Heritage Education for Primary Age Through an Immersive Serious Game

A. Luigini and A. Basso

Abstract Heritage education is an activity that is increasingly present in the educational paths of schools and museums. Cognitive mechanisms and representative devices must be thoroughly analysed and designed in order to promote the creation of didactic paths to foster effective learning experiences. Immersive visualization technologies are well suited for gamification applications and the technological and economic accessibility of VR HMD (head-mounted display) viewers makes these technologies particularly attractive for the development of potentially more widespread methodologies. The present contribution will describe an educational path, and its related experimentation, on the cultural heritage about the production of the typical bread of the Val Pusteria area—and the rural life around it. The project was aimed at primary school children and was based on a serious game in Virtual Immersive Reality.

1 Introduction

In 2018, around 55 million people visited the Mibac museums,[1] an increase of about 10% as compared to the previous year. As Mibac Museums General Director Antonio Lampis stated, "*Few areas are growing by 5% these days. [....] I always remember that in museums the real result to aim for is not to sell tickets, but to be able to offer, as the rules say, real experiences of knowledge*". The goal was to offer effective experiences of knowledge to visitors to museums, exhibitions and any other area in

[1]Data available on the website of the Ministry of Cultural Heritage and Cultural Activties, at the following link: http://www.beniculturali.it/mibac/multimedia/MiBAC/documents/1550245833146_2018_Musei_Tavola6_al_13-02-19.xls.

A. Luigini (✉) · A. Basso
Faculty of Education, Free University of Bozen, Bolzano, Italy
e-mail: alessandro.luigini@unibz.it

A. Basso
e-mail: alessandro.basso@unibz.it

C. Bolognesi and D. Villa (eds.), *From Building Information Modelling to Mixed Reality*, Springer Tracts in Civil Engineering,
https://doi.org/10.1007/978-3-030-49278-6_10

Fig. 1 Equirectangular panoramic views and perspectives of some interiors related to the serious game levels. Rendering software used, Octane Render by Otoy

which you can be exposed to cultural heritage. Not entertainment, not only the cult of the past, but experiences that leave an indelible mark on visitors. This is the goal that we wanted to translate from the museum environment to bring it to schools.

How can an effective experience of knowledge be built to pursue such goal? In order to suggest a methodology, it would be necessary to refer to theories of a general nature and then to decline them in the case of our interest (Fig. 1).

In the psychological field, Jerome Bruner (1956) reminded us that our thought is continuously poised between a logical-scientific dimension and a narrative dimension, where the latter refers to a deep, primordial need of our civilization to build meaning for the manifestations observable throughout life, or, in short, to interpret reality. If *logical-scientific* thinking provides clarity and organizes knowledge, narrative thinking investigates the polysemic value of knowledge and the experience of knowledge. In this indeterminate certainty, it allows individuals to find their own role within the narrative. About fifty years after the formulation of the first theories on narrative thinking, Bruner further deepened his studies underlining how two dimensions of narrative thinking are fundamental: the first is the "narrative creation of the self" as a fundamental component of the construction of a subjective dimension of identity, and the second is the interpretative dimension, which allows us to overcome the limits of given solutions. (Bruner 2002). Many other studies have developed individual aspects or entire theories of narrative thought, especially in the field of psycho-pedagogical sciences. Later literature (Egan 1986; Toolan 2001; Norris et al. 2005; Avraamidou and Osborne 2009) on the structuring of narratives useful for educational processes, have inspired some choices in the design of the Serious Game in the present work.

Among other theorizations, the seven components to build a story, proposed by Norris et al. (2005)—Event-tokens, Narrator, *Narrative appetite*, Past time, Structure, Agency, Purpose and Reader—seem to highlight important factors to be taken into account in the design of an educational path. In particular, the concept of *narrative appetite* (Norris et al. 2005 p. 541), that is, the ability of a narrative to feed the desire to discover what will happen and how the story will end, is indeed really important when creating a very concrete experience of knowledge, as the one build in our proposal.

In an essay on the cornerstone of digital techno-culture, Giuseppe Longo (1998) offers us a gnoseological reflection, underlining the diametrically opposed nature between two profiles of knowledge construction that our civilization has developed over time: the first, of an archaic profile, in which "knowledge [is] *tacit*, global and immediate, implemented by the body and embodied in its structure and its biological functions […] guided by the affective and emotional system", and a second one, "more recent from an evolutionary point of view, […] *explicit* knowledge, implemented in the forms of abstract logic and in general in rationality. (Longo 1998, p. 58). This new counterpoint between the emotional dimension and the rational dimension confirms how the dichotomy of the elaboration of our experiences at the psychological level necessarily requires a planning of museum experiences, or more generally educational, with an equally dichotomous approach (Luigini 2019b).

It is evident how is important, in this process of development that we are moving towards the realization of an effective cognitive experience, to focus on the user all these design cares that we are anticipating: in fact, we have applied a User Centred Design methodology.

2 Serious_Game@Brixen

The use of digital technologies for art and heritage education is a key research topic (Champion 2016; John et al. 2017; Luigini and Panciroli 2018; Challenor and Ma 2019, Luigini 2019a; Hu et al. 2019). In particular, the use of serious games seems to be increasingly widespread in the context of Digital Heritage (Ioannides et al. 2017; Basso 2019).

The VAR.HEE. project on Virtual and Augmented Reality for Heritage Education in school and museum Experience, funded by the ——, is developed in the period 2018–2021 and aims to use advanced representation and visualization technologies for the design and implementation of educational heritage education courses dedicated to both primary schools and exhibition contexts, such as museums or temporary exhibitions, and experienced in an immersive and participatory environment. One of the most important criteria that we have given ourselves was the widespread replicability of the paths, so we decided to use technologies available and commercially accessible (three-dimensional modelers and low profile visualization software and

Fig. 2 Pano2VR interface for interactive virtual tour editing. Attic level scenario

digital stereoscope like Oculus Rift) to an audience averagely literate from the point of view of computer technology (Fig. 2).

The project is developed by an interdisciplinary team coordinated by architect and digital representation scholar and in which other disciplines participate: cognitive psychology and pedagogy from the ———, as well as the partnership of scholars from the universities Alma Mater Studiorum University of Bologna, University of Camerino and University of L'Aquila.

The project during the first year was developed with regard to the design of the educational paths. The didactical path was completed from January to April 2019, while the assessment was executed from 28th to 30th of May of the same year. The didactic paths have been developed together with the teachers who have joined the experimentation. To maximize the pedagogical value of the didactic path, it has been preferred to build the activities starting from the didactic planning already foreseen for the school year 2018–19. The choice, agreed with teachers and school managers, fell on a didactic path on the water cycle and its sustainable use, which needed a complementary design to allow integration with a process of heritage education.

3 Bread and Its Tradition as a Cultural Heritage

The role of cultural heritage in primary education is increasingly important (Branchesi 2006; van Boxtel et al. 2016). Both in the academic field and in the daily practice of teachers, cultural heritage enters every day into the educational process at primary age and often transforms its overall dynamics.

After the raccomandation No. R (98) 5 of the Committee of Ministers to Member States concerning Heritage Education of 1998, which underlines the role of heritage education, it was in 2005 that the Faro Convention of the Council of Europe Framework Convention on the Value of Cultural Heritage for Society, to which Italy adheres only in 2013, which acknowledges the universal value of heritage education. In 2015, the General Direction for Education and Research of the MIBACT Ministry of Cultural Heritage and Activities and Tourism issues the fundamental Circular n.27/2018 DG-ER Piano Nazionale per l'Educazione al Patrimonio Culturale 2018–2019.

The cultural heritage speaks of our history and the civilization that has produced the present society, and for this reason it is a macro-theme that potentially affects every area of knowledge.

In the project described here, the cultural heritage is represented by all the natural raw materials, the knowledge that allows us to produce and transform them, the traditional culture that revolves around the traditional bread of the Puster Valley, such as, for example, the traditional farms and the tools of rural life. In this project, as it should be in any heritage education project, there is no rhetoric to regret the "time that no longer exists", but the awareness that handing down cultural heritage is a way to build identities, to know our origins and think about our future.

The didactic activity started with a visit to the Südtiroler Landesmuseum für Volkskunde in Teodone (BZ), where the children followed a path already organized by the museum staff, on the rural tradition and the preparation of the bread in Val Pusteria. The visits of the two classes participating in the experimentation, was before the testing of our educational paths in VR of at least 2 months.

4 Look, Move, Learn

From the point of view of methodological approach, the implementation of the serious game has required in-depth reflection and the search for innovative solutions from the procedural point of view but accessible from the technological and economic side.

First of all, we must consider that the target group were children of the 2nd and 4th years of primary school (about 7–8 years the first and 9–10 years the second), with their own cognitive structure, their own time of adaptation and their own collaborative mode. In order to adapt the device to the children, the theory of cognitive load, which explains some mechanisms capable of facilitating learning, has been taken into account from the earliest stages. In particular, the *redundancy* of textual information was avoided, capable of becoming dispersive beyond a certain threshold, favouring visual information; the whole serious game was set up with a *sequencing* process and the "*tasks*" required of the child were broken down and then reaggregated into small groups (*chunking*) and presented in modular units with the same internal sequential structure.

As a result of these evaluations, it was decided to organize several observation points, in other words "visual stations", for each environment: the first series dedicated to the observation of the environment itself, without further stimuli, and only the last following the activation of the "play" button—for the solution of the puzzles. This sequencing of the internal structure—and its decomposition—made it possible for the children-players to maintain their concentration when necessary and to be free to explore the visual space, when possible.

The Serious Game is developed in seven successive environments, which lead children to visit a farm from the outside and from the fields of wheat, through the kitchen, the bedroom, the living room (*Stube*), the barn and the roof, and then come back to the outside at the outdoor oven.

Each environment has at least two points of view: the first, dedicated to observation, and the second, dedicated to the gameplay. The reasons for such a distinction lie in the need to reduce the potential distraction generated by the need to explore during the game: in digital environments—immersive but also non-immersive—each user is naturally led to explore the space (by motor or visual means) to understand its characteristics and to build relationships between their body and the environment. Thus, the first point of view—dedicated only to visual exploration—becomes the moment when the user enters into contact with the digital environment and, for subsequent thresholds of detail, pays attention to ever more detailed information. In this way, probably, the activity to be carried out in the second point of view—the proper game—can enjoy more attention and "represent" more consistently the knowledge and skills of the player.

Once you have reached the point of view containing the game, the latter needs to be activated by a hidden button—under the feet—and visible only in the case of the passage of the pointer. This attention was necessary to avoid unintentional activations that in beta testing were numerous.

When the game was activated, the players had to demonstrate knowledge and skills acquired during the visit to the Folksmuseum in Teodone by means of quizzes or by means of predetermined activities (such as the correct selection of ingredients needed to knead rye bread).

The transition to the next environment is determined by the correctness of the quiz solution. Thus, constituting the phase of the dichotomous structure of Norris et al. (2005, p. 542).

In every environment the players were able to visually explore the rural life, in analogy with what happened during the visit to the Museum of Teodone: environments, materials, furniture, furnishings and landscape have been reconstructed through a philological study concerning the heritage of the South Tyrolean traditional farms.

The conclusion of the game is, as already mentioned, an external scenario, in which the teacher of the class—previously taken up with the technique of the green screen and inserted in post-production in the HDR 360—which summarizes some of the contents of the path, acting as a "pedagogical condenser" of the path itself: this expedient is fundamental to close the construction of the narrative path, to satisfy the narrative appetite enunciated by Norris et al. (2005, p. 541).

Particular attention was required by the vision system, both in relation to maintaining the balance of the cognitive load and for the limitation or cancellation of the effects of kinetosis or cybersickness (Al Zayer et al. 2020; Rossi and Olivieri 2019; Basso et al. 2019). More and more cases are observed of people who, during or after the use of digital stereoscopic viewers, show symptoms such as nausea, dizziness, headaches, increased sweating. Psychological and physiological sciences have been studying the phenomenon for a long time. (Reason and Brand 1975; Treisman 1977; Riccio and Stoffregen 1991), also because the onset of these symptoms is also observable in other situations, not only if subjected to a digital stereoscopic vision, such as during travel by car, train and plane or for astronauts during space flights.

Especially for children aged 2–12 years, who seem to be the subjects who most easily present these symptoms (Reason and Brand 1975), attention to the smallest detail is important to reduce or eliminate the manifestation of these symptoms.

The three main theories that have tried to explain the onset of motion sickness, progenitor of the more specific cyber sickness, are *the theory of sensory conflicts* (Reason and Brand 1975), the *Treisman's evolutionary theory* (1977) and *the theory of postural instability* (Riccio and Stoffregen 1991).

In a nutshell, the theory of sensory conflicts focuses on the discrepancy that occurs in the ocularvestibular system when our visual system and our balance system provide contrasting stimuli, causing discomfort that manifests itself with the symptoms described above.

Treisman's evolutionary theory explains motion sickness as a disturbance caused by mobility systems that conflict with the evolutionary parable of our species, which probably would need a slower adaptation to transport systems such as the car, the train or visualization systems such as digital binoculars. Another possibility that is explained in evolutionary terms is that one of the first symptoms of the intake of poisonous substances is sensory alteration, and that therefore nausea is a mechanism of selfdefence of the organism that feels attacked by a "poison".

The *theory of postural instability*, however, tells us that our organism is programmed to maintain the stability of its posture in relation to the environment in which it is located, and in the case of VR the change—sudden or not—of the surrounding environment, may produce cybersickness.

The design responses that we have elaborated foresee the reduction or cancellation of the risks listed above through some specific settings of the representation device. First of all, we have chosen to limit the interaction of the player to the visual system, choosing to realize the serious game starting from 360° static images—rendered starting from digital models—and using a *teleportation locomotion system* similar to what happens, for example, in the Google Street view system, probably already known and therefore "familiar" to the recipients of the project. Walking-based systems would probably have required greater *body involvement* of children, and in the case of locomotion managed by touchpad controllers, an increased risk of discrepancy between visual and motor stimuli.

To move from one point to another, activate game phases and interact with the quizzes, it was therefore preferred to adopt a "point and click" system that can be activated both with a pointer sensitive to the movements of the VR viewer and with the touchpad controller (but only for students of the 4th year). This choice has allowed users to reduce adaptation times to an extremely low threshold and has allowed them to enter the game in an almost natural way.

The approach is not unprecedented (Argyriou et al. 2017) but the plus-value of this work is the continuity of the research path that starts from the pedagogical project, continues with the design of the game and the architectural environments, then with the engineering and the constitution of the device of representation and then ends with the experimentation and the collection—with the subsequent analysis—of experimental data.

5 Construction Phases to Support an Interactive Reconfiguration of Spaces for the Serious Games

In the case study in question, the operations of three-dimensional reconfiguration focus on the diffusion of cultural heritage through graphic-digital models derived from reconstructive hypotheses and documentary investigations on some historical structures characteristic of South Tyrol, the Masi, pursuing the project of editing a serious game (SG) that would stimulate a young user to interest in topics related to history and local culture.

This new method of cultural dissemination is part of the wider field of Visual Tecnoculture (Gigante 1993) and Interactive Design, where the theories on *Digital Cloning and Digital Crafting for Virtual Migration* (Basso 2016) are explored as tools of contemporary communication, hypothesizing different stages of development in support of a digital reconfiguration of spaces aimed at an experience of virtual reality for education through emotional-cognitive perception (Argelaguet et al. 2016).

These operations require technical and methodological complexities that cannot be separated from digital survey methodologies, obtained through integrated methods, such as photo modelling or data acquisition through the laser scanner. In the procedures of digitization of real spaces, the study of historical data, photographic documentation and previous manual surveys carried out on the physical and cultural context contribute to develop an overall vision aimed at defining physical, plastic and chromatic characteristics that can enrich the experience of knowledge of the object detected. In addition to self-modelling processes, manual modelling can be used to create props[2] in order to improve the exploratory-immersive experience within interactive platforms compatible with HMD (head-mounted display) optical displays, where excellent care is required for the visual details (McLellan 2001).

In relation to execution time and budget, the methodological and operational procedure has therefore provided for the experimental use of different modelling software, Polygonal and NURBS, and compositing tools, useful to semantically divide the digital elements for transfer to interactive exploration platforms, together

[2] Objects—3d scene models designed to recreate the atmosphere of digital explorable environments.

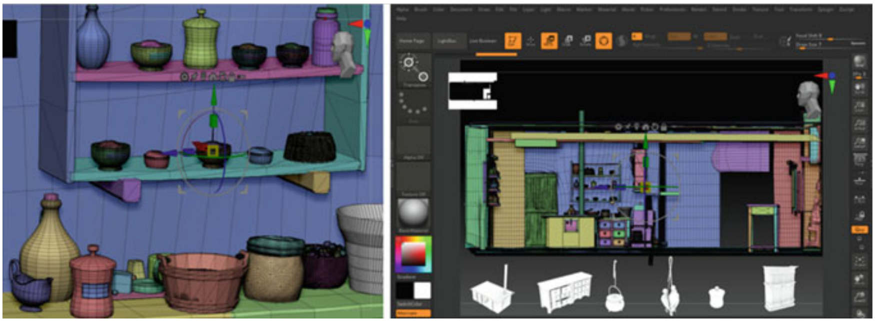

Fig. 3 Automatic retopology, sculptural detailing and texturing added within Pixologic Zbrush

with rendering tools and mesh optimization tools aimed at generating visual detail during the immersive experience.

We choose to follow a workflow aimed at obtaining 3D models suitable for virtual transfer to RTR Unreal Engine 4.24 platform and at the same time suitable for the use of these assets 3d on other compositing software such as Cinema4d+Otoy Octane Render with the aim of generating 2d equirectangular images compatible with Pano2VR to simulate three-dimensional environments for editing interactive virtual tours VR[3] adaptable with active optical viewers—in the case study was used the solid Oculus Rift system.

In this regard, it was essential to follow specific measures for the optimization of three-dimensional assets in order to make the 3d elements involved in the project light in terms of digital weight without sacrificing the apparent formal complexity and therefore the visual quality of the same.

The executive pipeline includes a series of procedures that bring this particular methodology closer to that used in the editing of new generation video games, where graphics and lightness are essential to make the 3D assets exploitable on interactive platforms such as Unreal Engine, born as a platform for the creation of video games and now used in cultural operations and scientific design programs (Fig. 3).

6 Digital Cloning Procedures

The reconfiguration of complex environments has assumed, in order to obtain a realistic metric formal restitution, the simultaneous use of two reconstructive approaches: a first method related to a correct definition of the spatiality and proportions between the various compositional elements of the architectures, regarding the perception of the magnitudes of the volumes of the scene—these characteristics can be drawn

[3]The system provides for the experimental use of multiple platforms linked together within an active exploration in virtual space: is developing the ability to switch from a gaming mode from Unreal Egnine space to a virtual tour 360 exploration aimed at educational insights.

from an in-depth analysis of three-dimensional data obtainable only through procedures of digital survey—and a second method of manual modeling aimed at the specification of the various 3d assets based on the study of drawings, videos and historical photographs, with the aim of obtaining an aspect linked to the "sentimental" perception of the reconfigured environments, involving the use of the chromatic component, the morphology of the small objects and the identifying plastic details, always keeping in mind the structure of the game, with any paths, collision factors and combinations with the elements involved in the VR experience (Gershenfeld 2012; Steuer 1992).

The case study then developed two synchronic paths for the digital survey:

- Photo modelling from photo data set acquired in real sample environments (some typical farms were chosen)
- Manual Modelling from interpretation of historical images of indoor environments.

Agisoft Metashape and Meshroom are the photomodelling software used for the reconstruction of the point cloud and the mesh model that has returned the real environments surveyed to scale. A single Maso model was not used, but 3d digital information was used to understand the exact functional division of the environments and how the rooms were structured and the arrangement of the furniture. From these data, new typological models were then drawn, capable of tracing the same characteristics.

On a practical level, the workflow adopted was based on the semantic decomposition of elements by similarity of the material or through other criteria of subdivision. The simple procedure allowed a series of uninterrupted steps: the digitized models were developed in particular using Rhinoceros 3d and M.O.I 3d, as far as the modeling of macro structural elements related to the architectures is concerned, while for the props, i.e. furniture and furnishing assets, it was preferred to use some polygonal modeling functions of Maxon's Cinema 4d, software able to offer alternative tools for the creation and correction of the meshes.

C4d offers many advantages aimed at a correct transfer to other interactive platforms, such as TwinMotion, recently acquired by the EpicGames team, or Unreal Engine. It is a good idea not to change the spatial coordinates setting of the pivot associated with the models so as not to compromise the phase of exchange between the various programs used, despite today Unreal has simplified the procedure of sharing 3d resources through the use of the DataSmith plug-in. A possible phase of UV mapping and projection of the hd photographic textures on the model is delegated to Pixologic Zbrush, a famous digital sculpting software used in cinema and graphics. This software is able to manage millions of polygons at the same time and offers many useful tools to improve detail but it is essential for the automatic retopology of the exportable model (Fig. 4).

The topology obtained through autogenerative triangulation algorithms, during the transition from NURBS modeling programs to polygonal composers (export/meshing phase), can lead to the creation of an excessive number of polygons, in terms of weight byte, to be compatible with an RTR of the type of Unreal,

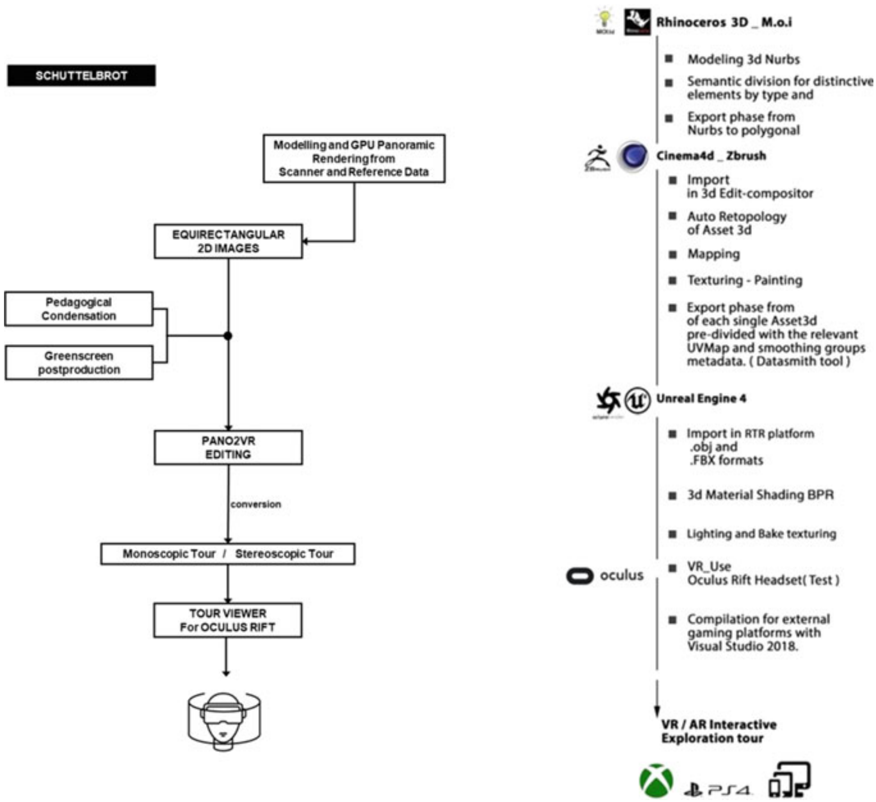

Fig. 4 Graphic scheme synthesis of the serious game development workflow

also generating multiple visual artifacts in the calculation of light maps and in the correct attribution of normal polygons.

An automatic retopology procedure (plug-in Z-Remesher) is therefore necessary, a usually very complex phase that can be completed with good results through different automatic methods within the Pixologic software, exploiting functions related to the management of Voxel algorithms and polygonal subdivision that have allowed a balanced optimization of 3D assets, texturing and the relative creation of UV Map corresponding to the new mesh generated, always distinguishing the structural and solid parts from the different decorative parts, and merging the assets associated to the material shaders with the same characteristics. To generate detail in order to make every 3d asset introduced in the serious game scenario more credible we have chosen to use Pixologic Zbrush again.

The software has recently introduced in its latest release some specific tools to add sculptural detail in a direct and flexible way using external 3d models or previous sculpting interventions made on the 3d object. The HistoryRecall brush offers the possibility to capture the depth position of carved details of a model using the Undo

History timeline, and then project those details onto a completely different model using brush strokes. The very useful thing is that HistoryRecall does not require models to have the same topology or the same number of vertices. It serves to redesign the details of the sculpture between models and to project the details of the sculpture by hand rather than through the Project All options, which is the methodology still in use today to project the detail between 3d objects. HistoryRecall allows you to take the position of a model in 3D space and store it in the Undo History slider.

After the position is stored, you can take the *History Recall brush* and ap-ply the stored status to another mesh, projecting the details to the other model. If both models do not match and overlap in the same 3D space, the projection will be faulty. This feature requires both model surfaces to be matching and overlapping in 3D space for a successful projection.

Once the 3d objects are obtained with the new topological mesh quod, it is possible to increase the levels of subdivision in non-destructive way, thus maintaining the lower polygonal levels. This feature will allow us to generate depth maps, from the normal map to the Bump maps, Displacement or Vector Displacement maps, a ploy to simulate a hd detail on a low-density polygonal model that works well in interactive software. Returning to Cinema4D, the compositing program, through a bridge system (GoZ), prepares the model for the next export phase to Unreal Engine, distinguishing the hierarchical order of the elements according to semantic criteria, defining the assets to be considered in the project as instance cloning object and building the draft of a game level then to be completed on the real time rendering platform. Cinema4d also allowed to generate 360HDR Panoramics in Equirectangular format, using the advanced Octane Render rendering engine that implements the fast Nvidia GPU unbiased calculation to offer an excellent photorealistic quality of the lighting.

The Virtual tour, compiled on Pano3VR using 360 panoramas generated with Octane, is an alternative simplified game path for unfamiliar users to a full immersive exploration of the digitized environments. The simplified Serious Game has used equirectangular images to simulate environments that can be explored in 3d from a single point of view across the various gaming sessions, the playing structure is based on simple multiple-choice questions and cognitive mini-games in which specific elements of the scenario must be selected in order to proceed with the tour. Right or wrong answers are identified through invisible buttons that follow linear input-output systems (Virvou and Katsionis 2008).

Depending on the answers, seven scenarios are explored plus the final scenario in which it is possible to acquire, in a simple and fast way, a lot of information on the local cultural heritage, on the traditional rural life and notions about typical places in South Tyrol, such as the Masi.

7 Game Design Procedures and Interactive Structuring

Unreal Engine 4.24, used in the complex development of the levels, has been selected for its excellent quality of interactive real-time visualization and for the simplicity of managing the algorithms of animation and management of input-output actions through the “Blueprint” system. Blueprints is the visual scripting system within Unreal Engine 4 and is the fastest way to develop a prototype game. Instead of having to write code line by line, you can configure input and output actions through a visual interface: drag and drop nodes, set their properties in a GUI (Graphical User Interface) and drag node links to connect. This design method is a complete scripting system based on the concept of using node editors to create game elements within Unreal Editor. As with many common scripting languages, it is used to define classes or object-oriented objects (OO) in the engine. When using UE4, you often find that objects defined using Blueprint methods are in the common language called only “Blueprint”.

This system is extremely flexible and powerful as it provides designers with the ability to use virtually the entire range of concepts and tools generally available only to programmers. In addition, the specific Blueprint markup available in the C++ implementation of Unreal Engine allows programmers to create basic systems that can be extended by designers to other compatible platforms.

The software is able to easily offer an excellent fluidity of the exploration not secondary aspect of the experience because in the VR simulation it is appropriate to have a frame rate ranging from 30 fps up to 60/80 fps, to avoid disorientation and cyber sickness.

The management of simulated lighting effects and the physically correct rendering of materials has been done directly within Unreal: the impartial BPR shaders not only use Normal and Bump maps to return to the optimized model the detail of the original high-resolution polygonal model, but correctly simulate the behavior of real materials, such as translucency or opacity, while the effects of light and shadow are imprinted directly on the textures, through a procedure called Texture Baking/Lightmap. This method allows to economize the calculation of the gpu related to the simulation of global illumination made only once and automatically imprinted on the texture maps, when compiling the environment can be explored without excessive effort by the graphics card even on platforms with less performing computing power.

With the introduction of the new Nvidia RTX graphics cards it is expected that Light map methodologies will become obsolete because Path Tracing calculations will be done in real time in the future. Today this procedure is already possible but not yet applicable in scenes of great structural complexity, because the denoise system that eliminates light artifacts noise and the visual update on screen during photon simulation is still too slow and not accurate for indoor scenes. In the case study we have therefore relied on the solid method of texture baking.

For both versions of the game the implementation of the Oculus Rift, on VR Tour-viewer support, has allowed a good synchronization with the movements of the head and a correct positioning of the optical cone, thanks to its sophisticated gyroscopes and motion sensors, allowing a good virtual identification (Metz 2015). Joining the Unreal/Tour-viewer+Oculus system is a fundamental resource in terms of communicability of visual information, storytelling but also, at a macro level, in terms of the focus of interest for the conservation and enhancement of the Heritage (Bennett

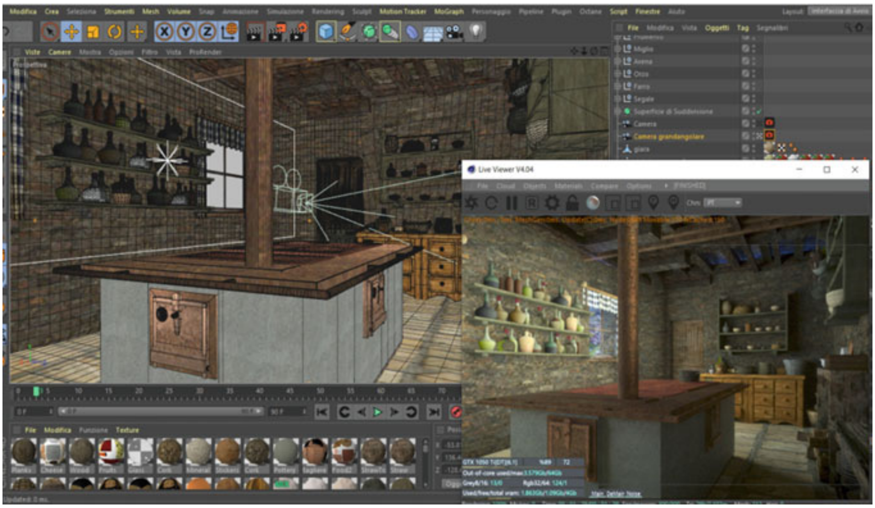

Fig. 5 Cinema4d interface as level compositor, external rendering engine used Octane Render by Otoy for photorealistic light output

et al. 2008). The choice to edit a serious game in three-dimensional environment compatible with the VR experience, is the repository of a complex conceptual value, reasonably aimed at implementing a reference system, ideal in the assumptions, concrete in the solutions and holistic in the objectives, which is a valid alternative to the canonical teaching systems (Schuemie 1999) (Fig. 5).

8 Methods

8.1 Participants

The sample included 15 students attending the second year (7-8-year-old) and 21 students attending the fourth year (9-10-year-old) of the primary school "——", located in ————. They were all checked, before participation, in order to exclude severe diseases. All of them had had normal or corrected-to-normal vision. Informed consent for their participation was obtained from their parents and from the Principal of their School.

8.2 Materials and Procedure

The reduction of adaptation times and the naturalness in engaging the game, as described in the previous paragraphs also in relation to the system of participation in the game, was very effective: the participation, in fact, was organized into several groups of 7 children, one of which was called “*operator*”—who wore the VR viewer—and the other 6 were called “*observers*”—who participated watching the projection and movements of the operator in the virtual environment on a large screen—.

Each environment was explored and activated by the operator, while the observers could interact at certain times and could help the operator in case of uncertainties or difficulties in the quizzes. At the end of the experience in one section of environment, the operator was replaced by another child in the group and joined the observers. The observations were structured in different forms: the first, during the whole experimentation, was a series of video footage with four cameras, two of which were arranged frontally and laterally to the operator’s position, one was arranged to frame the observer’s players and one at 360° to allow a synchronous relationship between the operator, the observers and what happened during the game in the virtual space. At the same time, a member of the research team recorded each event that was considered significant by the coordinators, so that the audio-video data could be more accurately analyzed.

Subsequently, three questionnaires were administered to the players. The first one was based on the standardized test sITQ_PQ for measuring the “presence” in virtual environments, proposed by Witmer and Singer (1998). It included 5 questions, evaluated through 5-levels Likert scales, and it was administered as soon as the operator phase was completed and before entering the *observer phase*. The second one was a test of approval of the experimentation, including other 5 rating questions on 5-levels Likert scale, which was administered at the end of the game by all members of the group. The third one, was aimed to assess the permanence of knowledge and skills acquired during the experiment and was administered at school after about a week from the VR experience and included a mixture of Likert-scale, closed and open questions, to investigate general evaluation of the VR experience and what has been learnt due to the VR experience.

9 Results

The reduction of adaptation times and the naturalness of engaging the game, also in relation to the system of participation in the game, was very effective: the participation, in fact, was organized into different groups of 7 children, one of which was called operator—who wore the VR viewer—and the other 6 were called observers—who participated by watching the projection of the operator’s movements on a large screen. Each environment was explored and activated by the operator, while the observers could interact at certain times and help the operator in case of uncertainties or difficulties in the quizzes. At the end of the experience in one environment the operator was replaced by another child in the group and joined the observers. In this way the experience was shared, no child felt uncomfortable feeling alone in a virtual space for a long time[4] and in fact—even judging by the results of the questionnaires after the experiment—they experienced the game more continuously.

The observations have been structured in different forms: the first, during the whole experimentation, is a series of video footage with four cameras, two of which are arranged frontally and laterally to the operator's position, one is arranged to frame the observer's players and one at 360° to allow a synchronous relationship between the operator's behavior, those of the observers and what was happening in the game. At the same time, a member of the research team recorded each event that was considered significant by the coordinators, so as to be able to analyse the audio-video data more accurately and directly access a specific "event". Subsequently, 3 questionnaires were submitted to the players: the first, based on the standardized test sITQ_PQ for measuring the "*presence*" in virtual environments, proposed by Witemer and Singer (1998) administered as soon as the operator phase was completed and before entering the observer phase, the second as a test of approval of the experimentation administered at the end of the game by all members of the group, and the third, to evaluate the permanent knowledge and skills acquired during the experiment, submitted at school after about a week.

In summary, the results of the analysis of the data collected—which are still under processing—allow us to argue that the level of adaptation and operation of children during the experiments, thanks to the design measures mentioned above, was excellent: 76.8% respond positively or very positively to questions about adaptation in immersive environments, 67.9% positively or very positively about the confidence with immersive environments, and 94.6% positively or very positively about the visual involvement of immersive environments.

The understanding of the value of the natural landscape and the correlations between the responsible use of water, also in the domestic environment or in daily actions, and the effects of these attentions on the global climate has been good and observable in most cases.

The acknowledgement of cultural heritage as a virtuous vision of humankind's relationship with water was satisfactory in many cases—more than 70% of the tests were fully satisfactory—but not in all cases: probably the playful aspect and the satisfaction of having passed a level of the game by responding positively, may have reduced the attention of some participants by limiting the potential scope of learning. These cases are undergoing further analysis in order to identify possible improvements in the gaming device and its presentation as a function of individual diversity.

[4]The exploration and solution of each level of the game required a time ranging between 6 and 10 min which, even in the absence of experimental data on it, can be considered an effective time frame to eliminate any risk of cyber sickness due to overexposure of children to VR.

In general, the experimentation has been very positive, showing how a careful design of educational paths to heritage education—natural and cultural—through immersive serious games, is an effective methodology to build an effective experience of knowledge.

References

I Piano Nazionale per l'Educazione al patrimonio culturale (2015–2016), available at the link: http://dger.beniculturali.it/wp-content/uploads/2019/05/Primo-piano-nazionale-educazione_2015-2016.pdf

II Piano Nazionale per l'Educazione al patrimonio culturale (2016–2017) available at the link: http://dger.beniculturali.it/wp-content/uploads/2019/05/Il-secondo-piano-nazionale-d_educazione-al-patrimonio-culturale-2016-2017.pdf

III Piano Nazionale per l'Educazione al patrimonio culturale (2018–2019), available at the link: http://dger.beniculturali.it/wp-content/uploads/2019/05/PNE_allegato.pdf

Argelaguet F, Trico M, Hoyet L, Lecuyer A (2016) The role of interaction in virtual embodiment: effects of the virtual hand representation. In: Proceeding of IEEE virtual reality conference. Greenville, South Carolina, USA, pp 3–10

Al Zayer M, MacNeilage P, Folmer E (2020) Virtual locomotion: a survey. IEEE Trans Vis Comput Graph 26(6):2315–2334. https://doi.org/10.1109/TVCG.2018.2887379

Argyriou L, Economou D, Bouki V (2017) 360-degree interactive video application for cultural heritage education. In: 3rd Annual international conference of the immersive learning research network. Coimbra, Portugal 29 Jun–26 Jul 2017 Verlag der Technischen Universität Graz. https://doi.org/10.3217/978-3-85125-530-0

Avraamidou L, Osborne J (2009) The role of narrative in communicating science. Int J Sci Edu 31(12):1683–1707. https://doi.org/10.1080/09500690802380695

Basso A (2016) Il Riuso virtuale degli edifici, rivivere il Reale con lo strumento digitale. In: Reuso Pavia 2016_Contributi per la documentazione, conservazione e recupero del patrimonio architettonico e per la tutela paesaggistica. Atti del convegno internazionale, a cura di S. Parrinello, D. Besana, EDIFIR edizioni, Firenze 2016, pp 182–187. ISBN 978-88-7970-8016-6

Basso A (2019) Serious game and 3D modelling for the immersive experience development in digital tale. In: Parrinello S (ed) Digital and documentation. Pavia University Press, Databases and Models for the enhancement of Heritage, Pavia

Basso D, Saracini C, Palladino P, Cottini M (2019) Travelling salesperson in an immersive Virtual Environment: Experimental evaluation of Tracking system device. Adv Intell Syst Comput 919:519–529

Branchesi L (ed) (2006) Il patrimonio Culturale e la sua pedagogia per l'Europa. Armando Editore

Bennett AL (2008) The potential and uniqueness of virtual environments for education. New horizons in adult education and human resource development 22(3):53–59

Bruner J (1956) A study of thinking, New York: Wiley, trad. it. (1969) Il pensiero. Strategie e categorie, Roma: Armando

Bruner J (2002) Making Stories. Law, literature, life, New York: farrar, strauss and giroux, trad. it. (2006) La fabbrica delle storie. Diritto, letteratura, vita, Roma-Bari: Editori Laterza

Challenor J, Ma M (2019) A review of augmented reality applications for history education and heritage visualisation. Multimodal Technol Interact 3:39

Champion E (2016) Critical gaming: interactive history and virtual heritage. Routledge, New York/London

Circolare n.27/2018 DG-ER Piano Nazionale per l'Educazione al Patrimonio Culturale 2018–2019

Gigante MA(1993) Virtual reality: definitions, history and applications. Virtual Real Syst 3–14. https://doi.org/10.1016/b978-0-12-227748-1.50009-3

Gershenfeld N (2012) How to make almost anything: the digital fabrication revolution. Foreign Aff 91:43

Hu X, Ng J, Lee JH (2019) VR creation experience in cultural heritage education: a preliminary exploration. Proc Assoc Inf Sci Technol 56:422–426. https://doi.org/10.1002/pra2.42

Ioannides M, Magnenat-Thalmann N, Papagiannakis G (eds) (2017) Mixed reality and gamification for cultural heritage. Springer International Publishing, Cham.

John D, Shaw L, Cheetham P, Manley H, Stone AA, Blakeburn M, Gosling K (2017) Educational virtual reality visualisations of heritage sites. In: Eurographics workshop on graphics and cultural heritage, pp 189–193

Longo GO (1998) Il Nuovo Golem. Come il computer cambia la nostra cultura. Roma-Bari: Editori Laterza.

Luigini A (ed) (2019a) Proceedings of the 1st international and interdisciplinary conference on digital environments for education, arts and heritage earth 2018, Springer, Cham

Luigini A (2019b) Digital bodies. Digital experience. Digital heritage. In: Parrinello S, digital and documentation. Databases and models for the enhancement of Heritage, Pavia University Press, Pavia

Luigini A, Panciroli C (eds) (2018) Ambienti digitali per l'educazione all'arte e al patrimonio. Milano, Franco Angeli

McLellan H (2001) Virtual reality. McLellan Wyatt Digital, New York

Metz R (2015) Inside the first VR theme park. Report MIT technology review. https://www.technologyreview.com/s/544096/inside-the-first-vr-theme-park/. Access 18 May 2017

Norris SP, Guilbert SM, Smith ML, Hakimelahi S, Phillips LM (2005) A theoretical framework for narrative explanation in science. Sci Ed 89(4):535–563. https://doi.org/10.1002/sce.20063

Raccomandation No. R (98) 5 of the committee of ministers to member states concerning heritage education del 1998

Reason JT, Brand JJ (1975) Motion sickness. Academic press, New York

Riccio Gary E, Stoffregen Thomas A (1991) An ecological theory of motion sickness and postural instability. Ecol Psychol 3(3):195–240

Rossi D, Olivieri A (2019) First person shot: interactive dynamic perspective in immersive virtual environments. In: Belardi P (ed) Reflections the art of drawing/ the drawing of art, Atti del 41 convegno dei docenti della rappresentazione, Perugia, sept 2019. Gangemi, Roma

Schuemie MJ, van der Mast CAPG (1999) Presence: interacting in virtual reality. In: Proceedings, twenty workshop on language technology, vol 15, pp 213–217

Steuer J (1992) Defining virtual reality: dimensions determining telepresence. J Commun 42(4):73–93

Toolan MJ (2001) Narrative: a critical linguistic introduction. Routledge, London

Treisman M (1977) Motion sickness: an evolutionary hypothesis. Science 29:493–495

Van Boxtel C, Grever M, Klein S (eds) (2016) Sensitive pasts. questioning heritage in education (New York/Oxford: Berghahn, 2016, 294 pp., ill., isbn 978 1 78533 304 0 hardback, isbn 978 1 78533 305 7 ebook)

Virvou M, Katsionis G (2008) On the usability and likeability of virtual reality games for education: the case of VR-ENGAGE. Comput Edu 50(1):154–178

Witmer, Bob G, Singer, Michael J, (1998) Measuring presence in virtual environments: a presence questionnaire. Presence 7(3):225–240

Egan K (1986) Teaching as storytelling: an alternative approach to teaching and curriculum in the elementary school. London: Althouse Press.