Article

Alternative Divulgation of the Local Sculptural Heritage: Construction of Paper Toys and Use of the Minecraft Video Game

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Abstract: At present it is easy to digitalize sculptural heritage in 3D. Three-dimensional models allow for visualization of the work from all angles. The result can be seen in three-dimensional visors, in virtual reality, or by means of 3D-printed replicas. However, the recipient continues to be, as is also the case in books and videos, a passive spectator of the cultural patrimony. In order to promote participation and to increase interest in local heritage, alternative methods for promotion of the digital patrimony have been developed. In this article, two means of publicizing local (less-known) heritage in an active manner have been described. On the one hand, the transformation of 3D models into cut-outs (paper toys) where it is necessary to make the sculptures by hand, and on the other hand, the incorporation of the models into the video game Minecraft, an immersed 3D world which permits visiting or generating content. To validate these alternatives, two examples based on the sculptures of Santa Cruz de Tenerife (Spain) have been created, and they have been used in pilot studies in schools in order to obtain a first appraisal of user satisfaction.

Keywords: sculptural heritage; divulgation; paper toys; Minecraft

1. Introduction

The concept of cultural patrimony is permanently in construction through time, and defines those objects, spaces, and traditions which are considered an essential part of the culture of a society and which should be conserved and transmitted to the next generation [1]. One part of the tangible cultural patrimony and street furniture is urban sculptures. In this article, as a pilot trial of alternative publicizing of this patrimony, the collection of sculptures from the 1st International Exhibition of Santa Cruz de Tenerife (Spain) will be worked on.

The publicizing of the patrimony has traditionally been carried out by means of images, videos, the Internet or, at best, via a direct visit to the patrimony of a city or to museums to observe the works [2]. As the sculptures are three-dimensional objects, if they are published via a flat resource as in the case of images, information is lost, limiting the understanding of the works [3,4]. With the appearance of 3D technology and digitalization, there are new possibilities to conserve and publicize the patrimony [5,6]. Currently, numerous databases containing digitalized patrimony in three dimensions exist [7]. Large companies, organizations, and museums are the first interested parties and the most advanced in this sector [8]. As one example, the Smithsonian Museum [9] has free 3D models of its patrimony for three-dimensional visualization and allows the downloading and printing in 3D of all of its models under the Creative Commons license [10]. The 3D technology

for the dissemination of three-dimensional patrimony is already incorporated into higher education. For example, the University of Alicante offers the Master's in Virtual Heritage and aims to research the adaptation of emerging technologies to the needs of the area of heritage, focusing their research on generating technological solutions and 3D for the conservation and study of heritage. This includes 3D modelling, augmented reality, and virtual reality applied to the cultural heritage.

Every day, three-dimensional technology offers more possibilities; however, in the majority of cases, the available resources—although offering interaction on the part of the viewer—continue to be merely expositive material which does not need external participation. In this article, two digital alternatives which permit the dissemination of local or less-known heritage via constructibles and video games, which require the active participation of the user and which incite interaction, are described. In order to validate these alternatives based on urban sculptures from Santa Cruz de Tenerife, two pilot studies have been carried out in schools, and they have been validated with users via satisfaction questionnaires.

2. Materials and Methods

2.1. Alternatives for the Dissemination of Digital Heritage

In order for the 3D digital heritage to be no longer merely expository and to allow for interaction with the user, at present there are multiple alternatives [11,12]. Among them, we may highlight virtual tours (Figure 1a) [13,14]; environments or realities in 3D [15,16]; virtual museums and exhibitions [17–19]; interactive digital worlds like, for example, Second life [20] or Active Worlds [21], serious video games [22,23], augmented reality [24–26], etc.

Apart from the digital environment, a common way to know heritage via active participation is via the construction of three-dimensional models by the person concerned. These models are usually ready-made and represent elements of the patrimony which are very well-known internationally, like, for example, the Aphrodite of Milos (Figure 1b) or the Parthenon [27]. The prefabricated constructions (Figure 1c) are usually made of foam board [28], Lego [29], plastic, wood, or paper, among others [30].

| (a) | (b) | (c) |

Figure 1. Alternatives for the divulgation of heritage: (**a**) virtual tours; (**b**) well-known patrimony, the Aphrodite of Milos; and (**c**) prefabricated constructions.

From 3D digital models and using simple software, you can make paper cut-outs. This software allows automation of part of the process of the creation of the cut-out, the final objective of which is the construction of the sculpture. This technology is usually called paper engineering or paper toys.

The term "cut-outs" or "paper toys" is generally applied to the printed picture on paper or card which, when cut out and assembled, becomes a toy. The history of cut-outs is connected to the very cultural history of a society. These paper toys have formed part of the children's universe since the XVIII Century, being affordable and educational entertainment, as well as being a documentary and social record of the period in which they were printed [31]. The pedagogue Friedrich Froebel (1782–1852) was the first to incorporate the folding of paper into the preschool educational context, considering the action of folding paper as a recreational activity whereby children develop psychological and creative aspects [32]. Currently, the creation of paper toys is included within so-called paper technology or paper

engineering. Such technology refers to the collection of knowledge and techniques for design using paper, mainly via its possibility of being folded and cut, bestowing it with three-dimensionality [33,34].

On the web there are resources which disseminate heritage by means of Paper Toys. Commonly on these pages, the best-known patrimony may be found; for example, the Eiffel Tower or Sydney Opera House. However, less-known resources are lacking. In this work the guidelines for which any person may, using 3D digital files, develop paper toys of the heritage of their city will be explained.

Another possibility for publicizing the sculptural patrimony in an active way for the consumer is via an immersive virtual world in three dimensions. Immersive virtual worlds are digital environments in which a participant uses a digital avatar to interact with the environment [35]. Many alternatives exist for the creation of these digital worlds. In this article a simple and low-cost option is proposed which consists of developing a world using the Minecraft video game. This option offers the possibility of interactively travelling through the digital patrimony and also permits the construction or destruction of the environment, without being bound to predetermined rules.

Minecraft (Microsoft, Redmond, Washington) was launched in May 2009 for computers and in 2012 for Apple's IOS and Android [36]. The worlds may be created and customized by the very user using building blocks of different materials which remind one of LEGO and provide freedom without any objective or script to create what is desired [37,38]. It is a game in which the players are not simply consumers but are also active in the development of the game. Minecraft permits the creation of a world from blocks, building each element piece by piece, but also prefabricated or personalized complete 3D models may also be inserted, allowing the player to navigate on a map and follow the rules built by another person [39].

Minecraft has been used as an educational resource with regard to the teaching of historic buildings and the promotion of creativity or interest in discovery, among others [40]. In other research it is claimed that as it is a sandbox-type game, without rules, the player may build anything and so the user is free to use their creativity [41]. However, as in paper toys, worlds of Minecraft which represent local scenes are lacking.

2.2. 3D Digitalization

Both to introduce sculptures within the world of Minecraft and to create paper toys, it is necessary to begin from a 3D digital model. These models may be obtained from online databases, but there is also the possibility of generating our own material of 3D patrimony at a low cost and with progressively simpler programs.

For this article, two examples have been produced based on urban sculptures in Santa Cruz de Tenerife. The 3D digital models of the sculptures correspond to previous work for publication via three-dimensional models in the classroom [42,43]. These sculptures were created with the free version of a 3D modeler program (Sketchup, Trimble Navigation, Sunnyvale, CA, USA), through free photo-modeling app (Autodesk Recap) and a low-cost 3D scanner (3DSense from 3D Systems). The sculptures belonging to the I International Exhibition of Street Sculpture of Santa Cruz de Tenerife (Canary Islands), which was held between December 1973 and January 1974, were digitalized. The exhibition was a cultural event with the idea of creating a museum space breaking with traditional commemorative sculpture. In the exhibition, a total of 43 sculptors of such standing as Joan Miró, Henry Moore, Óscar Domínguez, Martín Chirino, and Eduardo Gregorio participated. Currently, 30 of the works are distributed mainly in García Sanabria Park and in the Rambla of Santa Cruz. The collection of sculptures present in the city today is an open museum of urban sculptures of great value (Figure 2).

(**a**)　　　　　(**b**)　　　　　(**c**)

Figure 2. Sculptures belonging to the I International Exhibition of Street Sculpture of Santa Cruz de Tenerife: (**a**) Monumento al Gato from Óscar Domínguez; (**b**) Femme Boutielle from Joan Miró; and (**c**) Hombre from María Simón.

Once the sculptures were digitalized, the three-dimensional models were included in a sculpture catalogue, available for free download on the Internet (see the Supplementary Materials). The sculptures are presented printed in 3D and in the traditional book format (Figure 3) where the sculptures are described in a fact sheet (name, description, author, year, materials, dimensions, and link with additional information) with one or various photos of each sculpture and a schematic map of the city with its location. The difference with respect to a conventional catalogue lies in the inclusion of two links: one to access the online visualization of the 3D model and the other to download and print the sculpture in a 3D printer. The links are presented as hyperlinks for the digital version of the catalogue along with a QR code to access the printed format. However, this catalogue remains a static resource which does not require recipient interaction any further than that of observation and manipulation in the case of printed sculptures.

Figure 3. Sculpture catalogue and boxes with the printed sculptures.

2.3. Diffusion via Paper Toys

The material described in this section was generated from the previously indicated 3D models. The design of a paper toy has traditionally been work earmarked for experts as it is necessary to create a two-dimensional template from a three-dimensional object. At present, numerous software applications exist which in general tend to facilitate or enable a process which is very complicated to carry out by hand [44–46].

Currently, free technology exists (SketchUp, Pepakura, Foldi, etc.) which allows for the automatic creation of a paper toy from a 3D model [44]. These applications permit the transformation of a 3D digital model into a flat figure which may be printed on paper. The aforementioned paper figure is cut using scissors and the original 3D figure may be reconstructed.

The design of a paper toy using the digital means described below constitutes a process which consists of three phases. The first phase consists of obtaining a three-dimensional digital model; the second phase is deploying this 3D model to create a flat template; lastly, postproduction is used to add details and color. In order to explain each of the stages, the Monument to the Cat sculpture by the Spanish artist Óscar Domínguez has been chosen as an example. This sculpture was part of the I International Exhibition of Street Sculpture in Santa Cruz de Tenerife between 1973 and 1974, and it is at present located in García Sanabria Park in the city.

In the digital display, the three-dimensional model is transformed into a two-dimensional template. This step is essential and is the most characteristic in the design of a Paper Toy. For that purpose, various free applications exist, like, for example, 123D Make, Pepakura Designer, or plugins for SketchUp (among which there are Unwrap and Flatten Faces). For this example, 3D design software was used. SketchUp accepts the installation of various free plugins which expand its features. Among these, we find Unwrap and Flatten Faces which allow for the location of selected sides on the floor. This program does not create the template automatically; instead, it is necessary to slowly unfold connected sides to achieve the final template. In addition, it is necessary to draw the tabs to subsequently build the model in paper. In spite of this, it is a very interesting option as it allows us to create a personalized model and unfold it as we wish. Its user difficulty may be considered medium, and it is suitable for users with knowledge of Sketchup (Figure 4).
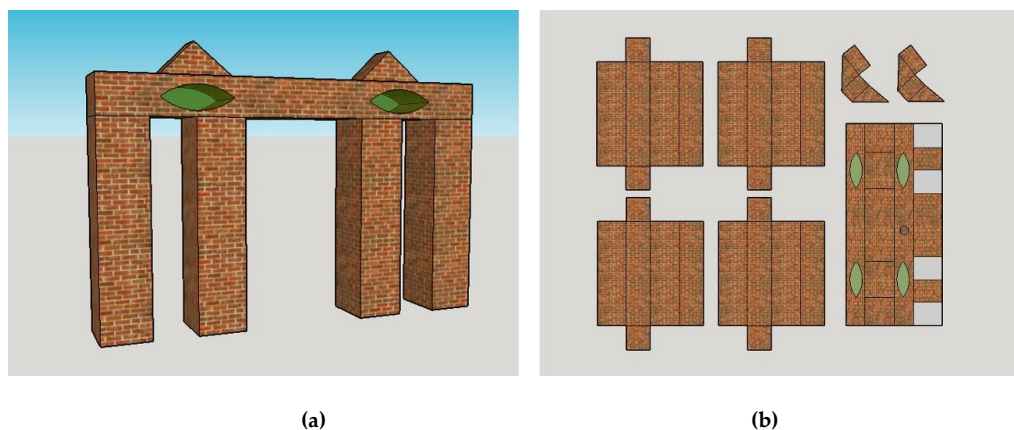

(a)   (b)

Figure 4. Monument to the Cat sculpture: 3D geometry (**a**) and top view of unwrapped and flattened faces (**b**).

In the postproduction stage, the cutout is personalized using any graphic design program (Photoshop, Illustrator, Gimp, Inkscape, etc.). At this stage the finishing graphic elements are added, like color or images which simulate texture, etc. The template may also be produced without color, offering the possibility of coloring the models.

To obtain an initial assessment of the possibility of diffusion of the patrimony using the designed paper toy book, a pilot trial was carried out using 27 students (divided into 13 groups of two and three people) from the Echeyde II School (CPEIPS) in Tenerife, in which the participants had to cut out and build the paper sculptures. At the end of the activity, a questionnaire was given to the participants. This questionnaire, with a total of four questions, was rated according to the Likert scale from 1 to 5, where 1 is not in agreement and 5 represents totally in agreement. It asked about the interest this material created to know about the patrimony, about the ease of use, and about the usefulness to understanding the three-dimensionality of the sculptures. The time taken to build each of the paper toys was also measured.

2.4. Diffusion via the Virtual World of the Minecraft Video Game

Just like the paper toys, a world in the Minecraft video game was created using the 3D models described in Section 2.1. The virtual world of Minecraft is a simplified reconstruction of reality using blocks. In our case, a world was created which represents the Rambla and the García Sanabria Park of the city of Santa Cruz de Tenerife in Spain. In that area of the city, the sculptures of the I International Exhibition of Street Sculptures, a sculptural heritage which is representative of the city, may be found.

The sculptures are oversized in the game to avoid loss of detail on transforming them into a block element. In order to roam the virtual world, it is estimated that approximately half an hour is required—a similar time to that needed to walk down the Rambla in the real world. The construction of the virtual world began with an extra-slim map into which elements of the world like trees, roads, gardens, etc., were incorporated. In order to carry out this task, a complementary program called MCEdit, which allows for large areas to be selected and materials to be applied, was used. Materials such as predesigned trees were used to optimize the creation time of the Minecraft world.

To add the 3D models of the sculptures of Santa Cruz de Tenerife, it was necessary to transform the 3D digital formats (Figure 5) into Minecraft formats called Schematic. A very simple and free way to carry out this transformation step is by using Tinkercad (Autodesk, Inc., San Rafael, CA, USA) [47]. In order to introduce the 3D file generated in the previous step into our world, MCEdit was again used. Finally, in the game, a sign was added to each sculpture with its name and the corresponding artist to complete the scene. Additional description can be added by using the "book and Quill" tool in Minecraft.
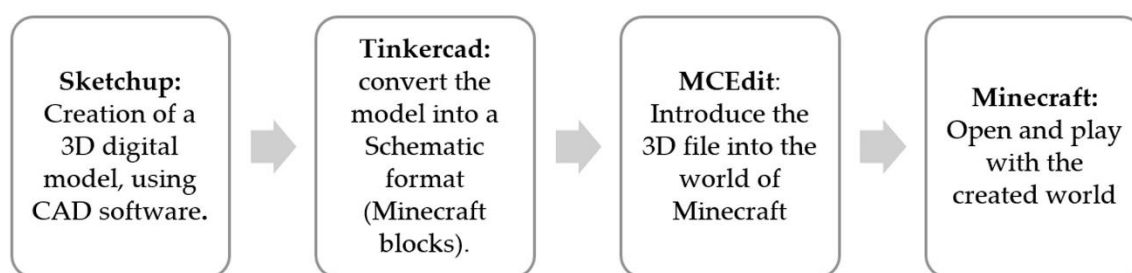

Figure 5. Process to introduce the 3D digital models into Minecraft.

In order to obtain a first appraisal of the possibilities of diffusion of heritage using the designed Minecraft world, a pilot test was carried out using 16 students (distributed into five groups) from the first year of Baccalaureate in the MM. Dominicas Vistabella de Santa Cruz de Tenerife school; in this test, the students had to roam the created Minecraft world and visit all the sculptures. At the end of the aforementioned activity, a satisfaction questionnaire was given to the participants. This questionnaire, with a total of six questions, was rated according to the Likert scale from 1 to 5, where 1 is not in agreement and 5 represents totally in agreement. It asked the students if they considered Minecraft to be a useful way to learn about patrimony, about its ease of use, and if they considered it to be a good complement for learning. In the aforementioned activity, the time required to finish the entire route was also measured.

3. Results

With respect to the diffusion of cultural patrimony via Paper Toys, the results were as follows: A total of 12 paper toys of local sculptures located in the city of Santa Cruz de Tenerife were created. The templates of these cutouts were grouped in book format for publication. The selected sculptures readily lend themselves to creating paper toys, as the geometry of the majority of them is simple.

In spite of this, in many cases the model was simplified to facilitate its construction.

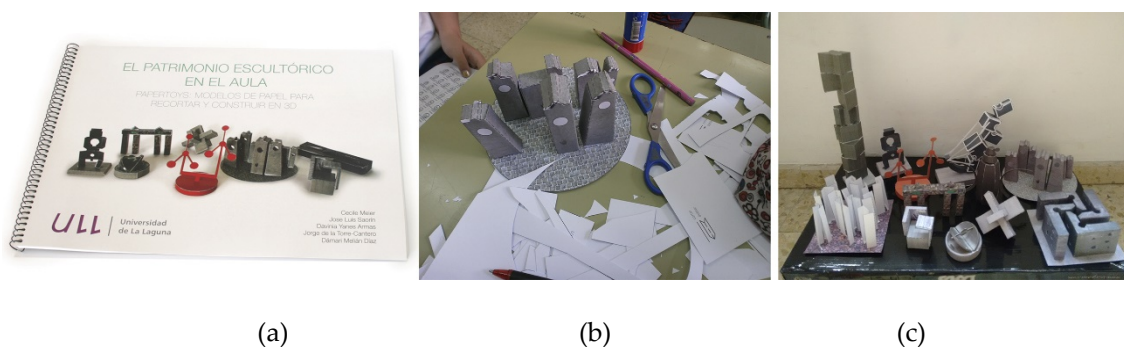The book (Figure 6) is available for download (see Supplementary Materials).

(a)　　　　　　　　　　　　(b)　　　　　　　　　　　　(c)

Figure 6. The paper toy book (**a**); pilot test in the classroom (**b**); result of the pilot test (**c**).

In Table 1 we may see the average time that the groups of students took to finish the sculptures. Some of the sculptures were not built, as the students had freedom of choice of the templates and some were not chosen. On the other hand, other models were constructed several times by different groups. As is logical, the time spent on each sculpture and its completion depended on the skill of each group of students.

Table 1. Results for the construction time of the paper toys.

Sculpture	Finished	Total Finished	Average Time
Femme Bouitelle (Joan Miró)	no	0	-
Introversión (Josep María Subirachs)	yes	2	30 min
Macla (Eduardo Gregorio)	yes	3	38 min
Monument to the cat (Óscar Domínguez)	yes	2	37 min
Hombre (María Simón)	yes	1	40 min
Untitled (Feliciano Hernández)	no	0	-
Móvil (Francisco Sobrino)	no	0	-
Homenaje a Millares (Claude Viseux)	yes	2	35 min
Tribute to the Canary Islands (Pablo Serrano)	yes	1	50 min
Dado para 13 (Remigio Mendiburu)	yes	2	87 min

The results of the questionnaire on paper toy satisfaction in the pilot trial carried out in the Echeyde school are shown in Table 2.

Table 2. Results of the questionnaire on Paper Toy satisfaction.

	Questions	Results N = 27
1	Building paper toys of sculptures is an interesting resource for learning about sculptural heritage.	3.78 (1.01)
2	Building paper toys is an interesting activity to help understand the three-dimensionality of the sculptures better.	4.41 (0.84)
3	I would like to carry out more activities like this in the subject.	4.74 (0.66)
4	The building of the paper toy has been easy.	3.48 (1.09)

With respect to the diffusion of the patrimony via a Minecraft world, the results were the following: A Minecraft world was created (Figure 7) using low-cost or free technology. In this case, it was necessary to buy Minecraft licenses (23.95 Euros) in order to have an official version installed and to be able to share and import a world created by another person. On saving this world, a version is created in a folder of the computer. This folder may be shared with other users. The world is available for free download (see Supplementary Materials).
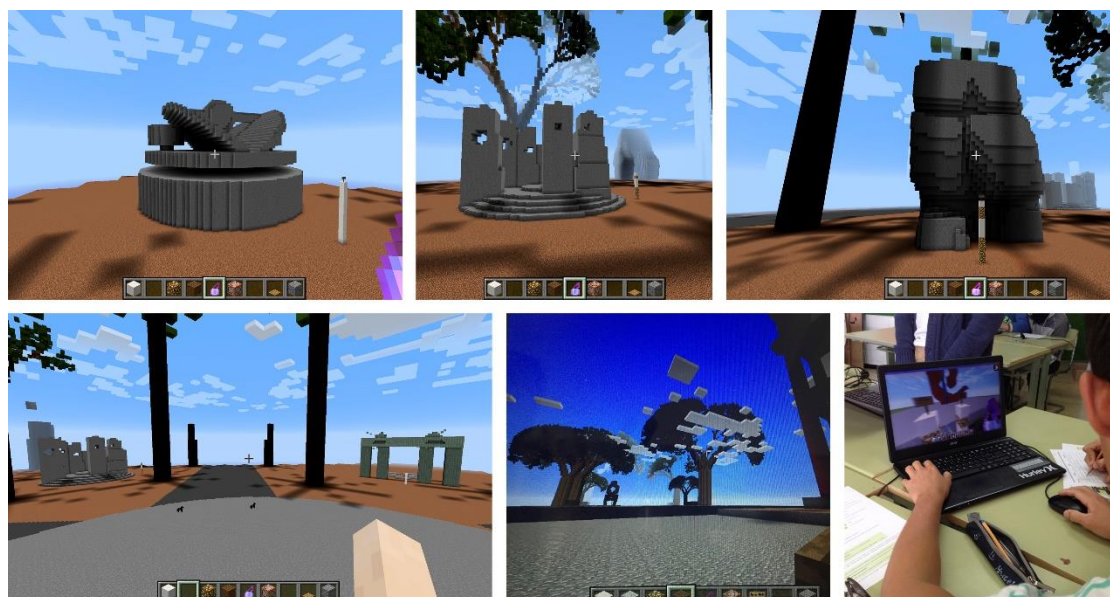
Figure 7. Views of the virtual world created in Minecraft.

The time control for the activity was carried out by noting the start and finish times (Table 3). The route was planned to be carried out in 30 min; it is important to note that the majority of the users needed more time than expected.

Table 3. Results of the questionnaire on paper toy satisfaction.

Group	Start Time	Finish Time	Total Minutes
Group 1	9:00 am	9:45 am	45
Group 2	9:00 am	9:45 am	45
Group 3	9:15 am	9:45 am	30
Group 4	9:00 am	9:45 am	45
Group 5	9:00 am	9:45 am	45

The results obtained confirm that the route through the Minecraft world may be carried out in a predetermined time, and the students appraised the activity positively. The results for the Minecraft satisfaction questionnaire in the pilot trial carried out in MM. Dominicas Vistabella in Santa Cruz de Tenerife are shown in Table 4.

Table 4. Results of the satisfaction questionnaire for Minecraft.

	Question	Results N = 16
1	I would like to do more activities based on Minecraft	4.29 (0.73)
2	I believe that the use of Minecraft increases my motivation to study and learn in class	3.71 (1.07)
3	Learning with Minecraft is a good complement in combination with traditional materials	3.79 (0.97)
4	It has been easy for me to operate in the world of Minecraft	3.93 (1.07)
5	The use of a world of Minecraft is useful for the teaching–learning of urban sculptural patrimony	4.14 (0.66)
6	Carrying out the activity has made me aware of the urban sculptures of Santa Cruz	4.14 (0.77)

4. Conclusions

With respect to the diffusion of cultural patrimony through paper toys, it has been confirmed that the creation of personalized paper toys of the patrimony of any city is possible via free and simple-to-use programs, appropriate for any person without advanced knowledge of computing.

The exercise carried out with paper toys in a secondary education classroom allowed us to conclude that it is a cheap and accessible resource which allows the students to build and visualize the sculptures in three dimensions with neither the need for technology nor the need to leave the

classroom. In this way they also manage to appreciate the three-dimensionality of a work better than when only a flat image is available. The average time the students took to build the different models ranged between half an hour and one and a half hours. The time spent on each sculpture and its completion depended on the skill of each group of students because, eventually, fine psychomotor skills are required to build paper toys.

According to the results of the questionnaire, the building of paper toys was considered by the participants to be an interesting resource for learning about local sculptural heritage (3.78/5). They also considered that the building of paper toys was an interesting activity for learning about the three-dimensionality of the sculptures (4.41/5).

On the other hand, the participants positively rated the educational experience with the use of paper toys as a didactic resource and showed great interest in carrying out similar activities in the subject of Plastic and Visual Education (4.74/5); they also considered the building of the paper toy to have been easy (3.48/5).

With respect to the diffusion of cultural patrimony by means of Minecraft, it may be concluded that to replace or complement visits to the sculptures of a city, it is possible to build an immersive virtual world without advanced knowledge of computing by using the Minecraft video game. In addition, the creation of a world in Minecraft with the necessary complementary programs is free, allowing anyone to be able to create their own local digital environment. The only cost would be the purchase of the Minecraft licenses (23.95 Euros) to allow other users to access the created world.

The Minecraft virtual route was completed without any problem by the participants in less than an hour (45 min on average). The virtual route described in this article may be carried out in any room with computers. It is not necessary to have knowledge of Minecraft, as almost all young people know how to use it and cope in a virtual environment, and those who do not can learn in a few minutes.

It should be emphasized that the prospect of more Minecraft activities was considered in a positive way (4.25/5) and that the experience motivated them to study (3.71/5). The participants found it relatively easy to operate in the Minecraft world (3.92/5). In addition, the activity serves not only for learning purposes, but also makes the users conscious of the existence of the local sculptures of Santa Cruz (4.14/5).

As the final conclusion of this work, we indicate that alternatives may be created, starting from 3D models of less-known heritage, which allow the user to interact with sculptures in a new way. These alternatives are well considered by the users not only as a means of diffusion but also as learning material. In addition, simple digital programs and tools exist which allow for the creation of these alternatives by anyone at a very low cost, or even for free. Frequently, similar results are achieved thanks to expensive tools. For the two proposals put forth in this work, the results obtained are similar. It also would be interesting for future research to consider targeting a wider range of users (use for example, older people).

Following the work described in this article, a 3D interactive virtual world is being created using the Unity video game engine. In this way, the problem of the cost of the Minecraft license is solved, and the generation of material in different formats and for different platforms like virtual reality, webGL, mobile devices, etc., is allowed.

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