Gamification in Architecture: The Future Interface in Design as an Incentive to Participatory Democracy

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Abstract: The research illustrates an innovative approach to urban planning by using a collaborative digital platform that encourages involvement and interaction between citizens, technicians and administrators. Leveraging the proposed digital platform, the citizen becomes a promoter of urban renewal, triggering processes of inclusion, participation and civic engagement. The study focuses on the use of BIM (Building Information Modeling) as a base model that becomes the setting for a desktop gaming platform: it determines a virtual three-dimensional (3D) interactive environment, based on a desktop application, for the training of citizens and their collaboration for the creation of new design ideas, as well as for proposals for the refunctionalization of existing buildings. In this way, the ultimate user becomes itself designer, creator of an intervention, thinking about spaces and hypothesizing different functions. It is thus strengthened the role of active participation of citizens and governance of the territory of the P.A., which becomes a subject able to manage contributions of different nature, with a view to co-design and co-production of services. Furthermore, the successful integration of HBIM (Heritage Building Information Modeling) and the application opens the way to new applications of involvement, learning and interactive training, which require a detailed and reality-based built environment as a context in which to act.

1 INTRODUCTION

The diffusion of ICT among households, which has increased in recent years, appears to be held back by the persistence of material and immaterial factors of exclusion, demonstrating how there is often no correspondence between the digital opportunities offered and actual use(Yun, 2023). While in the creation of knowledge and its application and diffusion many of the monitored indicators show improvements, in Italy it seems that the overall participation of citizens remains at a relatively low level and, in general, the objectives of eParticipation are not fully achieved, continuing to lag behind the average of E.U. countries. Among ICT applications, eGovernment represents an opportunity to increase public administration efficiency and improve relations with citizens(Casillo, Cecere, Colace, Lorusso, et al., 2024). Technology takes on extraordinary potential, becoming an enabling tool for the construction of policies and practices of social inclusion and development, in line with the principle of user-centeredness recalled in the European and national guidelines for the development of ICT in Public Administration (objectives of the Three-Year Plan, based on the indications emerging from the new

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European programming 2021-2027, on the principles of the eGovernment Action Plan 2016-2020 and on the actions provided by the Tallinn eGovernment Declaration (2017-2021), whose indicators measure the level of digitization throughout the E.U.). The idea of "shared administration" involves the interaction of various actors and collaboration between institutions and citizens. In this context, the role of public communication becomes crucial, both as a tool to promote listening to citizens and solicit new ideas and proposals, and as a way to raise awareness of the value of the resources belonging to the community and the importance of citizen participation in its realization.

To overcome participation problems, many governments have turned to social media and social networking tools, with three potential communication strategies: representation, citizen engagement and networking with the public. The networking approach emphasizes a dialogue, while engagement invites co-production of content without necessarily involving contributors in the dialogue(Battista & Uva, 2023). Several initiatives have led to the creation of eParticipation platforms, enabling digital participation online via ICT technologies. Various examples in recent years have demonstrated the potential of digital technologies to facilitate social inclusion and urban regeneration processes. Through collaborative digital platforms, we have gone from simple sharing of information between citizens and P.A. to the birth of co-design processes of services, up to forms of self-organization. These include Easy Vocal System (Evs), i.e. tools for vocal navigation of sites, to make the portals of public administrations more accessible and usable; Public Participation Gis (Ppgis), i.e. tools that use methods such as Gis (Geographic Information Systems) technology for participative decision making; Knowledge Management tools to collect, organize and distribute knowledge to those who need it, at the time and in the context in which it is required; decision support solutions. The use of collaborative digital platforms in the perspective of a shared administration has already experimented in the case of the Miramp project in Turin (Kang et al., 2022), born in the wake of a pilot experience, Crowdmapping Mirafiori Sud, whose main purpose was to determine whether the use of ICT, in particular the method of participatory mapping (crowdmap), could generate and support processes of social inclusion (Sethi, 2017). Even though these solutions have been introduced, citizen participation remains at a low level, so eParticipation objectives have not been fully met. One of the main reasons identified, why initiatives to date have not achieved sufficient participation, is the problem of the digital divide and social exclusion (Sethi, 2017). Local governments mostly stick to representation, applying "push strategies" to provide one-way information. There is a substantial immaturity of web strategies, which are not modulated on citizens' empowerment needs. Few studies investigate real interaction with stakeholders, especially through the experience of quieter voices, recognized as a key advantage in online crowdsourcing approaches in participatory design, and even fewer focus on how content type influences user engagement(Brabham, 2009). Governments have not yet been able to effectively use data inferred from social media as crowdsourcing tools, replace traditional data collection, rigger funding mechanisms, particularly in "bottom-up" initiatives, and new forms of citizen-led urban regeneration (Seltzer & Mahmoudi, 2013; Stiver et al., 2015). The present research aims to explore this potential critically.

To engage citizens and encourage digital learning, there are several examples of learning based on 3D gaming environments, often web-based to overcome problems with hardware devices available to individuals, widely recognized for their value in learning and training (Cook et al., 2012; González & Blanco, 2008). In the area of Engineering and Architecture, some studies rely on the use of 3D design technology such as Google Sketchup or Building Information Modeling (BIM) and different applications of ICT for the dissemination of cultural heritage (Casillo et al., 2023; Edwards et al., 2015; Sylaiou & Papaioannou, 2019; Tommasi, 2021; Wojciechowski et al., 2004). However, the outstanding challenge remains in building a realistic and detailed large-scale setting in the 3D game engine. This is dictated by limitations due to most 3D game engines, not being designed to create architectural buildings with complex shapes and rich detail, and by interoperability issues between various 3D design software and traditional game engines(Casillo et al., 2022). Today, these limitations are overcome thanks to advances in data interoperability in BIM modeling software and the new development of Web3D technology: thus, the conditions are in place to import an existing 3D design, and hence a Heritage Building Information Modeling (HBIM), to create a complex and realistic building environment for an immersive virtual experience(Casillo, Colace, Gaeta, Lorusso, et al., 2024; Chen et al., 2017; Guida et al., 2021; Matos et al., 2022). Despite the development of BIM applications, the use of the three-dimensional model to create 3D interactive computer games is still an

unexplored field. Existing research on BIM-based computer games is based on the application of stand-alone games to be installed on the user's computer, although an approach that leverages Web browsers is preferred to allow greater inclusion and sharing.

2 LITERATURE REVIEW

In a span of four decades, video games have not only surpassed but also outperformed traditional forms of mass media, such as television and film, emerging as the preferred vehicle for delivering immersive experiences(Casillo, Cecere, Colace, Lombardi, et al., 2024; Della Greca et al., 2024). Parallel to the expansion of the video game market, a growing interest has emerged in the potential use of these tools as educational media. The market for serious games, valued at $2.5 billion in 2015, has more than doubled by 2020, indicating a growth trend that portends further development in the future (Shipley & Utz, 2012). This significant increase in the market testifies to the growing interest of the entire industry in this mode of learning, suggesting a shift in the educational approach.

In the analysis conducted by the authors (Pasqualotto et al., 2023), the "challenges" related to the use of video games as educational tools are highlighted. The need to design serious games capable not only of arousing players' initial interest in the subject matter, but also of maintaining that interest over time, thus ensuring effective learning, is emphasized. In addition, the importance of engaging gameplay, closely related to the educational content, is reiterated in order to prevent the game experience from becoming monotonous, while at the same time being able to effectively convey the acquired notions outside the playful environment. Designing an engaging and motivating serious game requires in-depth knowledge of the topics covered, pedagogy and game design dynamics, often involving synergistic collaboration between experts from different disciplines (Lazarinis et al., 2022). The main difficulties in implementing a serious game relate primarily to the combination and balance between the playful elements and the educational content. Scholars in the field suggest that this integration can take place through two distinct approaches: an endogenous approach, which incorporates the educational content into the structure and rules of the game, making the gameplay itself a learning tool; and an exogenous approach, which involves a separation between educational content and gameplay, indicating that the game simply serves as a vehicle for the transmission of the topics (Roumana et al., 2022).

The entire body of literature on the topics of "serious gaming" and "gamification" is unambiguous in emphasizing the need to develop new ways of transmitting information and acquiring skills, making them more interactive and engaging. Unlike traditional learning environments, serious games place the emphasis on the learner, whether used in formal education or in more specific contexts such as vocational training, military training or situations where real simulations are impractical due to time or logistical issues. In addition, a working group presented a game app developed in Unity using 3D models of a Greek temple and a Roman statue. It shows that learning about cultural heritage through gaming, especially in Virtual Reality, is more engaging and realistic than traditional methods. The application has potential for educational use in various contexts and can be expanded with other digital assets (Lazarinis et al., 2022).

In particular, serious games applied to cultural heritage preservation stand out for their crucial role in promoting interest in historic monuments and sites. In a context in which these assets are threatened by various factors, such as natural disasters, aging, climate change, and urban development, it has become a priority international goal to preserve interest in these places not only among those who hold decision-making responsibilities at the territorial level, but especially among new generations, who are destined to inherit these assets. Community involvement, particularly of young people, can be fostered through 3D technologies and, in particular, games based on virtual or augmented reality. Augmented reality, by facilitating a special interaction between user and environment, emerges as a particularly effective tool for narrating not only the physical environment, but also the intangible heritage of a place (Cantone et al., 2023).

An illustrative case study concerns the creation of a serious game using virtual reality and Global Positioning System (GPS), based on the concept of a "treasure hunt," designed to explore the Archaeological Park of Pompeii (Clarizia et al., 2022). In this game, users are guided to explore the actual site to locate points of interest (POIs) and discover its historical anecdotes and key features. The game's educational-oriented design involved experts in the field in selecting routes and identifying the most relevant POIs, incorporating short descriptions within the game to effectively convey key information about the visited site.

Of course, the choice of the most suitable game interface depends on the specific objectives and target audience. In one specific example (Petridis et al., 2021), the authors developed a web app rather than a serious game, designed as an inexpensive and easily customizable alternative for teachers. Through this web interface, teachers can upload a background image, which serves as the main game area, and identify on it a series of points of interest (POIs) associated with text descriptions, photographs, video clips, external links, questions, and quizzes. Defining these POIs and adding related material allows teachers to set scores for various activities and set a minimum score to pass the tests. A practical example illustrated in the article concerns the ancient Greek city of Amphipolis, in which the graphical interface recalls elements of ancient Greece, the cursor is represented by Pegasus, and pop-ups with ancient philosophers present the teaching materials uploaded by teachers for each POI. Students, after acquiring the necessary knowledge, must answer questions, each associated with a different score based on difficulty; having reached the minimum required score, they receive a virtual certificate of completion.

The "Smarter Household" project implemented an energy monitoring system in 19 social houses in the United Kingdom by connecting users to tablet devices. A serious game was used to raise residents' awareness of energy consumption and promote efficient behaviors. Preliminary results show the potential benefit of participants applying the lessons from the game to their daily activities.

A particular case of a serious game focused on cultural heritage preservation is the game "Architectural Jewels of Lublin," presented in a specific article . This game combines physical and digital space in an intriguing way, incorporating advanced computer technologies. It is a board game enriched with computer elements, developed to promote the history of the city of Lublin and increase players' knowledge of architectural monuments. In the course of the game, two players compete by placing 3D printed models of the monuments on the Old Town map, answering questions about the city's history. The educational goal is pursued through the correct placement of objects on the board, which trigger educational questions or provide detailed descriptions in case of error. A study conducted on a sample of 98 students showed that those who participated in the game achieved an average level of knowledge 80 percent higher than students not involved. The project, "Gaming & Geography," focuses incece on integrating video games into geography teaching by proposing a reflective analysis model to facilitate the educational incorporation of video games, demonstrating that students actively participate in virtual geographic contexts and reflect on them. The researchers support the use of the model, pointing to a significant contribution to considering video games as legitimate geographic tools (Morawski & Wolff-Seidel, 2023).

Finally, the integration of gamification into the sustainable design course at Chulalongkorn University in Thailand explores how during a three-year period, nine eco-game projects were tested, revealing improved environmental and design learning. However, effectiveness is affected by the complexity of the game rules, the length of the testing period and the students' concentration. The article suggests that although gamification promotes playful and design learning, further research is needed for full systemic integration and to promote pro-environmental behavior change. In addition to introducing new educational approaches, serious games are emerging as useful tools for stimulating active citizen participation in decision-making processes, especially in complex urban issues. These games offer political representatives and urban planners the opportunity to use innovative tools to illustrate complex urban issues, facilitate participation, and overcome power and trust barriers between different stakeholders (Ampatzidou et al., 2018). Due to their unquestionable application potential, serious games can make citizens participants in the decision-making process and involved in shaping the interventions themselves.

In summary, reviewing the existing literature, it is clear that digital technologies, with a particular reference to serious games, are a valuable support for triggering processes of confrontation and growth in a variety of contexts.

3 THE FRAMEWORK OF THE PLATFORM

The need to encourage the involvement of all groups of citizens in the interventions of re-functionalization and enhancement of the built abandoned heritage has led to the birth of a new interactive platform. The goal is to promote social inclusion through the training of the citizen who, with his ideas, enters into the design of the spaces of which he will be the final user. Digital technologies significantly increase the access and availability of participation. The platform is designed to reach as many stakeholders as possible and involve different citizens. The analysis of data from the Italian

National Institute of Statistics (ISTAT) on the relationship between citizens and ICT shows how the use of the Internet is growing strongly: young people are confirmed as the most frequent users of the web, but the spread is beginning to be significant also among those aged 65-74, reaching 41.9%. Nevertheless, it remains evident that 41.6% of users have low digital skills. The European Parliament and the European Council identify e-skills as one of the eight key competencies for lifelong learning, necessary for each citizen to succeed in the social environment . To maximize social inclusion and avoid the digital divide, the architecture of the proposed solution foresees the involvement of different social categories, avoiding limitations and discrimination in contributing to the initiative, whether it refers to the availability of technology, their education or their resources. The platform will be developed and optimized for different devices to overcome the first barrier and thus include younger citizens who do not own a P.C. The online channels will work favorably towards the young, educated and "technologically qualified" sector of the population. With a clean and immediately understandable interface, the platform includes online surveys and social media frameworks such as a discussion forum and commentary function. The result is a communication tool that is no longer unidirectional but rather bidirectional, providing a wide-ranging communication between citizens and decision-makers, obtaining a correct, unlimited and not a fragmented flow of information (Rose & Sæbø, 2010). Users are rewarded through a score; each user will reward one idea, determining a ranking based on the most popular projects.

The framework has been implemented as a Desktop application, on an experimental basis, using the development tools offered by the Oculus and Unity 3D environments. It was therefore modeled a three-dimensional environment in which users could move freely. As for the method of interaction with the virtual world, it was chosen to use a controller based on real-time hand tracking. The movements of hands and fingers are recognized by special sensors present on Oculus visors to interact with the virtual world. BIM modeling is inserted into the virtual environment as a container where users can make their design choices. In addition, libraries of 3D objects are prepared with which users can interact directly through Hand Tracking controllers, offering the possibility to position objects within the space freely. Two main categories of users are part of the system: expert users, who have the task of updating and enriching the library of object families, both standard and ad-hoc created for the specific intended use; simple users, on the other hand, interact with the virtual environment by making changes and customizations. An external forum platform allows all types of users to discuss design ideas. Any feedback from the discussions will be given to expert users who can then make changes to the design.

Therefore, the objective of this architecture is to offer an integrated collaborative environment able to put users in communication with the P.A. to develop a project idea based on the real needs of the user who will become the final user. It was also developed an integration with the main social platforms to allow a rapid sharing and dissemination of ideas and content. To promote social inclusion and eliminate the digital divide, the desktop application, with a user-friendly interface to ensure clarity and ease of use regardless of the level of education and personal skills, is directly integrated with other social media for immediate sharing of published projects. It has been studied how the immediacy and simplicity of the interfaces of social networking platforms, such as Facebook and Instagram, has allowed people to integrate these sites into their daily practices, showing a significant contribution to public life (Kleinhans et al., 2015; Rodríguez-Domínguez et al., 2011) both in providing online information and for a better dialogue with citizens. The application provides an online help section at the start to illustrate functionality and how to insert one's contributions. There are then three successive levels of interaction:

3.1 Choice of Function

In this first level, it is possible to estimate between the alternatives of new functions pre-viewed for the recovery of public spaces, which held optimal from the customer. To carry out a pondered choice, selecting every possible function, a popup is opened that allows to visualize an interactive map dialoguing with the GIS (Geographic Information System) platform, updated real-time, that helps to individualize the location of such acts-activities on the territory examined, with a ray of investigation up to 10 Km. Confirmed the choice, the percentage of consents for every available option will be visualized. In addition to the hypothesized functions, there is the option of free choice to suggest further functional proposals that will be launched and, if necessary, validated by officials of the P.A. designated to pronounce on the suggested proposals.

3.2 Table and Figures

The gamification section of architecture was set up to involve a large segment of users to eliminate the existing barriers between technical designers and citizen end-users. Several previous studies, examining both the history and possible future scenarios of architectural design, showed that the latter would likely incorporate the interactivity achieved by gaming. Computers had brought about a new way of visualizing designs, allowing them to be viewed at different scales and with considerable precision, but resulting in model presentations that were just as "static" as those previously available. This is because they did not allow for the kinds of interactions with viewers provided by video games (Meder et al., 2017). Thus, the concept of playfulness in architectural design was born. According to Pennington and Perlberg (SIGGRAPH 2014), this takeover was based in part on the observation that the boundaries between design and game technology were becoming increasingly blurred, which was similar to the blurring of boundaries between cinema and games, a trend that has only increased, to achieve freedom and interactivity. Another boon of playfulness and interactive design is portability. Design ideas can be easily transferred between portable devices with interactive design tools, no longer locked in a desktop computer. Portability enables real-world freedom. Thus, an immersion in a virtual reality develops, where the user can immerse himself in a virtual, reality-based architecture, where the design of a space will be fully realized and "experienced" virtually before the intervention is even realized. The design possibilities are endless, from the insertion of surfaces and objects to the choice of materials. Through the gamification of architecture, the user becomes a designer to improve a given project's usability, livability and longevity.

3.3 Forum

Finally, there is a space for reports, divided into three macro-categories: Criticalities, suggestions and promotions of positive initiatives to enhance the site. This space will also allow the opening of honest discussions to activate the involvement of the various stakeholders.

4 CASE STUDY

The Cultural heritage can be an essential element to base intercultural and interdisciplinary dialogue with citizens. One of the ways to initiate such actions is through participatory planning, which involves the target audience from the earliest stages of a given project. After more than fifty years of experimentation, the themes of industrial archaeology are still an unexplored field of research, increasingly linked to the strategic management of territories. The redevelopment of abandoned sites is a significant aspect of current urban policies. In this perspective, this research is framed, which intends to involve the citizens of the municipality of Battipaglia (S.A.), Italy, urging them to become protagonists and designers of an example of industrial archaeology, the former tobacco factory Farina. The complex of the former tobacco factory Farina, founded in 1920 under the direction of SAIS, Società Agricola Industriale Salernitana, is now owned by the City of Battipaglia, a town known for being one of the most productive agricultural areas of the Sele Valley, of which it is also the main industrial center.

Today the tobacco factory, indicated as a building identity, both for its size and location, requires a particularly complex and challenging reuse project. The complex is a disused building shown as an emergency, which characterizes the landscape and the identity of *Battipagliese*. Its favorable position and unquestionable historical-architectural interest make it a potential "cultural container" flexible to new productive destinations. It is necessary to imagine a wide range of possible functions as far as uses are concerned. However, the potential effects of some functions in terms of increased demand for mobility and especially for parking must be carefully evaluated. Today the complex is composed of rectangular blocks aligned and parallel to the road. The neglect and abandonment have devastating effects, turning memory elements into rubble. In the process of administrative innovation undertaken by the public administration, the increasing space given to the participation of citizens in decision-making processes has improved the quality of administrative action, allowing a better understanding of the context and the consequences of the various possible alternatives.

With this aim, the platform was born, totally web-based, developed on three levels: "Choice of a function", where the user can decide between different possible functions, based on an analysis of related activities on the territory, easily identifiable through an interactive map based on GIS information updated in real-time; "Create your project", where the user becomes a designer, and finally the section "Forum", to activate collaboration and debate. Among the possible functions for the former tobacco factory, at the moment, the functions of Library, Fair Pole,

Market and Film Set have been hypothesized. The interactive map helps the user to orientate and to make well-considered choices according to the different needs. Among the proposed functions, 37% of the users opted for the Fair Pole to promote a regeneration process of the complex and the surrounding urban context, focusing on enhancing and promoting local products, preserving the heritage of biodiversity, as well as the local agricultural products. An innovative aspect is covered by the section that allows the user to create his project, immersing himself in a three-dimensional context in which to move. Through a Scan-to-Bim procedure (Figure 1), starting from an integrated survey through a synergic approach of aerophotogrammetry methods and Simultaneous Localization And Mapping (SLAM), an accurate three-dimensional model has been generated, corresponding to a Level of Accuracy 20 (LOA20).

Figure 1: The 3D point cloud to the BIM model is achieved by importing the point cloud in .rcp format into Autodesk Revit 2021 software.

This model, created using Autodesk Revit software, was exported in the .FBX format and imported into the Unity3D game engine, which through the .FBX file format allows importing geometric properties, textures and other materials from BIM models. For the development of the game, in addition to the model of the complex, other 3D objects were also loaded into the platform to be imported into the 3D environment as objects, again in .FBX format. Thus,

Figure 2: Demo application.

Figure 3: 3D online game environment. On the left, the building is obtained through the HBIM model import. On the right, two design proposals are created by users through the insertion of furniture elements imported by users and appropriately positioned in the scene.

an online 3D game platform is generated, using the HBIM model of the tobacco factory to create an online interactive 3D training environment, in which the citizen takes on the role of an architectural designer, proposing interventions and creating real spaces within the reality-based container model. The goal was to create a virtual environment easily customizable in every aspect, to encourage the training and creativity of the individual user. The various elements can be imported and positioned in the scene, with the double possibility of placing through coordinates (X, Y, Z) or directly through "Drag and Drop" (Figure 2). The various imported elements can be scaled and modified through the properties menu. The project, once completed, can be shared (Figure 3).

Finally, the "Forum" section allows you to make reports, filtered by a back-office system for the management of reports consistent with the administrative workflow and quality standards required of the P.A. In this way, consultation and informed participation become tools available to users to lead to policies that better understand the community's needs and increase support and trust in public institutions and their actions. Among the problems reported, the most numerous involve interventions that would lend themselves well to the activation of participatory processes with a modest budget: the presence of architectural barriers and the presence of multiple abandoned or disused areas. Among the positive realities, on the other hand, the presence of areas used for the primary school located near the site, large areas used for parking that meet the needs of the inhabitants and the various initiatives

developed before the pandemic in some of the blocks used for recreational use were reported.

5 RESULTS AND VALIDATION

The case study's game environment underwent a series of qualitative and quantitative verifications. In fact, non-expert users tested the virtual environment, not only to verify the effectiveness of the proposed product and its various design proposals, but also to assess the overall value of this type of proposal. The validation phase consists of two distinct moments: the first involves analyzing the results of the architectural choices within the model to understand the proposal for re-functionalizing the environment under study. Subsequently, a second phase assesses the user's experience, aiming to gather feedback and enhance the product from the user's viewpoint. Thus, 34 users were involved, who are part of the neighborhood of the building under study, in order to gather development evaluations of the neighborhood from those who live in the neighborhood every day. From the initial phase of the study, it became clear that the proposal for a covered market area received the most suggestions, as illustrated in figure 3. In fact, 27 out of 34 users returned a setup within the virtual environment that took into account various sales points located within the tobacco factory, while only 5 out of 34 users proposed the setup of a library and study area. Lastly, the remaining users suggested the establishment of a restaurant, reception area, and coworking space. Subsequently, questionnaires were administered to the same users to verify the effectiveness of the proposed game tool in order to improve its appearance, functions, and purposes. The initial part of the questionnaire aims to characterize the user for statistical purposes. Below are the questionnaire some responses appropriately collected and grouped for better visualization. (Figure 4, 5 and 6).

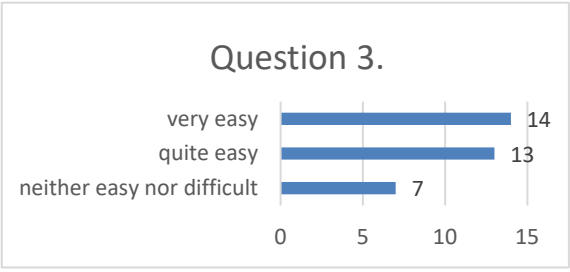

Figure 4: How easy was the interaction with the platform?

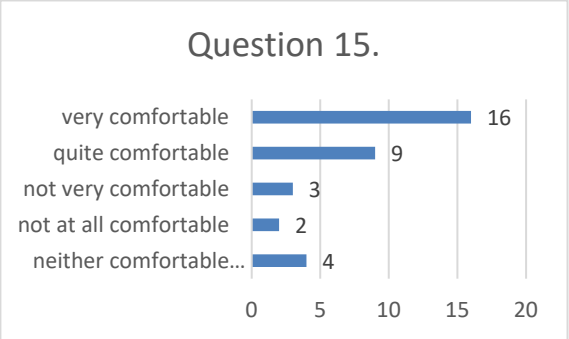

Figure 5: How comfortable did you feel using the virtual reality environment?

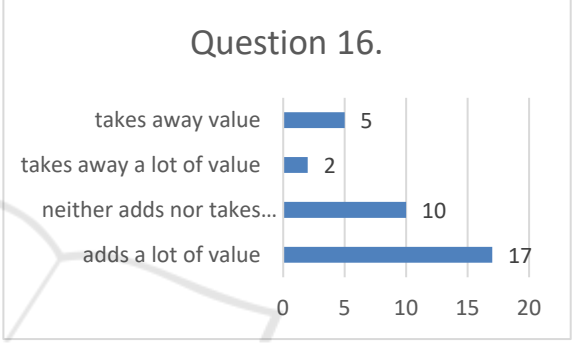

Figure 6: Do you think virtual reality adds value to the process of democratic participation?

6 CONCLUSIONS

The experience shows how digital technologies are valid support to activate confrontation mechanisms that can feed and foster the development of an administration open to dialogue, triggering processes of inclusion, participation and civic engagement. Moreover, the network allows citizens to become familiar with the P.A. initiatives, eliminating the barrier between decision-makers and users, enhancing the new systems of listening and user involvement in the perspective of building a renewed urban governance. The interactive three-dimensional (3D) virtual environment of the Tobacco Factory, based on a desktop application, allows evaluating how HBIM and gaming technology have now reached a level of development that enables the creation of virtual environments for learning and user interaction, overcoming the limitations due to data interoperability in the transition from BIM model to Unity3D game engine. The integration of BIM modeling with desktop viewers proves to be an effective solution for all applications that require a sufficiently accurate built environment as a context.

By selecting the ap-propriate game engine and BIM authoring tools, we created an immersive 3D BIM learning environment.

In the future, it is planned to expand the prototype realized on a Web platform, in particular by making use of the new WebXR Device API standard. The transition to a Web-based application would allow the creation of a platform accessible to a much wider audience and thus break down the barriers mentioned earlier. This kind of technology would basically allow anyone with a smartphone to access the virtual environment and actively participate in developing a project idea.

Implementing this environment prototype using HBIM modeling to create a virtual game environment has great potential in the AEC domain. For example, a future perspective may be using proven Web 3D technology to aid in training workers on construction sites regarding safety measures. A further line of development could concern the restoration sector, allowing to act on the three-dimensional virtual reality obtained starting from an ABIM (Archaeological Building Information Modeling) model and operate interventions on the model without directly affecting the physical structure.

In the future of cultural heritage, extensive growth is expected in the application of gamification and the metaverse to engage audiences in innovative and educational ways. A key area of development involves the use of immersive experiences through augmented reality (AR) and virtual reality (VR), allowing visitors to explore historical or artistic environments interactively. Metaverses offer the opportunity to create digital versions of museums, archaeological sites and historical places, making it possible to take virtual tours, interact with objects and learn in immersive ways. Interactive narrative becomes a popular form of engagement, allowing visitors to take on roles in historical scenarios, make decisions and influence the development of the story. Educational role-playing games are another important aspect, allowing players to immerse themselves in specific historical eras and face challenges related to the historical context. Gamification systems that offer incentives and rewards, both virtual and physical, motivate visitors to actively participate and continue to interact with cultural content. Global collaboration becomes possible through gamification and metaverse projects that involve participants from all over the world, facilitating the sharing of cultural knowledge and different perspectives. Artificial intelligence personalizes experiences based on visitor preferences, ensuring optimized engagement. Blockchain technology finds application in guaranteeing the authenticity of digital cultural assets and managing the ownership of works of art, creating a safe and reliable environment for enthusiasts and collectors. Furthermore, the integration of sustainability principles in gamification and metaverse pro-jects promotes eco-friendly practices and raises awareness towards the conservation of cultural and environmental heritage. These innovations represent just some of the potential ahead, underscoring how gamification and the metaverse will continue to transform how we interact with our cultural heritage.

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