figure (4): Saint-Jean church the Evangelist of Liege, Belgium, Source: Researcher, 2022

Game overview and purposes:

The Saint-Jean church is a remarkable example of Romanesque architecture in Belgium, and its construction in the 10th and 11th century reflects the influence of the Palatine chapel in Aachen, Germany. The architectural features of the church represent its cultural significance, and the virtual environment developed by the game highlights these features.One of the most notable architectural features of the church is its western façade, which is adorned with intricate stone carvings and features a series of arches and columns. The doorway is framed by a Romanesque arch and features a tympanum depicting the Last Judgment. Inside the church, visitors can admire the nave, which is

flanked by a series of round arches supported by massive piers. The nave also features a wooden barrel vault, which adds to the overall sense of grandeur and monumentality of the space. Another significant feature is its crypt, which is located beneath the nave. The crypt is an important example of Romanesque architecture in Belgium and features a series of columns and arches that create a sense of harmony and proportion. The walls of the crypt are also adorned with frescoes, which depict scenes from the life of Saint John the Baptist.The virtual environment developed by the game allows users to explore these architectural features in detail and provides a platform for recording and categorizing the cultural significance of the church. By highlighting the values recognized by a targeted public, such as architectural historians or art enthusiasts, or categorizing values based on various criteria, such as historical, artistic, or spiritual significance, the game can help to raise awareness about the cultural importance of the Saint-Jean church, and promote its preservation and restoration for future generations (Jouan et al , 2022).

Adopted workflow:

In 2021, master's students from the University of Liege's Faculty of Architecture investigated the site, and the information gathered was used to create a game to support architectural and archaeological analyses. The survey used various documentation methods, including laser scanning with a Leica BLK 360 laser scanner with a resolution of 5 mm at 10 m, and photogrammetric reconstructions at different resolutions. The game was created using Unity 3D, across-platform game engine that enables the creation of games and applications and their incorporation into realistic surroundings using AR and VR. According to academics, Unity 3D can enhance the realism of cultural heritage simulations through a variety of simulation engines. (Ibid)

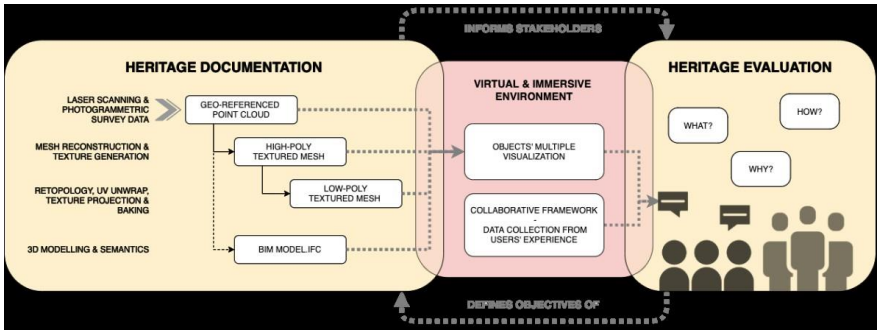

Figure (5): shows methodology adopted in this case studySource: (Jouan et al , 2022)

Communicated types of information

One of the main ways the game communicates architectural features is by providing users with a virtual tour of the buildings. This allows users to explore the structures in detail and appreciate their unique architectural elements. For example, users can explore the intricate arches, vaulted ceilings, and ornate decorative details that are characteristic of both buildings.

In addition, the game also provides users with information about the historical and cultural significance of these architectural features; e.g., users can learn about the origins of different architectural styles and the ways these styles were adapted and transformed over time to suit the needs of the buildings' various functions. Furthermore, the game communicates architectural features by allowing users to interact with different elements of the buildings. For example, users can manipulate virtual models of buildings to explore their spatial dimensions and gain a better understanding of how different architectural elements relate to one another. Users can also zoom in on specific details, such as the intricate carvings on the buildings' facades, to appreciate the level of craftsmanship and attention to detail (Ibid).

Engagement process:

In this case, the goal was to develop a virtual environment that facilitates the assessment of the value of built heritage. Suitable for explorers and scientist types of curious users, the game was developed with a particular focus on the integration and visualization of multiple representations of objects and the possibility of associating value judgments. It gives the players the option to assess how well conservation efforts fit with their opinions on the intrinsic worth of various aspects of the built environment. In fact, the game enables comparison of numerous plans and direct comparison of these projects to the relevance of the region thanks to the geolocation of values. This topic is particularly intriguing because it has the potential to significantly increase the relationship between the project and the value assessment, on conservation-related decisions.

The game's virtual environment was crafted to capture and store essential details concerning identified values. These values encompassed elements such as time, geo-location, linked items, value type, and comprehensive descriptions. Furthermore, the environment provides user with data while simultaneously facilitating the collection of invaluable insights from a diverse array of stakeholders. These stakeholders were carefully selected based on their varying levels of expertise, experience with the site, and degree of involvement in the project. Moreover, factors such as age, gender, and other relevant attributes were taken into account, ensuring a comprehensive representation of perspectives and opinions. Ultimately, this approach fostered a rich and multifaceted understanding of the game's virtual landscape and its significance to different user groups (Ibid).

Gamification elements and mechanics:

The game employs several gamification techniques that align with the Octalysis Framework's core drives. For instance, it leverages feedback and creativity (Core Drive 3) by allowing players to provide input and ideas on the historical building and its conservation process, leading to a more meaningful engagement with the content. Additionally, the game focuses on social influence and relatedness (Core Drive 5) by enabling players to share feedback with friends and build a sense of community, fostering a deeper connection with the game. Finally, the game caters to unpredictability and curiosity (Core Drive 7) by offering an unpredictable and educational experience where players can explore the historical building's architectural features in a non-linear manner, uncovering hidden details and learning about its historical significance.

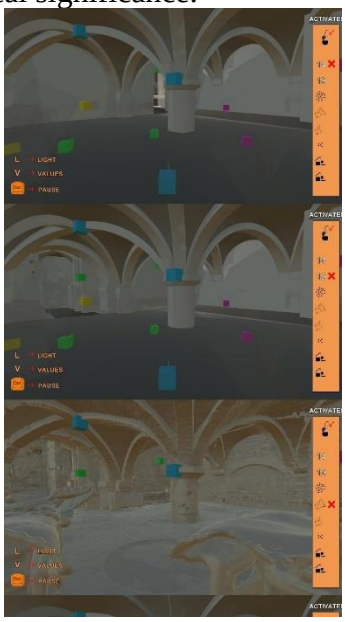

Figure (6): Shows the spatio-temporal changes over timeSource: (Jouan et al , 2022)

5.3. Case study 3: Basilica of Santa Croce, Italy

Figure (7): The main façade of the basilicaSource: (Bagnolo et al, 2021)

Case study overview and purposes:

The case study focuses on a basilica located in the Castello neighborhood of Cagliari, built in the 16th century by Giovanni Tristani's students, Giandomenico da Verdina and Giovanni Maria Bernardoni. The complex consists of two buildings connected by an overpass and separated by a portico. It was expanded in the 18th century by architect Antonio Felice De Vincenti, who added a two-level atrium with ten cross vaults supported by columns. Today, the complex serves as one of the seats for the University of Cagliari's Faculty of Engineering and Architecture.

The aim of the case study was to create a virtual tour prototype that could showcase the cultural heritage of the basilica, using the HBIM methodology and game engines. By using informative models that could be easily translated into development software, geometry and important datalike materials and lighting could be maintained. Additionally, the game engine allowed for interactivity, enabling players to access additional information about objects within the tour. It was important to accurately recreate the architecture, providing multiple perspectives and materialanalysis, without excessive hyper-modeling. A level of synthesis was necessary based on a critical analysis of architectural features. (Bagnolo et al, 2021)

Adopted workflow:

The game has two main components: Scan-to-BIM for model generation and tour development. The survey was conducted using laser scanning technology and the point cloud was cleaned up on Autodesk ReCap to provide a model that could be loaded into Revit for modeling. Different modeling techniques were used for different elements, with simpler ones modeled using specific families and more complex ones using Revit's predefined tools. Extremely complicated geometrical elements were synthesized to create recognizable representations. Unity was chosen for game development because of its simplicity and ability to directly export FBX format from Revit. The game is controlled with standard FPS video game controls and starts with a guide screen listing all tour commands. The game's design emphasizes exploring the architectural modeland interacting with its components to disseminate information. (Ibid)

Communicated types of information

The game conveys mainly factual information related to the architectural surroundings. The game focuses on both architectural and artistic features such as ceilings, columns, doors, walls, and baroque ornaments. The HBIM model provides a realistic spatial experience of the building's actual dimensions. The game also includes technical and material images that offer scientific factswith each interaction. These features can be further developed to communicate spatiotemporal changes of historic buildings in future editions. However, it should be noted that this case study isbased primarily on tangible elements and does not consider intangible dimensions such as historicevents or social contexts. (Ibid)

Engagement process

The incorporation of a basic movement system transforms the model into a space that the user can explore. In addition, because Unity's collision management is preconfigured, the user is free to take additional actions beyond simple walking, such as climbing or descending steps, jumping, or even "falling" from elevated parts, which helps to increase immersion in the environment. The finding of new knowledge through engaging with the architectural features or furniture in the scene also promotes exploration and, in a way, rewards it. Moreover, the game allows the users to discover artistic features in the building such as: baroque ornaments and ceilings. In addition, this game corresponds with the personality of the scientist users who are interested to learn new things through observation and research. It provides them with simplified scientific information on some aspects of architectural conservation mechanism for example: degradation of architectural elements due to incorrect restoration projects. (Ibid).No target age group is mentioned in this case. However according to the discussed gameplay, it canbe deduced that it is more suitable for young people than children. The game is tailored for educational purposes. It offers the opportunity to get more technical information about the historicbuildings. Most of the communicated information in the game is based on layers of simplified technical and scientific facts about architectural conservation in general and the studied historic building in specific. Such information can be beneficial and memorable for some users, especially the interested ones or the experts (Ibid)

Gamification elements and mechanics:

According to the octalysis framework, this game leverages two core drives: Development & Accomplishment, and Unpredictability & Curiosity. The game's collectables, which increase cultural awareness, motivate players to progress further and unlock more areas of the historical building, thus fulfilling the Development & Accomplishment core drive. The game also caters to the Unpredictability & Curiosity core drive, with its free movement option that allows players to explore the building in unpredictable ways. This feature mimics commercial first-person shooter games and provides a personalized way for players to unlock the game, rather than following a traditional linear progress. Overall, these core drives help make the game engaging and motivating for players to continue playing and exploring the historical building.

5.4. Case study 4: The Church of Nostra Signora della Speranza, Italy

Figure (9): Interior view of church point cloud. Source: (Argiolas et al , 2022)

Case study overview and purposes:

The historical church located in the Castello district of Cagliari, Italy, is a prime example of Gothic architecture. Its architrave portal is a distinguishing feature that is adorned with the Aymerich family coat of arms, which adds to the church's historical significance. The portal's intricate design includes ornamental reliefs and carvings that depict religious motifs and figures, such as Madonna and Child. Inside, the church features a single-bay nave and six chapels. The ceiling design incorporates ribbed

half-vaults and a cross vault, which creates a unique and stunning visual effect. The vaults are decorated with intricate frescoes and motifs that depict religious themes, such as angels, saints, and biblical scenes.The church's architecture also features a variety of arches and columns that support the weight of the structure. These elements are not only functional but also serve as decorative features that enhance the church's overall aesthetic appeal. Additionally, the church's use of natural light through its stained glass windows further highlights the intricate details of the architecture. (Argiolas et al, 2022).

Adopted workflow:

To begin the workflow, the first step is to gather architectural data for analysis. Spatial data is primarily obtained through architectural and urban surveys, while historical data iscollected from governmental and private archives. The Scan-to-BIM process starts by creating point clouds using either laser scanning or photogrammetry. Although these methods can be seen as alternatives, laser scanning offers higher accuracy and quicker capture times, while photogrammetry is more cost-effective and user-friendly.

Communicated types of information

The game is focused on a historical church and presents architectural and historical information in the form of multiple-choice quizzes, reordering puzzles, traditional jigsawpuzzles, and rotating-tile puzzles. The difficulty of the puzzles increases as the game progresses. (Ibid)

Engagement process

This case study is built solely on exploring the church’s interior, which has been virtually devoid of furniture and simplified in some areas. The user can interact with the environment with curiosity to gradually uncover each of theprovided objects and architectural details.Young people between the ages of 10-15 were determined to be the target age group as they are the most likely to benefit from thesuggested experience. This decision was made as it was thought that the specified study themes might be too precise for users below this threshold, whereas older users already possess the interpretive abilities necessary to effectively use more conventional educational resources such as: websites, books, and pamphlets (Ibid).The case study uses four different types of puzzles based on the architectural and historic features of the studied church. It is noted that several researchers highlighted that puzzles have positive impact on the user brain and its neural functions related to memory. Working on a puzzle strengthens the connections between brain cells, boosts mental agility, and improves short-term memory. Additionally, solving puzzles boosts dopamine production, which controls mood, memory, and focus. Every time a user solves a puzzle successfully, dopamine is produced. Puzzles can enhance logical, visual, and spatial reasoning if they are practiced frequently. (Ibid)

Gamification elements and mechanics:

The game focuses on two core drives: Development & Accomplishment, and Empowerment of Creativity & Feedback. The game challenges players with historical puzzles that become increasingly difficult as the game progresses, while also providing small details that encourage players to interact with the environment. However, players cannot provide feedback or impressions on the information presented in the game. The game also caters to the core drive of Unpredictability & Curiosity, as players explore thevirtual environment of the historical building and interact with various artifacts to obtainadditional information. This keeps players engaged and intrigued, always learning new aspects of the game and the building itself. Overall, the game provides a unique opportunity to experience and learn about the historical cathedral in a virtual and interactive way.

6. DISCUSSION

The four case studies incorporated various types of information, including factual and tacit information, to engage users in learning about cultural heritage. However, the usabilityof the games differed, and some were more user-friendly than others. The games also targeted different age groups. When using the Octalysis framework of gamification, core drives 3, 5, and 7 were commonly employed, while core drives 1, 4, 6, and 8 were underutilized.

Table 1: Overview of the comparative analysis for the four selected sites

Game Data			Communicated information								Engagement				Gamification core drives							
			Factual OR PLICIT				Tacit															
Case	Main purpose	Workflow (HBIM)	Architectural	Artistic	Spatial	Scientific facts	Events	Intangible context	Social context	Character	USABILITY	CURIOSITY	AGE	MEMORABILITY	Cored drive 1	Cored drive 2	Cored drive 3	Cored drive 4	Cored drive 5	Cored drive 6	Cored drive 7	Cored drive 8
1	Virtual Tourism	Laser scan+ togramm.+ Unreal engine	■		■	■	■				UX	E/S	N/A	Spati o			■		■		■	
2	Raise Awareness	Laser scan+ togramm.+ Unity 3D	■				■	■	■		UX	E/S	N/A				■		■		■	
3	EDU-TAINMENT	Laser scan+ Unity 3D	■		■	■					INTE R.	E	10-15	N/A			■		■		■	
4	EDU-TAINMENT	Laser scan+ Unity 3D	■			■					DGB	E	10-15	Puzzles		■	■				■	

Aspect	Santa Maria della Pace	Cloister of Saint-Jean	Basilica of Santa Croce	Church of Nostra Signora della eranza
Location	Italy	Belgium	Italy	Italy
Architectural Style	Renaissance	Gothic	Gothic	Baroque
Year of construction	1482-1483	13th century	1294	1630-1660
Building Function	Religious Complex	Church	Basilica	Church
Architect	Antonio da Sangallo the unger	Unknown	Arnolfo di Cambio	Cosimo Fanzago
Building Materials	Brick, Stone, Marble	Stone, Brick	Marble, Stone	Marble
Notable Features	Dome, Portico, Cloister	Cloister, stained glass	Frescoes, tombs, chapels	Frescoes, stucco decorations
BIM Tools Used	Revit, AutoCAD	ArchiCAD, BIMx	Revit, AutoCAD	SketchUp, AutoCAD
Gamification chniques	Virtual tours, quizzes, gmented reality	Puzzle games, quizzes, tual tours	Virtual tours, quizzes, gmented reality	Escape rooms, quizzes, treasure nts
Target Audience	General public, students, chitects	General public, students, chitects	General public, students, chitects	General public, students, chitects

The above table summarizes the four studied cases according to the mentioned parameters. This section is dedicated to the analysis, comparison and add some notes to the already implemented cases. These notes will be the primary steps towards the creation ofthe GHBIM guidelines (explained later in chapter 5).It is worth mentioning that the four case studies main purposes are comparable and similar to some extent. Edutainment, training, and virtual tourism were the most common themes among the studied cases. Regarding the HBIM use in the game, both case study (1) and (2) used both laser scan tools and photogrammetry for the scan toBIM process while case study (3) and (4) was based totally on laser scanning. For the game development, case studies 2,3,4 used unity 3D as their main game engine while case study 1 used the unreal engine. which is a popular real-time 3D creation platform. It provides a suite of tools and technologies for creating high-quality interactive experiences

across various platforms such as video games, virtual reality (VR), augmented reality (AR), architectural visualizations, simulations, and more.Communicated information through the games varied between factual and tacit information. Factual information including: Architectural, spatial and scientific facts were the most used, spatiotemporal changes were used as the main theme in case s (2) and (3) as it is the most suitable tool to communicate ideas for non-experts especially when the historic building layers of history are complex and interconnected, whereas tacit information such as social and intangible dimensions of the historic case studies were used seldomly used as the state of conservation reports of case study (1) and (2).In terms of usability, case study 1 used a user-friendly interface that classifies the provided mini games according to the user types. Whereas case study 2 allowed the users to interpret the values of the historic building according to their value judgement, two navigation modes were applied: the first-person perspective and the free navigation. Case study 3 had a limited amount of user interactions. However, it provides theuser with the spatiotemporal experience for the studied historic building. Finally, the last case study used the dynamic game balancing (DGB) technique with 4 types of puzzles games that get harder in difficulty with the advance of the user progress.

Two types of curious users (The Explorer and The Scientist) were given the whole attention of the studied cases while the other two types (The Inventor, and the artist) were not considered at all. Future developments can use some selected aspects and values of the historic building to evoke all four types of curious personality andencourage them to participate actively in the gaming experience. Regarding the age limits of the game, it is deduced that both case studies 1 and 2 are open for various types of users with no age-related differences while the other two casestudies are oriented mainly to young people between the ages of 10 and 15 with some sections that can be used by older target groups. On Memorability section, both case studies 1 and 2 used the spatiotemporal changes of the historic building as a tool for igniting memories of the user's, whereas case study 3 lacks memorable items as it was based mainly on dry technical information and scientificfacts for educational and academic purposes. Finally, case study 4 utilized different formations of puzzles to boost the short-term spatial memory of the users. The Octalysis framework was used to analyze the gamification of the four case studies focused on historical buildings. Core drives 3, 5, and 7 were the most frequently used, with core drive 7 being used in all four cases due to the exploratory nature of the virtualenvironment. Core drive 2 was only used in one case, as it incorporated various puzzle formats to incentivize users. The researcher suggests that future GHBIM experiments should utilize previously unused core drives, such as core drive 1 to create a sense of responsibility to protect the building and core drive 4 for users interested in recreating historical environments. While core drives 6 and 8 are not directly related to cultural heritage, they could be adapted by game designers to fit the heritage context.

7. CONCLUSION

The four case studies examined in this research all aim to use gamification as a tool toeducate people about cultural heritage. They used different techniques and game engines to communicate the significance of historic buildings to users, such as spatiotemporal changes, laser scan tools, and photogrammetry.Based on the analysis of the four case studies, the paper concludes that G-HBIM can be an important tool for educating people about architectural cultural heritage, as well as for the restoration and disaster recovery of historic buildings. In terms of education, G-HBIM can replace the traditional “dry” and abstract approach to teaching history to more engaging and interactive learning experience, which can be beneficial for people of all ages and expertise levels. It can also be used for virtual tourism, allowing people to explore historic buildings that may not be physically accessible. For restoration and disaster recovery, G-HBIM can provide an accurate representation of the building's structure and can be used to plan and execute restoration projects. In the event of a disaster, HBIM can be used to assess the damage to the building and assist in planning the necessary repairs.

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