

Experiences of knowledge transfer on industrial heritage using games, storytelling and new technologies: “A history of enterprises”

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ABSTRACT

The industry has a relevant spatial and socioeconomic importance in most of the Spanish cities and nowadays is one of the main urban economic activities. However, in many situations, and despite recent advances in the last two decades, industrial heritage is a value that is still not sufficiently widespread in society. The factories, their activity and their historical evolution are often disconnected and isolated from the daily life of the cities, being quite an unknown aspect for most of the citizens. This contribution presents the result of various experiences of knowledge transmission on the heritage value of industry, through the use of games and storytelling technique as an educational tool and the combination of different technologies (3D modelling, videomapping, virtual reality) as useful tools to spread the explanation of this phenomenon.

KEYWORDS

Industrial Heritage, virtual reality, games, storytelling

1 Approach and initial hypothesis. Urban history, factories and industrial heritage.

In many Spanish cities, industrial activity has significantly imprinted the urban structure over the last two centuries. Although the effects of the industrial revolution on urban areas came with a significant delay in comparison to what happened in other European countries, since the end of the 19th century factories have become key elements in understanding urban morphology [27,37]. Throughout the 20th century, in the different phases of the urbanization process, these facilities have undergone various processes. On one hand, initially some of them were integrated in the urban growth, maintaining their productive use; on the other hand, later, in many cases they have been dismantled and moved to the peripheries of the city, abounding in the segregation of the different urban uses; and, finally, some of them have not survived the process of urban transformation, ceasing their activity and being in many cases dismantled [7,8,13].

In all cases, these factories have preserved a significant piece of urban history and the collective memory of the cities, so their heritage value as testimonies of the social and economic evolution of the country is unquestionable. The concept of heritage in Spain (Law 16/1985 on Spanish Historical Heritage) has been used since the mid-1980s with approaches that in many cases are essentially based on historical and artistic considerations. In fact, the above-mentioned state regulations do not expressly include the consideration of industrial heritage, establishing a generic declaration that alludes to artistic, historical, paleontological, archaeological, ethnographic, scientific or technical values (among which it is implicitly understood that industrial activity is included) [15]. Despite this conceptual problem, the application of the regulations in a broad sense has allowed the cataloguing of various industrial Cultural Interest Assets (BIC). Furthermore, the Autonomous Communities have been developing regulations on Cultural Heritage that expressly consider Industrial Heritage and are beginning to catalogue and protect it with different inventories and measures [2]. The state has also implemented a National Plan for Industrial Heritage (initially approved in 2001 and updated in 2011 and 2016) and different entities and associations such as TICCIIH Spain (The International Committee for the Conservation of the Industrial Heritage) have developed a multitude of events, measures, actions, proposals and studies that have allowed progress and awareness of society in the consideration of industrial heritage as a value of high social interest [1,16].

The original conception of heritage exclusively linked to aesthetic or artistic values has clearly been overcome and has evolved in line with urban societies in recent years. In this context, the study of industry

in urban history, the evolution of factories and the consideration of the legacy of productive activity as industrial heritage is a matter of great interest and relevance [24]. This is the "youngest" heritage, with fewer attributes than that traditionally considered "old", but its contribution to the collective memory and urban identity should not be underestimated [28]. Industry is undoubtedly a singular activity, due to all the tangible aspects involved in the process of producing assets (raw materials, the transformation process, machinery, utensils, installations, ships and buildings, storage, energy and fuel, transport, etc.), but also due to its intangible component (processes, traditions, customs, knowledge, ways of life, organization, etc.) [3,38]. In this aspect, we must consider that the industry in a general perspective - as an activity - and as regards the factories - as containers of the activity - is part of our heritage, of those elements that, as a relevant part of our social evolution, reflected in the territory, we have given a value and, consequently, we are committed to preserve and protect [11]. This value is given not only by its economic, social and spatial significance, which it undoubtedly has, but also by its huge capacity for transformation, by the constructive power it has had historically, in the sense of creating and energizing territories, creating elements that remain in the culture of these places [40]. The industry has a more significant role than it is really given in popular culture. What is certain is that it turns out to be an essential asset of human activity in these urban areas and, consequently, is integrated into their territorial heritage, as a key aspect in the identification of their landscape and cultural heritage [18,19].

From this point of view, it is important that universities and research centers carry out actions to disseminate, transfer knowledge and enhance the value of industrial history in cities, contributing to extend the meaning of industrial heritage in a broad sense (beyond the figures of protection). In many Spanish cities, factories are unique elements of the urban landscape and, although in many cases they have not been protected or preserved with specific heritage figures, they do constitute groups of collective value that should be singled out. Most of these factories have a history of between 50 and 150 years of activity and therefore coincide in time with the greatest development and transformation of the cities in which they carry out their activity. They are, without a doubt, a unique witness of urban history and as such they must be considered, favoring the transmission of their own history to the rest of the city, opening the doors of these industries to the community. There is a clear challenge: to preserve, protect and enhance these resources that are part of the collective memory of the city and are an outstanding element of the urban landscape and a living testimony of the history of technology and work [14].

Based on this approach, this contribution presents the results of various experiences of knowledge transfer to the society of the value of industrial heritage in a city in northern Spain (Burgos). In the last five years, various initiatives have been developed to disseminate the industrial history and heritage value of different factories, explaining their origins, their production processes, the uniqueness of their facilities, the scope of their products, their social and economic impact on the environment, etc. Using new technologies and a script based on storytelling proposals to create innovative dissemination products focused on transmitting the meaning of industrial heritage. Under the slogan of "A history of enterprises", a multidisciplinary team from the University of Burgos composed of geographers, historians, engineers, computer scientists, technicians and experts in audiovisual communication and new technologies has proposed a sequence of exhibitions and dissemination activities as educational initiatives. This work summarizes its development and main conclusions.

2 "A history of enterprises": didactic experiences in the Industrial Pole of the city of Burgos (Spain).

The city of Burgos is located in the north half of the Iberian Peninsula and constitutes an urban area that reaches 200,000 inhabitants. It is a city with a strong historical background (founded in the 9th century) and a recognized monumental ensemble with more than 30 Cultural Interest Assests (BIC) and a wide patrimonial recognition (it is the only Spanish city that has three World Heritage Sites catalogued by UNESCO). However, it is a city with a marked industrial character.

The industrial history of the city begins with small initiatives during the second third of the 20th century, although these are activities of a markedly pre-industrial nature (manufacture of gloves, clothing, candles, chocolates, hats, etc.). On the foundation of the small network of those small artisan workshops the first relevant factories begin to appear: Paper Factory (1841), Earthenware Factory (1846), Gas Factory (1862), Light Factories (1889 and 1900), Sugar Factory (1900), Hydroelectric (1915) and Ceramic (1922). However, until the first third of the 20th century, industry was not yet essential to the urban structure. These

first factories, grouping only 3,000 jobs in a group of just over 32,000 inhabitants, still have a limited impact on the urban landscape.

The first really important industrial impulse in Burgos took place during the 1930s and 1940s, when new companies were created and industrial employment was doubled. During these two decades, textile, paper, chemical, food, footwear, metal and other machinery factories were established in Burgos. The city becomes a relevant industrial center and confirms its link with the productive activity. In 1950 Burgos reached 6,000 industrial jobs and doubled the percentage of the country's industrial workforce (20% in Burgos compared to 12% in Spain. In the middle of the 20th century these factories formed a first periphery that explains the first growth and expansion of the city.

However, the true consolidation of this industrial outline would take place from 1964, when Burgos was declared a Pole of Industrial Promotion by the government. This declaration implies the arrival of public subsidies for the installation of industries, which multiply the first industrial impulse. Burgos receives the aid of the Industrial Pole between 1964 and 1973, which causes a revulsive that radically transforms the previous structure. During this period, more than 19 billion pesetas were invested, creating 93 new factories with 12,726 new jobs. The average investment went from 60 million pesetas between 1954 and 1963 to more than 2 billion pesetas per year during the 1960s. In barely 15 years the city has doubled its population (from 82,000 to 156,000 inhabitants) and has extended from barely 700 ha to more than 2,200 ha of urbanized land - of this total, more than 800 hectares of industrial land. At the end of this period, during the 1980s, the city became one of the main industrial centers of the country, with almost 20,000 industrial jobs (35% of the working population) [4,5,10].

This industrial history has consolidated a culture associated with the factories in the city, maintaining the value of the cultural heritage of the industry. Despite the fact that Burgos has unfortunately lost a good part of its oldest factories, significant elements of its cultural heritage have been preserved in relation to this industrial identity and a large number of companies with a history of more than 50 years of activity. Table 1 summarizes the main elements of the cultural value of the industry in the city. Currently there are around 30 cultural assets associated with this heritage, catalogued in the Inventory of Industrial Heritage of the public administration. The most significant of these are the National Mint (Paper Mill), the old railway installations, the building of the primitive airport and some food, textile and energy production factories.

Table 1. Main references of the industrial heritage in the city of Burgos

Cultural Assets	Typology	Number	Operation	Dates
Paper Mills	Buildings and chimney	2	Paper	1830-1960
Railroad Station	Station	1	Railway	1860-1902
Locomotive Hangars	Hangar	1	Railway	1860-1902
Flour mills	Buildings	2	Food	1860-1930
Mills	Buildings and machinery	3	Food	1860-1930
Cards factory	Building	1	Others	1880-1940
Energy Factories	Buildings and chimneys	2	Energy	1890-1950
Silo	Buildings	2	Food	1920-1960
Airport	Buildings and warehouses	1	Aviation	1920-1930
Leather Factory	Buildings and warehouses	1	Tannery	1930-1950
Food factories	Buildings and warehouses	3	Food	1930-1980
Fabric factories	Buildings and chimneys	2	Textile	1930-1960
Other factories	Buildings, warehouses and chimneys	6	Various sectors	1940-1980

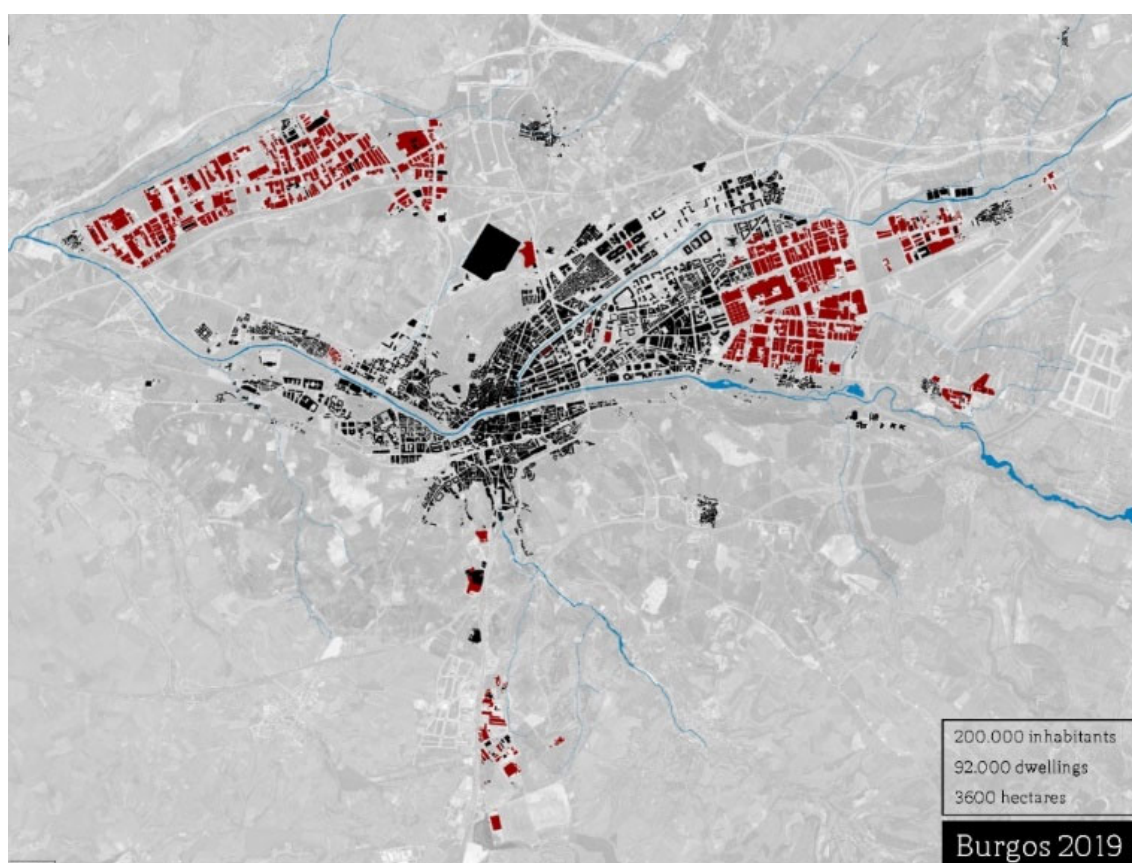


Figure 1. Industrial spaces and factories in the city of Burgos.

The presence of the factories has thus defined its urban evolution in the last century and has configured it as one of the main urban areas of the country in productive terms. There are currently more than 600 industrial enterprises operating in the city, employing nearly 20,000 workers directly, which means that almost one in four people working in urban industry. It is the second Spanish city in industrial land per inhabitant (112 m²/person); the third in percentage of industrial active population (23%) and in industrial

jobs per 1,000 inhabitants (98, double the national average); the fourth in percentage of industrial land over the total urbanized (37%); the tenth in total urbanized industrial land (nearly 2,250ha) and the twelfth in absolute industrial employment (nearly 20,000 workers). As can be seen in Figure 2, it is therefore characterized by an industrial profile that is well above the national average of cities of the same urban range [10].

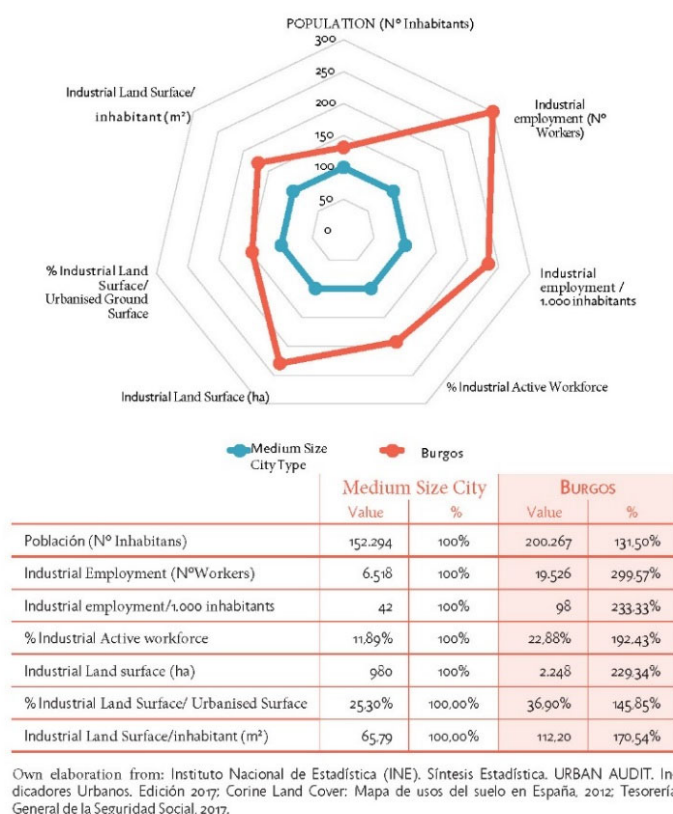


Figure 2. Industrial profile of the city of Burgos.

The presence of this industrial activity and the configuration of this productive profile has made it possible to identify singular enterprises with an outstanding trajectory in the last few decades in which educational proposals have been implemented. Specifically, six didactic exhibitions have been developed in which 35 industrial enterprises of the city have been involved. These initiatives have been carried out between November 2014 and December 2019. They have taken place in different auditoriums and exhibition halls, as well as in some cases in the industrial factories' own facilities. These exhibitions have been visited by nearly 33,000 people, having achieved a high impact in the dissemination of content related to the heritage of these factories. In all the exhibitions, traditional techniques have been used to show the contents by means of exhibition panels, showcases with objects, machines and documents. However, in each of them, as explained below, different methods and innovative technologies have been tested to overcome the usual forms of content transmission.

The most relevant initiative, with nearly 17,000 visits and 30 enterprises involved, took place between 2014 and 2015 in Burgos Forum Auditorium, with a wide range of communication results and the publication of a book with the industrial history of these enterprises. In this first initiative, a first experience with video-mapping techniques was proposed on an industrial art mural, as well as a storytelling proposal was rehearsed, through a sequenced script with guided visits. Likewise, touch screens were incorporated that allowed the user to interact with the different contents, offering a more dynamic result in the learning process. This initiative was entirely incorporated into an interactive website where a virtual tour of the site can be taken with all its contents. See: <http://www.burgosciudadindustrial.es/>

Table 2. Didactic experiences on history and industrial heritage in the city of Burgos (2014-2019)

FACTORY	ACTIVITY SECTOR	FOUNDATION YEAR	EXHIBITION NAME	DATES	NUMBER OF VISITORS	METHODS AND TECHNOLOGIES
30 different industrial factories of the city	Various	1890-1970	"Burgos, Ciudad Industrial. 50 años del Polo de Promoción y Desarrollo 1964-2014"	07/11/2014 07/01/2015	16.824	- Exhibition panels - Objects, machines and documents in showcases - Audiovisual screens - Storytelling - Touchscreens - Videomapping - Industrial Art - History published book [5]
Cerámicas Gala	Ceramic sanitary	1965	"50 años cerca de ti. Aniversario 5 décadas Fábrica Cerámicas Gala en Burgos"	25/03/2015 31/12/2015	1.826	- Exhibition panels - Objects, machines and documents in showcases - Audiovisual screens
Cerámicas Gala Gonvarri Industrial Grupo Antolín	Ceramic sanitary Steel products Automotive components	1965 1967 1950	"Empresas con Historia. Un viaje en el tiempo por la industria de Burgos"	29/09/2016 16/10/2016	6.476	- Exhibition panels - Objects, machines and documents in showcases - Audiovisual screens - Storytelling with actors - Videomapping - 3D Model - Virtual Reality - Video games - Industrial Art
Gonvarri Industrial	Steel products	1967	"Gonvarri 50 Aniversario. 1967-2017. Un recorrido por nuestra historia"	28/04/2017 31/12/2019	3.735	- Exhibition panels - Objects, machines and documents in showcases - Audiovisual screens - Videomapping - 3D Model - 3D Mockup - Virtual Reality
Bridgestone Hispania	Automotive tires	1964	"50 años de fabricación de neumáticos: la historia industrial de Bridgestone Burgos"	30/09/2017 19/10/2017	2.962	- Exhibition panels - Objects, machines and documents in showcases - Audiovisual screens - History published book [6]
Verallia Spain	Glass bottles	1965	"La fábrica de Vidrio de Burgos. 50 años fabricando botellas"	08/11/2019 31/12/2019	1.126	- Exhibition panels - Audiovisual screens - History published book [9]

32.949



Figure 3. Promotional poster and general views of the exhibition "Burgos. Industrial City". Year 2014-2015.

Also remarkable is the experience "A history of enterprises", which took place in the Cultural Córdón exhibition hall, showing the history and heritage of three enterprises: Cerámicas Gala, Gonvarri Industrial and Grupo Antolín. As detailed below, in this initiative a storytelling process was developed with professional actors with unique results in improving the process of knowledge transfer. The exhibition was visited by nearly 7,000 people and served as a rehearsal for testing video-mapping techniques, a broad virtual reality experience and the first interactive video game performance. "A history of enterprises" can also be enjoyed online in a complete way through a 360° virtual visit. This tour includes all the exhibition contents, but also the storytelling experience with the actors and the virtual materials summarized in video sequences. See: <http://www.empresasconhistoria.com/>

On the other hand, with a monographic character and carried out in the enterprises own factories, the exhibitions related to the industrial history of Cerámicas Gala, Gonvarri Industrial, Bridgestone Hispania and Verallia Spain have also been developed. In all of them, different techniques have also been tested to communicate contents of history and industrial heritage, combining videomapping, with virtual reality, videogames and three-dimensional modeling and elaboration of models. In this case, among the exhibitions held at these factories, the initiative held at Gonvarri Industrial's facilities is particularly unique.



Figure 4: Website, App for mobile devices, interactive 3D model and content showcases of the "Gonvarri 50th Anniversary" exhibition. Years 2017-2019.

This steel producer, currently one of the world's leading suppliers (with nearly 150 factories in 30 countries and more than 40,000 workers), began his career at the Burgos factory in the mid-1960s. In 2017, the enterprise celebrated the 50th anniversary of the start of its activity and planned a commemorative exhibition to disseminate its history, the value of its heritage and its industrial activity to the whole of society. For this purpose, an interactive exhibition was designed with a large 3-dimensional model at the entrance to its factory, as the main protagonist. This model was animated by means of a video mapping with a sequence that explains the history of the factory and was completed with videos that disseminate its evolution, animations that explain its production processes and a virtual reality room with an immersive experience that explains the history of the enterprise from its beginnings to its most recent global expansion. In addition, guided tours of the factory showed the history on large-format screens installed in the production halls themselves. To complete the proposal, a complete web page was designed (<http://www.gonvarriburgos.com/>) and an application for mobile devices in which it is possible to enjoy all this content, popularizing access to the technology that shows the industrial history of the enterprise ([Apple](#); [Android](#)). These references and the attached table show the main characteristics of all the techniques used in this exhibition, as well as details of the other experiences, whose methodology and results are presented below.

3 Objectives, methodology and techniques: integrating storytelling with new technologies.

In most traditional exhibitions, the display of content information is relatively passive. [23]. Visitors can only tour the exhibitions from a safe distance and very often do not have a guide or basic information to connect the exhibitions with the exhibition narratives [47]. In recent decades, many museums have introduced interactive installations (such as monitors, video projections, touch screens, etc.) to attract more visitors to their exhibitions and awaken their interest [33]. It also seeks to involve the viewer in the narrative and to have a unique social experience [49]. Unlike in the past, today's visitors are looking for interactive elements to participate and interact with the exhibition. [26]. In addition, exhibitions in which visitors actively participate are perceived as more enjoyable and are well worth revisiting [35].

From this approach, the educational experiences developed have focused on improving the traditional transmission of basic content, with the use of innovative proposals, more dynamic and with interactive elements to encourage visitor participation. To this end, it has been assumed that new technologies enhance learning processes, although the existence of a previous script with a well-defined scheme of contents has been considered essential. Thus, the storytelling technique has been implemented in most of the initiatives described, combining it with the use of new technologies to achieve a more efficient method. In developing the experiences of industrial history, an iterative design approach has been followed, always based on expert historians and geographers, as well as on observation and interviewing in situ.

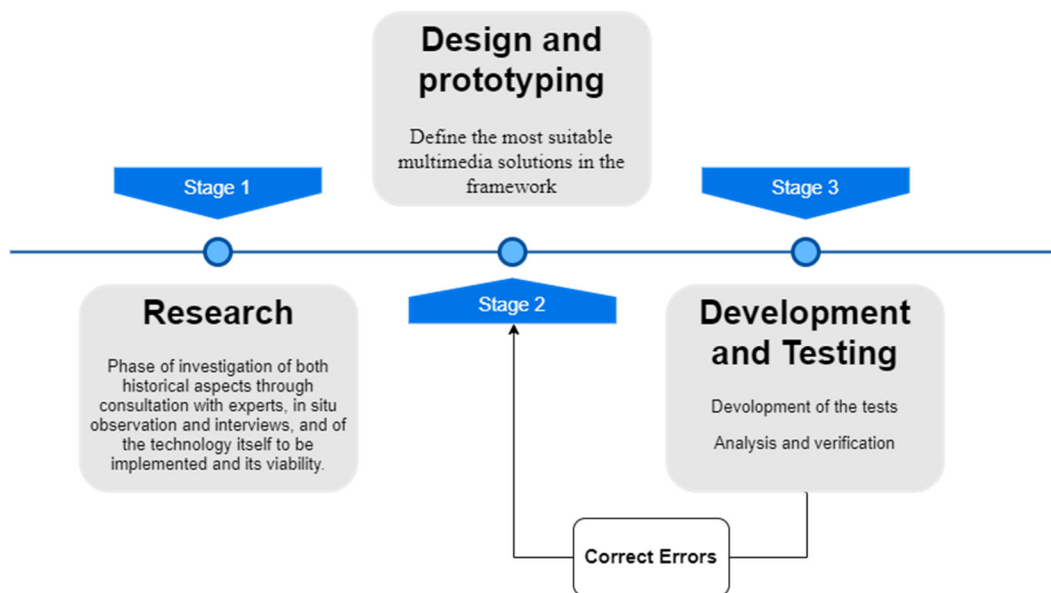


Figure 5. Methodology used in the design and development of the educational experiences

This methodology has been deployed for the design of all technological products and consists of 3 phases: research, design and prototyping, and development and final testing. The basic scheme of this model is shown in figure 5. This methodology has already been tested and validated in previous studies of cultural heritage reconstruction, so in these experiences we have been able to test its concrete application to the dissemination of history and industrial heritage. [21,22].

In particular, the objectives pursued with this method have focused on achieving that

- The user can see and experience the importance of industrial development in his city.
- The user understands the value of the industrial heritage and the meaning that the productive activity has in the urban identity and in the collective memory.
- The user can interact with the exhibition, participating actively and not just viewing panels and showcases with classic content having a playful and attractive experience while learning the contents proposed.
- The user is integrated into the experience, assumes it as his own and collaborates as part of the knowledge transmission system, participating in history as its essential keys are discovered
- After visiting the exhibition, the user disseminates the contents and experiences he or she has had to third parties.

To achieve these purposes, we consider it essential to maintain a good thread of content by immersing the visitor in a story that "catches" the visitor and makes it feel attracted to the message to be told in the exhibition. In this approach, the use of storytelling, generating a "fictional story" to tell the real story of the factories, has been the key driver. Storytelling and cultural heritage have been associated from the beginning of time with folk tales that convey the identity of places. This identity forms our culture and links us to a legacy. Therefore, in order to preserve this cultural heritage, it is essential to transmit it efficiently. Museums and exhibitions are essentially storytellers that transmit a story to the visitor and in that sense, storytelling is the best way to achieve good results. However, the knowledge about exhibitions is not immediately accessible to the non-expert public [41]. For this reason, museums have proposed interpretations of the objects. The adoption of more explicit narrative guidance in exhibition design makes the exhibition more accessible and attractive to the viewer. Today's storytellers need tools that capture the attention of their listeners and, ideally, improve their final retention. Some studies suggest that storytelling can be more memorable to the listener if it occurs in a relevant environment enriched with visual impressions and that it introduces the listener to a context that allows him or her to move away from everyday reality [36]. Furthermore, when complemented by digital media, this technique is able to better communicate cultural heritage-related content [43]. In this field, most of the research in the design of narrative experiences refers to examples of historical or archaeological heritage [22,44], with few references in the case of industrial heritage [29,46]. Advancing on this challenge and proposing results from the integration of new technologies in a storytelling sequence has been the main motivation for this contribution.



Figure 6. Promotional poster and different images of the rooms with technological experiences in the exhibition “A history of enterprises”.

In fact, the main objective in the design of the "A history of enterprises" exhibitions has been to guide visitors through a narrative that immerses them in a recreated space. The aim was for visitors to learn the

key historical facts related to industrial heritage in an attractive way, making it possible to make an emotional connection with the city's industrial heritage. In order to relate this historical importance of industry with today's society, a story was told through time so that visitors could understand, remember and be able to relate better in the context we were proposing. The idea is based on a simple principle: to use a fictional story to convey the content of the real story. To achieve this purpose, we use professional actors who represent a theatrical story that allows us to develop "a journey through time". The idea is that visitors really believe that they are travelling through industrial spaces of the past. The idea is to involve the visitor in a plot in which they truly participate and interact in an educational journey, which helps and facilitates the learning of the "real" story that they really want to tell. To facilitate the achievement of this goal, technology is added, with several of the digital materials mentioned (virtual reality, videomapping, video games, 3D models) that support the stage to make it more enjoyable, fun and innovative.



Figure 7. Different sequences of experience based on storytelling in the exhibition “A history of enterprises”.

Based on this approach, the stories are designed to be enjoyed in small groups of approximately 15 people, in visits of between 45 minutes and 1 hour. The beginning of the theatrical performance is centered on surprise, with the actors beginning to act when the audience is in the main room of the traditional exhibition. Visitors have been previously accredited by wearing a reflective vest that identifies them, and the actor guides them to participate in the interactive exhibition. From that moment on, a "journey through time" begins through different rooms that go beyond the initial traditional exhibition. In this way, visitors feel that they are participating in a unique experience, as they leave the conventional exhibition and immerse themselves in new scenarios specifically created for the history of the invented narrative. These new rooms recreate industrial spaces from the past, warehouses of the disappeared factories and places that the user could not otherwise know. In this way, the concerted groups that interact with the actors participate in a unique experience that a conventional visitor cannot acquire. In addition to this sequence of storytelling, new technologies are implemented in all these rooms, allowing the visitor not only to enjoy the theatrical event, but also to make it more efficient and notably improve the transmission of content. In this way, by integrating technologies into the historical narrative, the basic contents of the message of the initiatives carried out can be better established. Below is a brief explanation of each of the technologies used to achieve the objectives of this method, focusing on some examples of the cases presented.

4 Rebuilding and showcasing industrial heritage: the use of new technologies in historical discourse.

As indicated above, innovative experiences in the field of cultural heritage knowledge transfer are showing that the incorporation of new techniques for the dissemination of messages leads to increasingly better results [36]. In the context of today's information society, new forms of communication through the use of technology (neotelling) have come to be discussed as an efficient technique for obtaining evidence of training [34]. These new ways of communicating with the visitor must be carried out in such a way that these technologies go from being an end in themselves to becoming a tool at the service of the proposed story. The aim is that this narrative, through the integration of new technologies, should not only reach the intelligence of the spectators, but also appeal to their feelings and emotions [25]. In the experiences carried out in Burgos in relation to the transfer of knowledge of history and industrial heritage, a wide range of techniques have been used to develop the contents: panels, summaries and murals with documents and

images; machines, objects and products; display cases with documentation and old products; various audiovisual contents; publications of brochures and books; touch screens; video mapping on objects, walls and artistic murals; three-dimensional models of buildings and objects; video games; augmented reality and virtual reality. Of all the above-mentioned technologies, we have selected the four techniques that have stood out in the above-mentioned exhibitions for their greater use and results. Their main characteristics and application results are listed below.

4.1 3D modeling.

A very efficient technique because of the ease of integrating the results into videos, models, video games, augmented reality or virtual reality is 3D modelling. This process has been widely tested, modeling in three dimensions the scenarios of the old factories. With this technique a product is generated with which the user can get to know disappeared industrial spaces, transformed places and, in short, it is possible to reconstruct the industrial heritage in a very attractive way.

Depending on the type of reconstruction we are facing, we will have to use different approaches. The simplest one is if the object still exists, because we can use surveying techniques with a geodesic station, laser scanning or photogrammetry. However, if the object has disappeared or been totally or partially destroyed, these techniques are not useful. In these cases, the most common approach is the use of CAD tools. Although these CAD models will not be suitable for real time representation in video games or virtual reality applications, due to their high level of polygonal detail. The use of 3D models with fewer polygons in 3D environments is a fundamental part of these experiences. This increasing adoption of real-time representation involves the use of low polygonal load models to facilitate end-user interaction with them. Therefore, we use polygonal modeling tools such as Blender that facilitate the representation and optimization of these models in real time [17].

Following the previous methodology, in the first phase, the processes of acquisition of existing data sources related to the component of our industrial heritage to be reconstructed are considered. We investigate the documentation that is physically available. We look for documentary resources such as photographs, plans, etc. We interview the workers from the 1960s environments that will be recreated to gather relevant information for the reconstruction. If the object of the digitization still exists, even if it has changed, photogrammetry helps in its reconstruction and texture extraction. In the second phase, the 3D modeling of the previously documented environments is carried out. This 3D modeling must consider the final platform on which the model will be displayed, and if a real-time rendering environment will be used, a low number of polygons must be maintained, trying to achieve a good balance between performance and photorealism. Finally, in the testing stage, we verify that everything works correctly. For this task, we use templates, where all models can be tested in the same conditions. After these controls, the models are considered ready for the production phase. Based on this technique, the old Gonvarri Industrial factory has been reconstructed. This 3D model has been used in the "A history of enterprises" and "Gonvarri 50th Anniversary" exhibitions. The main objective of the project was to reconstruct the original factory building in Burgos in the 1960s in full 3D. This space is currently very much transformed. Therefore, it was necessary to recreate the original appearance of the factory, a relatively easy task with the available graphic documentation. In this first case, a virtual tour was designed that allows the user to visit the factory in the 1960s autonomously and explore the entire manufacturing process. The documentation phase was the most laborious part, due to the limited availability of documentary resources. In the case of Gonvarri, for example, only a couple of photographs of the original workspaces are preserved, with which to reconstruct the factory from the 1960s. In the investigation, the original factory was visited with an ex-employee who had worked there at the time, to gather very valuable details for the reconstruction. The original lathes are no longer available, although some very similar and newer models were found in another factory, which served, along with photographs and plans of the originals, to reconstruct accurate copies. Figure 8 shows a result of the complete three-dimensional reconstruction process of one of the factory's buildings.



Figure 8. Different perspectives on the result of the virtual reconstruction by means of 3D modelling of the old Gonvarri Industrial factory in Burgos. 1960s.

4.2 Videomapping techniques.

Secondly, video-mapping techniques have been used to create experiences that are integrated into storytelling. We could define this solution as the technology that uses video projectors to project a digital image on a physical surface [42]. Any diffuse surface can be used as a display screen. The most commonly used projection surfaces are the facades of buildings, but we also find many other examples of projection surfaces, such as projections on sculptures that recreate their original polychrome that is now lost [39] or to add information related to museum objects [12]. The advantage of this technology is that several people can witness the projection at the same time, so we are talking about a shared experience. This is very important in the field of museology because it enables interaction with the exhibition to take place in groups of people rather than as individual experiences. In museums, video mapping has been widely used as a way of increasing visitor interest in the exhibition. We also find multiple literature in museum solutions referring to interactive walls for displaying cultural content. [30]. There are also some drawbacks to the application of video mapping techniques in cultural exhibition environments. First, very controlled lighting conditions are usually required, such as a dark room. With ambient light, the projection will lose intensity and limit its color range. It is also necessary to consider possible occlusions that may occur due to the presence of other objects in the projection range, as well as that of the visitors themselves. Finally, the projected content must be adjusted very precisely to the object and any small movement can ruin the effect. With these issues in mind and taking steps to minimize them, this technique has been used in three of the experiences carried out on heritage and industrial history.

Firstly, at the exhibition "Burgos. Ciudad Industrial" an innovative proposal was carried out through the video mapping of a mural painted by a local artist. The video mapping proposed a dynamic sequence by means of the illumination of the painting and managed to make it "alive" by means of movement effects (smoke from the chimneys, activity in the factories and images with overlapped colors). The result was presented as an initial experience of the exhibition in which the user attended the introduction of the script of the visit contents. The room of the painting was arranged as a cinema room, where a film about a work of art is shown. Figure 9 shows some of the sequences of the animation projected on the painting.

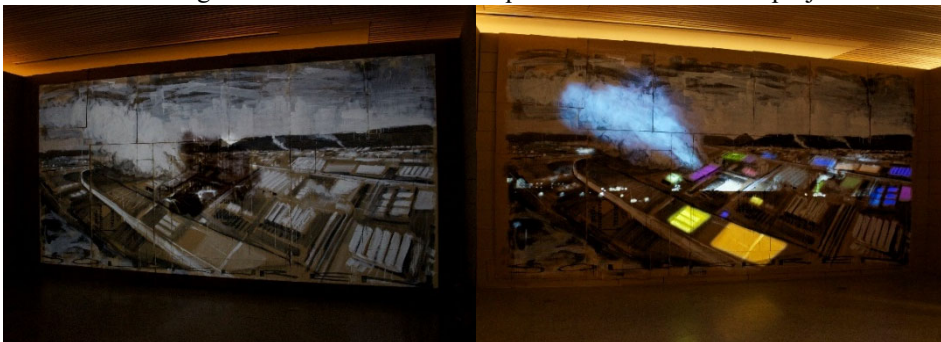


Figure 9. Sequences of the animation made on an artistic mural of an industrial space by means of video-mapping technique. Burgos Exhibition. Industrial City.

Secondly, video mapping was also proposed as an efficient technique in the exhibition "A history of enterprises". In this case, it was applied in a different way, looking for an original solution to recreate by

means of light and projection a ceramic oven from the old Gala Ceramics factory. It was not possible to install a real old oven in the exhibition since the technical measures to carry out this action were not feasible due to the costs and dimensions of the room. The small size of the room and the necessary visual effect of perspective made it necessary to opt for innovative solutions. In a room that contained a modern Gala bathroom, visitors could see through a mirror how the ceramic pieces came out of the factory's ovens. The projection took place in an adjacent room behind the mirror. The glass of the mirror becomes translucent and in the room behind it, which is completely dark, the operation of the oven is projected onto the real ceramic pieces (see figure 10). With this solution we allowed multiple attendees to observe the operation of the oven at the same time, avoided occlusions and made it possible for the visitor to participate in an experience that is impossible to recreate in real life in the exhibition room.



Figure 10. Recreation of the old oven room of the Gala Ceramics factory behind a mirror of a modern bathroom by means of video mapping technique on objects.

The third example of video mapping was carried out in the Gonvarri Burgos factory, proposing in this case a unique solution to shine light on the factory buildings built in a three-dimensional model. As a video explaining the history of the factory progressed on a screen, the different industrial buildings of the factory were lit according to the year of construction. In this way, the visitor is given a very graphic explanation of how the factory has grown in terms of surface area. The real model of the entire production complex has been built on a scale of 1/120 and with a level of detail that represents all the production lines. This allows the video mapping to also illuminate each production line as the video explains the process. The result is a very eye-catching product for the visitor since it generates a real animation effect of the 3D model of the factory. The effect generated can be seen in figure 11. In this case, the technical difficulties of the mapping process were compounded by the laborious and artisanal process of building the model with a high level of detail. The pieces of the model were drawn from the plant's CAD plans and then printed on pieces of PVC material and cut to size with a laser cutting machine. The lines and details were modelled in 3D and subsequently printed on a 3D printer with PLA filament and painted by hand.

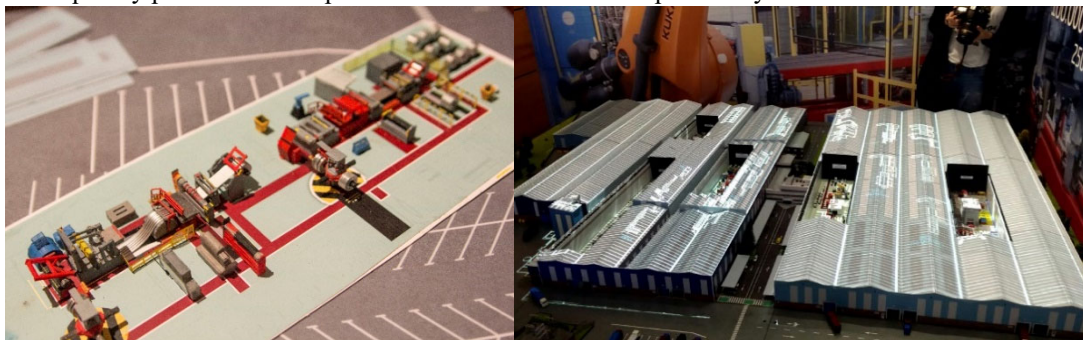


Figure 11. 3D printed pieces and video mapping on the scale model.

4.3 Video games and gamification.

As a third technology to disseminate the contents on history and industrial heritage we have used the incorporation to the discourse of video games. Using the intrinsic motivations of the visitor as fun produces a deeper interest and with a greater persistence in the proposed learning activities. This explains the success and why the adoption of video games for educational purposes in several areas, such as cultural heritage [48]. Video games can be used to create entertaining and cultural learning experiences since both features

can coexist without conflict because the entertainment factor engages the audience to participate, but the understanding of what they have learned would take place after the experience [45]. Several challenges are involved in creating video games with the aim of disseminating content on history and industrial heritage. Firstly, of a technical nature, since the high-quality 3D models generated that we have explained in previous sections are not easily represented in real time and limit the interactivity of the end user with the virtual reconstruction in many applications. Second, the management of large groups poses logistical problems and the main potential of the video game is interaction. To solve this challenge, different strategies have been used with which the user can and does take control of the applications being projected. In the case of Burgos, Ciudad Industrial this experience was carried out by integrating the video game into a large format touch screen (70 inches) on which the visitor could directly manipulate the contents with various options and questions that led to a result. The experience presented in the case of Gonvarri Industrial's factory is of major interest, as it uses the 3D model to integrate it into a terminal that allows the user to interact and move around the old factory. In this case, the video game experience recreates the daily activities of cutting and preparing steel sheets at the factory in the sixties. The spectator's feeling of involvement was the main objective. To this end, two objects were placed in the exhibition hall: a recreation of a steel coil and the control panel of a cutting machine. We used this real control panel from an old factory installation to link it to the virtual tour controls as shown in Figure 12. The experience was projected in 2D on a white wall, allowing large groups to interact. The video game was designed so that the user would follow a route showing the most relevant steps in the production process, transmitting an idea of their daily production activity in those years. This route was created in such a way that the user has the freedom to move around the nearby surroundings, but at the same time is obliged to follow a fixed route. This is a fundamental strategy, since total freedom of movement would lead to disorientation and would be lost in the didactic approach planned in the route through the factory.

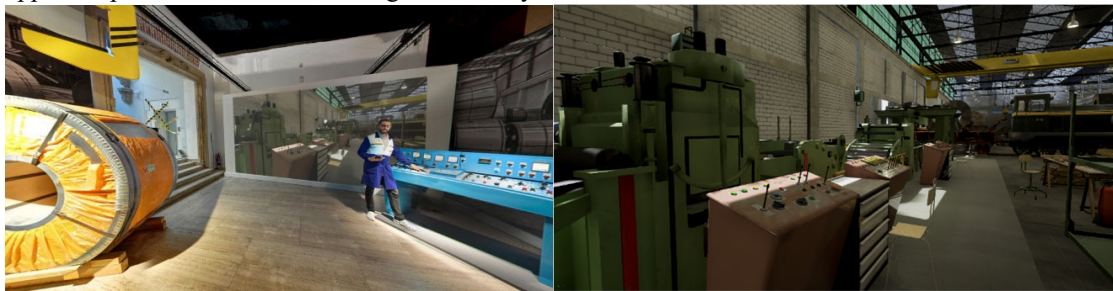


Figure 12. exhibition room about Gonvarri Industrial's old factory and detail of the Videogame.

4.4 Integration of experiences through Virtual Reality.

Finally, the technology that has allowed a more immersive experience for the visitor has been the incorporation of virtual reality experiences. We talked in previous sections that the use of new technologies is one of the keys to make our proposal more attractive to the general public. Immersive virtual reality (VR) is probably one of the most potentially effective technologies to serve this purpose. However, it is still rare to find immersive VR installations [20]. VR technologies have been proven to be effective in a number of areas, including enhancing the value of cultural heritage [31], increase student responsiveness and learning rates [22], and emphasize the feelings of wonder and excitement in the users [32]. The use of this technology can not only break the limitation of time and space but can also provide an environment that allows visitors to observe, study and interact in order to enhance the visitor experience and learning.



Figure. 13. Virtual reality room using visual experience stations integrated into mobile phones.

Based on these approaches, a 3D mobile virtual reality experience was performed in the exhibition “A history of enterprises” to recreate the expansion of a small car component factory in a leading automotive enterprise TIER1 (Grupo Antolín). The first objective was to convey to the visitor the expansion of the production process in the automotive sector over 30 years, from almost craft work in small-scale industrial facilities to mass production in large factories. The second objective was to transfer the physical sensation that the size of the first small factories was very different from the first large factories that opened at the same time in the city. With these objectives, virtual reality is the ideal tool, as we can perceive volumes and feel the scale of space and provide rapid spatial and temporal changes between scenes. Mobile phones were used to visualize these virtual reality environments. These were placed in a viewer attached to a height-adjustable vertical tube and handles. This solution provided us with an autonomous 360° virtual reality device. Five of these devices were installed, facilitating the flow of visitors and groups, as shown in Figure 13. The user could not move, but instead turned on himself to see the 360° image.

On the other hand, a high-quality virtual reality room with five stations with Oculus Rift glasses was planned. The room, as shown in Figure 14, was organized into two areas: on the one hand, the high-quality virtual reality helmets and, opposite these, in the form of a diorama, all the car components manufactured in the city. In this way, the user could see the real car parts that are produced in the city before putting on the glasses and, later, in the virtual experience he or she is shown the assembly process of the same vehicle with those parts in the enterprises facilities. The experience was designed to take full advantage of the capabilities of virtual reality.



Figure 14. Virtual reality room with automotive components diorama.

Virtual reality technology was also used in the exhibition at Gonvarri Industrial's factory. In this case, a room has been created with four stands that contain an experience in which the visitor can learn about the evolution of the factory and its production processes, as can be seen in Figure 15. The experience begins with a journey by train in which time passes quickly around it, allowing the visitor to see how the promotion pole developed until the construction of Gonvarri's factory and other nearby factories. In the following scenes, the user continues his journey through time, and the train enters the old factory and passes through different production halls of the same factory at different times until it reaches the current one.



Figure 15. Gonvarri Burgos virtual reality room and examples of virtual reality experience environments representing the factory 50 years ago and today.

5 Main results and conclusions.

The results obtained by applying all the technologies described in coordination with storytelling have given very interesting indications of the contribution that these new techniques make to the process of learning content related to history and industrial heritage. To measure the extent of the effect generated by this methodology, a process of mixed, qualitative and quantitative analysis has been carried out. From a qualitative point of view, nearly 100 interviews have been held with different users aged between 9 and 83, questioning in a general way the impressions generated in them by the learning process based on new technologies. From a quantitative point of view, in one of the experiences, A history of enterprises, carried out in 2016, a digital survey was developed using a form sent by e-mail to a sample of 394 people (aged between 18 and 79). About 30% of the respondents were under 25 years old, which confirms some of the answers related to the attraction of technology; 43% were between 26 and 50 years old; and the remaining 27% were older than that age. The response rates obtained were between 58% and 76% depending on the different questions. The results obtained by both methods of analysis are very illustrative of two essential aspects: on the one hand, the significant process of change in the user's perception of the industrial history of their city; and, on the other, the high value placed by most visitors on the contribution of technology in the process of transmitting content. Let's look at some details.

First of all, it is interesting to note that 24% of the people surveyed stated that they do not usually visit exhibitions related to cultural heritage and that, in this case, they went to the experience with curiosity because of the demand for the innovative offer of new technologies. On leaving the visit, 95% of users

rated the experience as very good or excellent, indicating the qualification as surprising or innovative. These figures mark a first reference in the result of the exhibitions, in that the activity carried out has been different to what users usually experience. But this does not confirm the objective set. It is necessary to analyze whether the contribution of content made in these knowledge transfer experiences has really reached each visitor in their learning.

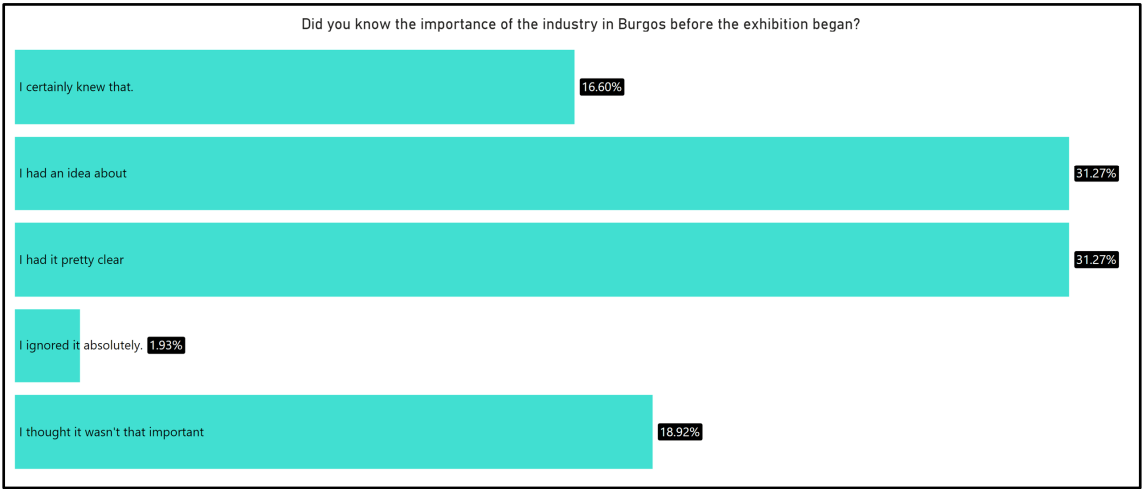


Figure 16. Results of the analysis. Question: Did you know the importance of the industry in Burgos before the exhibition began?

In this aspect, each person was asked about two aspects related to the value of industry in the city and its cultural or identity significance. On the one hand, they were asked if they knew previously the relevance of industrial activity in the city. Approximately half (47.9%) were clear or certain about this question. In other words, more than half of the people did not know clearly the relevance of urban industry. In relation to this idea, 53% of visitors before visiting the exhibition did not associate history or industrial heritage with culture. However, when questioned on this same aspect after the experience, this percentage fell to 8%, with 92% of users already stating that the city's industrial heritage is clearly related to culture (see figures 16 and 17).

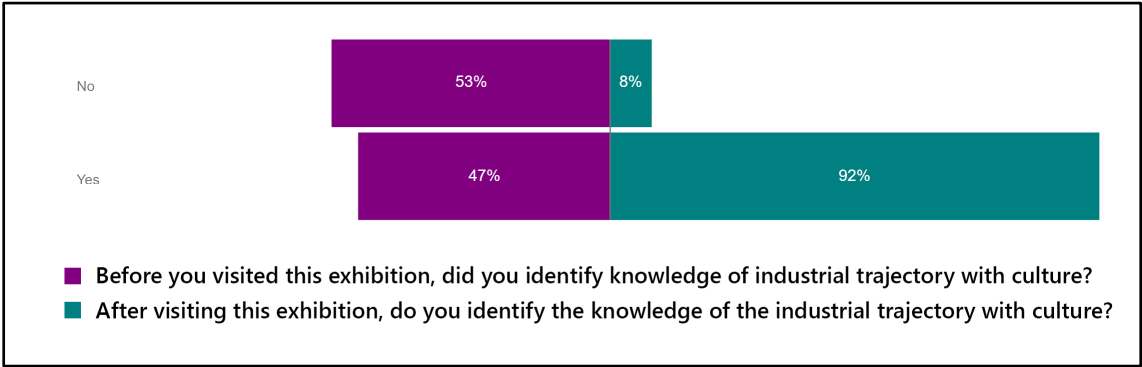


Figure 17. Results of the analysis. Question: does knowledge of the industrial trajectory identify with culture? Before and after visiting the exhibition.

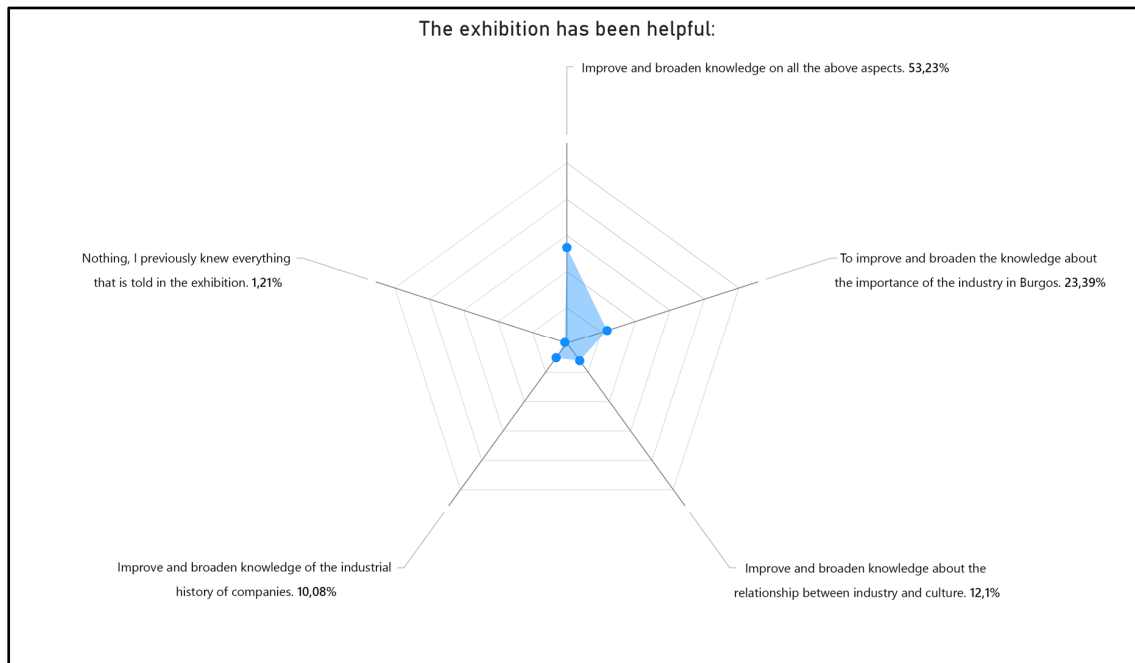


Figure 18. Results of the analysis. Issue: The exhibition has been helpful to...

In that way, the knowledge transfer initiatives have fulfilled their first objective, to the extent that they have served to disseminate and spread the appreciation of industrial history and its heritage significance. Moreover, in the analysis carried out, each visitor was asked specifically whether and to what extent the exhibition helped to improve and extend their knowledge of this subject. As can be seen in figure 18, 10% of the people indicate that the experience has served to improve their knowledge of industrial history, 12% suggest that their concept of the relationship between industry and culture has progressed, 23% indicate that they have broadened their knowledge of the relevance of factories in the city and, finally, more than 53% consider that the initiative has brought them improvements in their knowledge in all these fields together. The balance is therefore very satisfactory, as more than half of the visitors consider that the exhibition has brought about very notable improvements in this respect.

In this process it has been detected that the methodology based on storytelling as the guiding thread of the experiences has been very efficient in linking the visitor with a different and innovative experience, obtaining a high valuation. Specifically, 8 out of 10 people have said that storytelling with the participation of professional actors helps them to retain concepts better and improve their learning. Along the same lines, when asked how they found the training on the contents most attractive, more than 41% selected storytelling and guided activity with actors as the most efficient. However, this question already shows the high interest of technology as a complement to the script. 25% indicated the virtual reality experience as the best method for learning content and another 25% indicated the projected videos as ideal. It is important to highlight from this perspective that only 4% of the visitors have chosen the traditional panels or images as the best option (see figure 19).

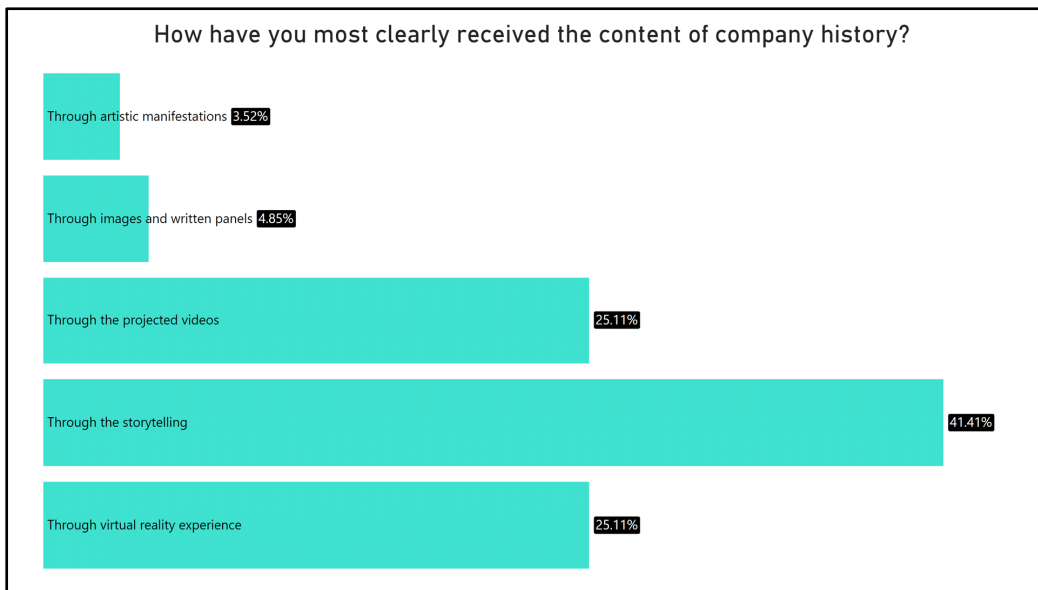


Figure 19. Results of the analysis. Question: In what way or by what method have you most clearly received the industrial history and heritage content of the exhibition?

Linked to this same argument, in the whole initiative it is immediately clear that the visitors have placed a high value on the technological experience. In the qualitative interviews, a high degree of appreciation was obtained for the use of virtual reality and video mapping at all ages, with particular significance for people under 20. This age group, with no previous interest in the subject, said they attended the exhibition attracted by the presence of virtual reality glasses and video games. And, later, they considered the history of the industrial heritage they had learned by actively participating to be interesting. The same data reflects the quantitative survey. Nearly 74% of the visitors chose the virtual reality room as the most attractive space in the exhibition, with a large distance to the rest of the options. The more traditional rooms or the intermediate spaces of the tour were hardly accepted, with video games, videomapping and the art exhibition receiving a higher evaluation (although with response rates of between 4 and 7%, always much lower than the massive option of virtual reality).

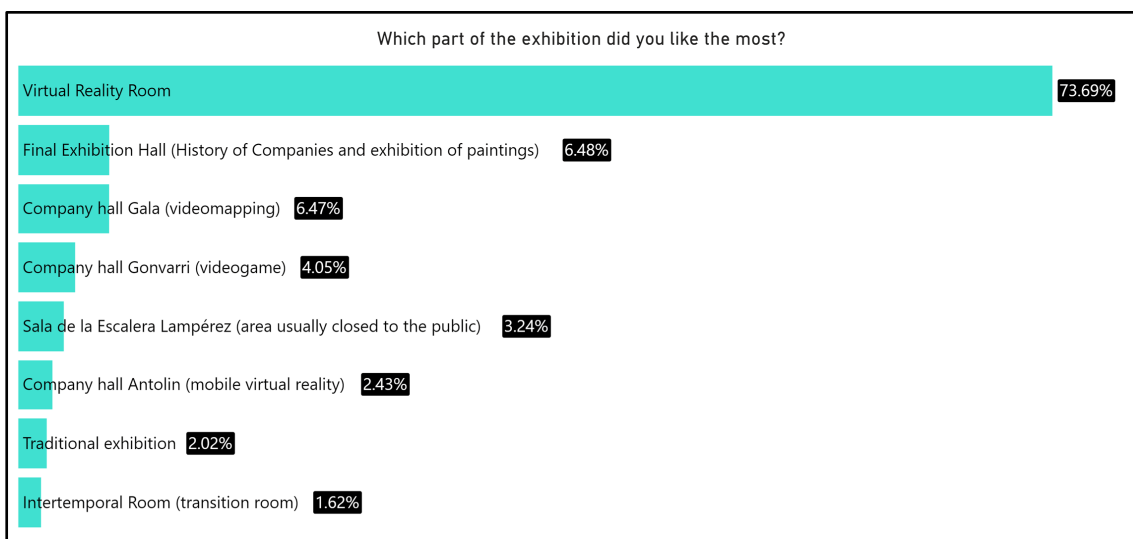


Figure 20. Results of the analysis. Question: Which exhibition space did you like the most?

However, the approach chosen in this question is not entirely concrete since, when spaces are identified, the visitor's response may be influenced by his or her conception of each room, his or her aesthetic appreciation of the place or the effect generated by the actor in each intervention. For this reason, each

visitor was specifically asked about technologies as a tool, beyond the room in which they were being used or the specific theme to which they were applied at the time. The results are equally interesting and point in the same direction. As shown in Figure 21, 56.7% of people chose to identify virtual reality as the most relevant technology for the transmission of content. Fifteen percent chose videos and screen projections and eight percent selected the utility of the video game for more active learning. The rest of the technologies are in a more dispersed position, with minority values between 1 and 4%.

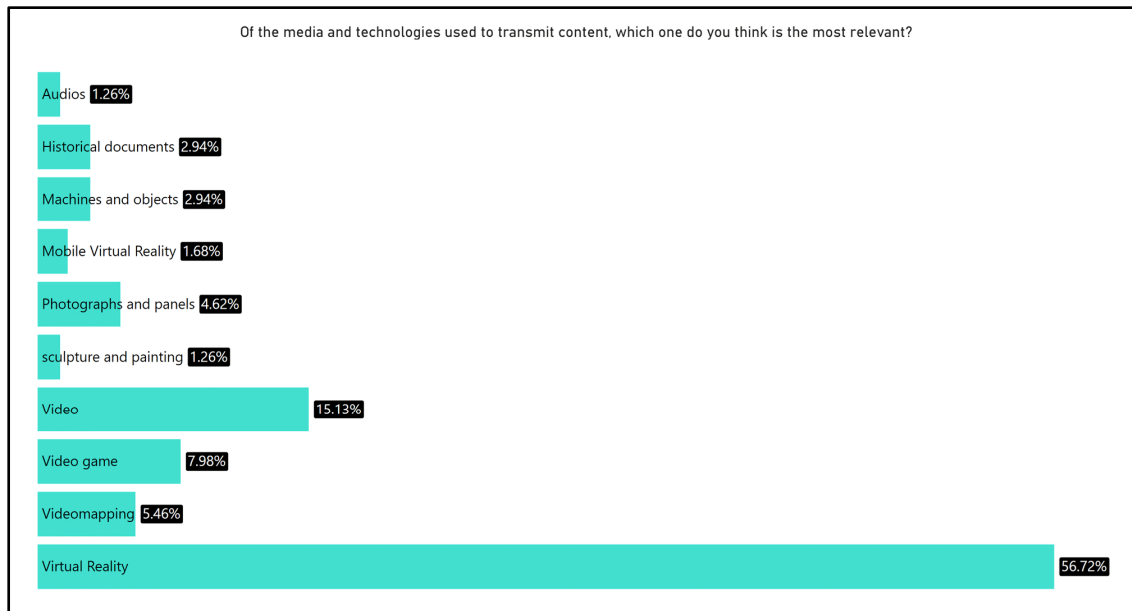


Figure 21. Results of the analysis. Question: Of the technologies used to transmit content, which do you consider to be the most relevant?

The prevalence of virtual reality, videos and videogames clearly remains when investigating with more questions. Respondents were asked to choose only four of the proposed technologies, selecting only those they found most interesting for transferring content. The answers are clear in the same direction. Eighty per cent selected virtual reality as the first option from these four options. 55% also chose videos and 46% chose among those possibilities the contribution of video games. These three technologies are thus consolidated in this study as the three clearest ways of improving learning about cultural heritage and aspects related to history and industrial heritage (see Figure 22).

Of the media and technologies used to transmit content, if you had to choose only four of the following, which would you select?

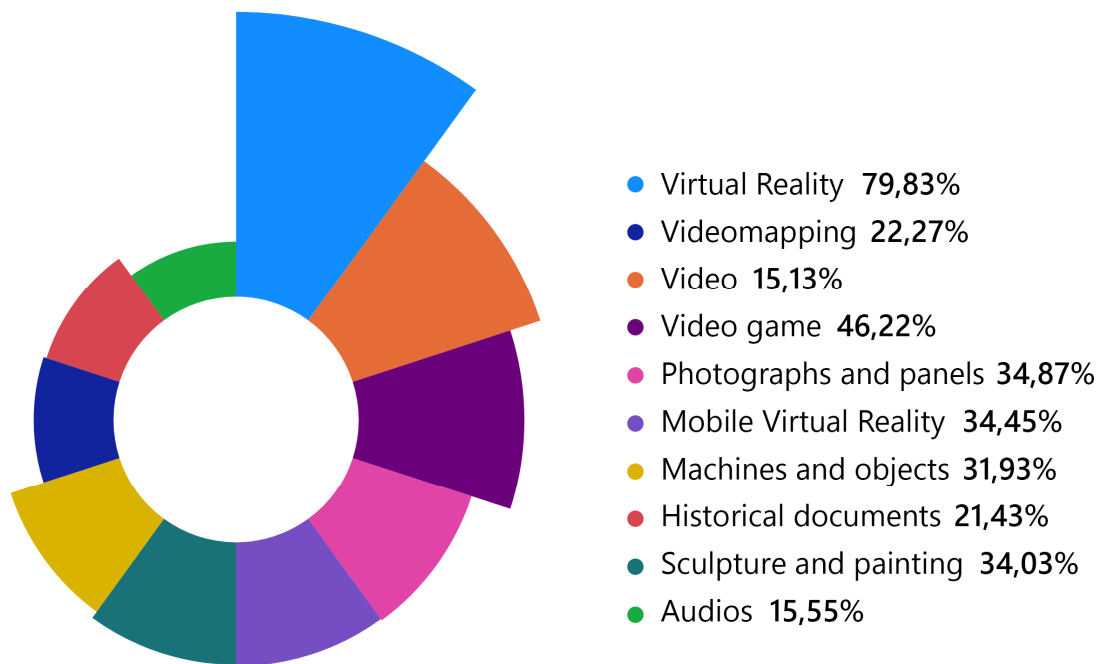


Figure 22. Results of the analysis. Question: Of the technologies used to transmit content, if you had to choose only four, which one would you select?

In conclusion, the results obtained show that the integration of new technologies into an innovative discourse that uses storytelling to transfer knowledge about heritage and industrial history is an effective method that enriches learning. The objectives set correspond to the results obtained and the general response of the users to the stimulus of participating in a dramatized event with a script that allows them to interact with innovative experiences achieves efficient improvements in the retention of the content by the visitors and helps to understand the value of industrial heritage and the meaning that the productive activity has in the urban identity and in the collective memory. Likewise, it is detected with a mixed analysis method (data and demonstrations) that people value very positively the tools of the new technologies that allow them to interact with the exhibition, participating actively and not only seeing panels and showcases with classic content. The value of urban history, the evolution of factories and the industrial heritage of cities is more easily transmitted to the citizen through interactive and participative experiences in which the visitor can enjoy complementary technologies that filter the content of the message. This allows the user to see and experience the importance of industrial development in their city. In this sense, virtual reality, due to its highly immersive character and its powerful visual capacity, heads the list of methods to advance in this type of educational proposals that, without a doubt, contribute to spreading more popularly the cultural value of industrial heritage and history.

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