3D Online Virtual Museum as e-Learning Tool
A Mixed Reality Experience

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Abstract: The paper discusses the use of 3D online virtual museums as educational instruments for children in economically disadvantaged communities. It discusses the advantages of simulation and immersion as learning enhancements, compared to traditional learning methods, using a case study based on the currently on-going work of development of a virtual museum (www.timemaps.net/timemap/?page_id=6). Presenting chronologically layered information, the museum offers a series of e-learning modules teaching traditional crafts technologies. The current audience is represented by children from a Romanian village community. The paper covers a description of the methodology used, as well as an evaluation of the usefulness of the solution by the target audience. In conclusion, the paper outlines a strategy for further development of the proposed e-learning solution.

1 INTRODUCTION

Distance-learning (Aldrich, 2009:48) has become a method of choice, using virtual environments in order to provide accessible education in underprivileged environments. We have used it as a solution to facilitate the access to education in remote and economically disadvantaged communities, by initiating an educational project – "The Maps of Time - Real communities-Virtual Worlds-Experimented Pasts" (Grant PN II IDEI), linking these communities to the research centres and urban education institutes, such as the National University of Arts Bucharest (NUA).

The paper presents one of the educational experiments within this research project, conducted by Professor Dragoş Gheorghiu in Vădastra village, Oltenia County, in southern Romania. Participation in the experiment has included specialists and teachers from our university, as well as teachers and children from three secondary schools. The experiment consisted in the implementation of a 3D virtual museum comprising 3 archaeological levels, with realistic reconstructions of ancient objects and using Mixed Reality (Milgram and Kishno, 1994) to augment the 3D virtual environment with video films. The educational content (3D reconstructions and the professional video films), was developed by masters' program students and artists from our university, under the supervision of Professor Dragoş Gheorghiu.

The objective was to create e-learning solutions supporting the teaching of traditional technologies in an intuitive, engaging, play-immersive manner, leading to the enhancement of the traditional, curriculum-based learning, through the use of innovative and cost-effective ICT technologies, and learning by doing (Dewey, 1938; Schank, 1995). Finally, the experiment aimed at the creation of a learning community. The paper presents the details of the learning experiment as a case study, in relation with other experiments that were performed in similar international and national projects, followed by an evaluation of the learning outcome. The conclusions of the experiments are presented,

Figure 1: The entrance in the virtual museum.

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validating the use of the 3D virtual museums as modern and effective learning instruments. The paper closes with an outline of the future development strategy.

2 THE IMPORTANCE OF MUSEUMS FOR EDUCATION

The limitations of traditional learning methods have been addressed in several papers. Relan and Gillani (1997) characterize formation using the traditional educational settlements as follows: a) Spatial and temporary structures, in which learners should adapt; b) Learning geographically limited to classrooms, laboratories, etc. and disciplines are taught at predetermined times and in a pre-established order; c) The physical presence of student and teacher in the same classroom is an indispensable requirement, so that learning can occur (see also Campas, 2008).

2.1 Traditional Museums

As early as the 19th century the museums started to be reconsidered for a systematic use as educational instruments. These "were placed on the front line in the educational agendas of the period. This was evident in the increasingly close connections between museums and the development of compulsory public schooling, and in the stress that was placed on the value of museums as instruments of adult education" (Bennet, 2004).

On the other hand, the educational results to be achieved from visiting traditional real-life museums have their limitations, due to: a) relatively conventional presentation methods; b) limited accessibility (in time and space); c) limited visiting time; d) static, non-interactive visits, often without a guide to provide explanations.

2.2 Modern Museums

As Germain Bazin anticipated long time ago, we live now in "The Museum Age" (de Leeuw 1999: 79). In the 21st century the modern museums improved the users' experience through the introduction of interactivity, and of the online versions of the institutions. Beside modern ICT technologies, today's museums promote:

- a new way to look at the past (Wheat-Stranahan et al., 2007);
- online multimedia content; The European Virtual Museum, implements a dynamic web site based on "user-friendly interactive databases", stating that a "System of Management for interactive databases (RDBMS) is crucial in order to create a virtual museum";
- an immersive experience using Virtual Reality applications and 3D modelling in online museum environments (Hermon, 2008).

2.3 The Advantages of Virtual Museums

Several advantages can be derived from creating and visiting virtual museums:

- unrestricted accessibility regardless of time and location;
- the capacity to display ancient monuments and objects in their complete form;
- (virtual) access to otherwise (physically) inaccessible places in a monument;
- the capacity to interact with the museum's objects;
- the capacity to enable virtual tourism (Maiorescu and Sabou, 2013; El Hakim et al., 2004);
- the capacity to use simulation and recreation as educational tools (Politis and Marras, 2008);
- the capacity to access complex museum presentations as reconstructed objects alone, or in their historical contexts, as well as objects augmented with explanations;
- an educational exploration at reduced cost, requiring only a good Internet connection;
- interactive communication of cultural heritage in public spaces (Trapp et al., 2012).

2.4 The Advantages of Learning in Online 3D Virtual Environments

The advantages of learning in 3D virtual environments, as a form of distance education (Annetta et al., 2010), have been outlined by several theoretical papers. Winn (2002) states that one important ability of 3D virtual environments is reification, by which objects that are not accessible to the human senses are transformed into "visible, audible and tangible objects" (Gell-Mann, 1994).

Another characteristic of 3D virtual environments is user's immersion in the virtual space, which creates a feeling of presence and stimulates the learning outcomes (Winn, 1995; see also Dickey, 2003; Dede, 2009). The immersion in an artificial environment can help learners to better understand the tri-dimensional dynamic processes (Winn, 1995), facilitates both the verbal and non-verbal communication and collaboration (Kappe and Gütl, 2009) or other "important life skills" (Annetta

et al., 2010).

The physical presence has a strong cognitive function, leading to a higher level of involvement of the learners in the learning process. This implication is considered more important for the "conceptual modification than the cerebral activity, typically necessary for problem solving based learning" (Clark, 1999).

A virtual world can enhance an experiential learning process through activities such as simulation and role-play. It also "promotes immersive learning as the learner can potentially experience the emotions and thoughts of someone in a simulated situation" (Macedo and Morgado, 2009).

These environments also support the self-paced learning style, i.e., the possibility for the student to resume or repeat the learning process.

For human sciences, 3D environments can have a stronger cognitive impact, as they give learners the feeling of being in the simulated reality, thus improving the understanding and memorization of the information. Possessing an important spatial component, the 3D virtual environments allow users to freely change the visualization perspective. Finally, not the least important aspect, 3D virtual environments allow the simulation of virtual time travel.

3 THE MIXED REALITY PARADIGM

According to the definition of Milgram and Kishino (1994) Mixed Reality (MR) is a "subclass of VR related technologies that involve merging of real and virtual worlds".

Augmented Reality (AR) is a technology, which allows an enhancement of the reality using virtual information (Azuma et al., 2001). When a virtual environment is augmented with content from the real world, the process is called Augmented Virtuality (AV). Milgram and Kishino (1994) proposed an integration of the two technologies, called Mixed Reality.

The augmentations enhance the learning outcome since "the AR/MR systems allow the augmentation of the user's perception of the real world, but also the use of existent visual and spatial abilities and an enhancement of the interaction capacities of the users" (Holza et al., 2011). This is why the AR systems have to "give their users the illusion that digital objects are in the same space as physical ones" (Costanza et al., 2009), and therefore "the digital objects need to be precisely positioned into the real environment and aligned with the real objects in real time" (Azuma et al., 2001). When the augmentation is applied to virtual environments this requirement is not imperative.

4 SIMILAR WORK

There are currently several projects which address the presentation of the virtual heritage: "Museums are now taking a much wider interest in the use of ICT to leverage better value out of their collections; a simple internet search on museums and ICT reveals many hits detailing museum activity "(White et al., 2004).

It is worth mentioning the online versions of the Romanian Peasant Museum (Bucharest), which offers virtual tours and online visualizations' or the Louvre Museum, which exposes 3D reconstructions of the museum's artifacts. Even though they are not implemented with an explicit educational objective, they are significant examples of the innovative technologies employed by online virtual museums.

Recently, several EU-funded research projects have aimed at developing innovative technologies for museums to create interactive 3D Virtual Exhibitions on the Web. For instance, AMIRE is a EU IST Program dedicated to the efficient creation and modification of MR applications, authoring metaphors and generic design recommendations and procedures. In the ARCO project the elaboration process is described as follows: "virtual exhibitions are created by digitising museum artefacts, which are then transformed into Virtual Representations, which can be X3D or VRML models or scenes" (White et al., 2004).

Another example is the virtual project "A History of the World in 100 objects" (AHOW) run by BBC Radio 4 and the British Museum in 2010 (Cmeciu and Cmeciu, 2013).

Within our project we sought to experiment with several e-learning solutions for the community of teachers and children at the secondary school of Vădastra, in order to address the needs for informal learning using modern IT technologies and e-learning paradigms, and evaluate the effectiveness of each particular solution for long-term use; for this purpose we developed mobile-learning solutions described in Ştefan and Gheorghiu (2013) and Gheorghiu et al. (2013).

5 THE RATIONALE OF THE RESEARCH PROJECT

The village of Vădastra, Olt county, southern Romania, was selected for several reasons: it is a clear example of the deep cultural crisis experienced by rural peripheral settlements in the early 21st century, a crisis brought about by rapid social changes; it is here that a decade ago our university had initiated a project to preserve the immaterial heritage of the village traditional technologies.

We felt that an overview of the history of the place (a palimpsest of successive habitations from prehistory to modern times) could, apart from facilitating learning, recreate a sense of its identity, which had been erased during the country's totalitarian period. As a topic that might interest the community through its pragmatic, economical aspect, we insisted on the rediscovery of ancient and traditional technologies, which form the immaterial heritage of the place.

Centering the learning strategy on this subject, the artists and technicians from our university began to develop e-learning lessons teaching different crafts representative for this geographical area.

Each of the solutions tested in the research project has proven its effectiveness in enhancing learning especially when solutions were designed with a clear learning outcome and also understandable for children to use, but also revealed some limitations: the difficulty to use the solutions outside the project because it required prohibitively expensive equipment; insufficient teacher support and insufficient engagement in the learning process.

This led us to the development of a more intuitive solution, usable with the technological means that the school already had, or could afford. Initially, we designed a 3D virtual museum as an informal e-learning environment for ancient traditional technologies, considering that this would better serve our learning objectives and prove appropriate for the target community group. Nevertheless we mixed the learning in a virtual environment with practical classes in a blended learning perspective (i.e., mixing several technologies and learning styles for an optimal learning outcome).

5.1 Research Questions

Our archaeological and pedagogical strategy was formulated after a research which can be condensed in the following questions:

a) which are the historical stages that can define the identity of a place?
b) which are the contexts representative for each of the identified periods?
c) which are the technologies representative for each of the chosen contexts?
d) which are the objects representative for each of the technologies?

6 CASE STUDY: THE 3D VIRTUAL MUSEUM FOR A VILLAGE COMMUNITY (VĂDASTRA, SOUTH OF ROMANIA)

After several archaeological experiments, a database of videos and 3D reconstruction was created and explored as a 3D virtual museum. Designed by Professor Dragoş Gheorghiu on 3 levels, to suggest the stratigraphy (sequence) of the major historical periods in the Vădastra village (i.e. the modern, Roman, and prehistoric), the museum contains exhibits specific to each period, which are augmented with videos representing craft technologies.

These augmentations of the virtual space are embedded in 3D virtual panels and are displayed as still picture frames. A click on the panel launches the videos in a separate window player.

The 3D virtual museum is implemented as a Unity3D application integrated in the project's website (www.timemaps.net/timemap/?page_id=6).

The virtual museum can be explored in a game-like manner: the mouse is used for camera (perspective) control; the direction keys, for spatial - temporal navigation.

To resemble a real museum, a character called "The Guide" was created, with the role of providing an explanation at the entrance of each level of the museum. "The Guide" is designed as a friendly persona, to engage the users, both children and teachers, to explore the museum. It is similar to a *Non-Player Character* in certain video games, but designed with a limited functionality within the virtual museum application.

6.1 The First Level of the Museum

The virtual Museum opens with a first "artistic" room: here, visual artists and experimentalists' interpretations of ancient and traditional objects are presented, as models of revitalization of both the high culture art and the folk art. Children learn that

modern art can be inspired by the traditional one, and artistic techniques to manufacture various objects are explained to them.

From here on children travel in space and time into the second room of the museum, which exhibits Roman objects, reconstructions of the fragments found in the village and in the nearby region and exhibited at the Romanaţi Museum in Caracal.

The time travel continues to the prehistoric past into the room displaying a Chalcolithic house (excavated in Vădastra in the 70s), together with reconstructed prehistoric everyday life objects.

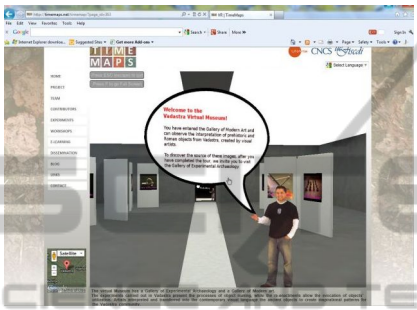

Figure 2: The "Guide".

6.2 The Second Level of the Museum

The second level is represented by the Roman period. Many technologies, such as manufacturing and pottery, or the textile art, have survived the period with very small changes until the pre-industrial period. This level has been reconstructed to emphasize a *villa rustica*, discovered by the first author near the village, in which different domestic industries are showcased: pottery, weaving, glass manufacturing or metal casting.

All the tools necessary for those technologies, the complete form of the villa and the surrounding landscape were reconstructed under the form of a Unity 3D Virtual Reality. The hyper-realistic reconstruction allows, as in the previous case, a strong immersion of the visitor. The augmentation of the 3D virtual space with records of the technologies to be studied, contribute to this process of immersion.

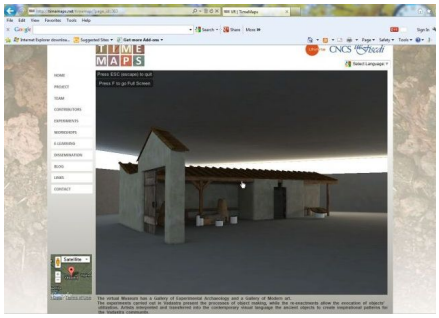

Figure 3: The Roman room of the virtual museum.

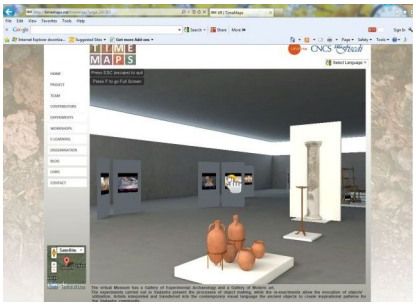

Figure 4: Objects in the Roman room of the virtual museum.

6.3 The Third Level of the Museum

The third educational level of the museum is represented by the Chalcolithic village (5th millennium BC), belonging to the eponymous Vădastra culture. Here also we wanted to highlight the technological traditions, especially the weaving one, which, as has been noted after the exceptional archaeological discovery of a prehistoric textile at Celei, near the Vădastra village, had continuity until relatively recent times. The children experience the living space of the prehistoric settlement and access the augmentations of the reconstructed house under

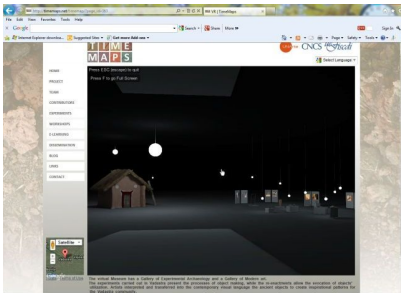

Figure 5: The prehistoric room of the virtual museum.

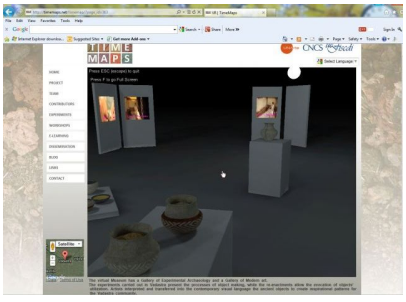

Figure 6: Objects in the prehistoric room of the virtual museum.

the form of videos presenting house construction techniques and weaving techniques for the Celei textile.

6.4 Technical Description

The modelling of the virtual museum was performed with Autodesk 3ds Max and Maya specialized software, which allowed not only to achieve the realistic reconstructions, but also to implement optimization techniques for the real time rendering of the 3D scenes and objects, such as texture baking and LOD (levels of details) optimization. The Unity3D platform was used in order to integrate the virtual museum in an online environment and to implement the Mixed-Reality techniques.

Unity3D is an authoring tool and a gaming engine for 3D video games and 3D interactive content, which support programming in C ++ or C # and also provides a powerful scripting language.

The reasons for selecting this platform were: performance optimization for real time rendering; multi-platform support for the Unity3D web plugin (Microsoft Windows and Mac OS X) and for applications (Windows, Mac, Xbox 360, PlayStation 3, Wii, iPad, iPhone, Android); and the advanced graphical editor.

To run the application in the web browser, the Unity3D web plugin is required. This can be a disadvantage when repeatedly running the application, as the web plugin has to be loaded every time. We tried to reduce this inconvenience by capturing the user's attention with explanatory texts.

6.5 The Methodology

The main purpose of our Virtual Museum is to integrate pedagogy and new technology (Annetta et al. 2006). The Museum offers a presentation of local history and of the technologies specific to each historical period in their historical context, by using virtual reconstructions. By presenting historical contexts virtually reconstructed, the design of the Virtual Museum offers the learners a structured information on: a) the objects of each context, in a 3D reconstruction; b) videos with technological gestures for creation of these objects; c) a series of performances of the usage of these objects during the historical periods.

For supporting the e-learning tool, each technology was filmed from at least two view points: the actor's view and the observer's view. In this way, the child who wishes to learn a certain technology has a complete understanding of the technological gestures. Teaching in a virtual and immersive environment allows flexibility in structuring the course material; the teacher having the following pedagogical objectives: a) acquisition of historical data; b) acquisition of technical data and skill development during the presentation of the technologies (Annetta et al. 2006).

It is worth mentioning the exploratory aspect of the pedagogical and learning activities, by engaging and capturing the attention of the children involved in the learning process. For this aspect we used an approach focused more on the direct teacher-learner relation. First, during the history or technological lessons, the local teacher navigates, together with the children, through the site and the virtual reconstructions, explaining to them the reconstructed local history. The second phase is the professional/practical approach: we organized during the summer of 2012 and 2013 a series of workshops (on textile and glass engraving) for the children in Vădastra, where they worked under the coordination of a teacher or a technician. During the school semester, this experience was evaluated remotely, from our university, in this way: a) the teachers transmitted to the children a theme from the Virtual Museum, which they individually studied. b) the teachers organized video lessons in which each child presented the results of his/her work, which has been further corrected and evaluated. In this case of learning by doing, the evaluation through questionnaires was not applicable.

Beside the 3D Virtual Museum, traditional methods of distance education were also used. Skype-based videoconferences were organized at our university in order to connect the academic specialists with the teachers and children from Vădastra, and to offer them various lesson plans. For example, we proposed to visit the Neolithic village and investigate how prehistoric art can be transformed into modern art.

At the beginning the university artists proposed different learning paths and explained in detail each object and its corresponding technology. Thus, using guided tours via Skype we could coordinate the actions of the school teachers to efficiently use the 3D Virtual Museum, eventually leading to sufficient proficiency so as to be able to create their own lessons. As a conclusion of these learning practices, Vădastra School has introduced two applied classes (on ceramics and textile), where the children could reproduce many of the Virtual Museum's objects. Consequently, our university has initiated with our students an online course in order to supplement the activity of the village teachers.

7 RESULTS EVALUATION

In the case of using the Virtual Museum for learning about the local history and for revitalization of arts and crafts of immaterial heritage, we applied two methods: a) the one of the local history teacher who will use semi-structured interviews; b) the one of the technology teacher who will use the visual contact with the children (direct or via Skype) for evaluation.

The 3D virtual museum was experimented for a six-month period, during which the project team provided technical and pedagogical assistance. The experiments took place in the Vădastra secondary school community, grades 1-4, 5-8, as well as in two urban school communities, Râmnicu Vâlcea (Central Romania) and Piatra Neamț (North Romania), allowing us to verify the effectiveness of our learning methods in different cultural environments.

Throughout the experiments, monitoring was performed by collecting feedback, suggestions, and recording of technical problems, thus gathering an important quantity of useful information. The data was collected using Google Docs together with the answers from 6 teachers (aged 25-40) and 9 children (aged 8-15).

To use the site of the project as an applied learning instrument, we further proposed a set of refined questions focused on the virtual and real experience of the children, which starts from mental immersion and ends with the manufactured objects:

Table 1: Questionnaire for results evaluation.

Which was the most interesting historical period?
Which were the most interesting objects?
Which object have you chosen to make?
How much time did you work for the practical workshop?
How much time did you work with the online teachers?
How realistic did you find the architectural 3D reconstructions? (answer with a mark from 1 to 7)
How realistic did you find the objects' 3D reconstructions? (answer with a mark from 1 to 7)
What have you learned from the 3D experience (local history, manufacturing of objects, use of objects, a.o.)?
Which were the criteria for choosing an object (form, texture, size, position in context)?
How many times did you play the film with the 3D reconstruction of your object?
What have you learned from these films (form construction, decoration making, a.o.)?
What can you make in the present? Can you manufacture an object without help? (answer by enumeration of the technological operations)

We also proposed a peer assessment (Aldrich, 2009), through which we asked the Vădastra school teachers to assess the professors who coordinated the lessons.

8 DISCUSSION

The post completion analysis of the project identified the following limitations of the approach: in some cases establishing the logical connection between the 3D reconstructed objects and contexts and the technological film required the viewers (children) to have prior knowledge of the subject, or to receive explicit guidance. Therefore, the learning process within a virtual environment must allow the teachers to design by themselves the guided tours, i.e. to have a greater degree of flexibility.

In spite of the opinion expressed in Di Blas et al. (2008), we considered the educational importance of 3D realistic reconstructions for the museum objects while we performed simplifications regarding the modelling of the museum space.

The technical problems were related only to the quality of the Internet connection and the delay caused by the loading of the Unity3D web plugin at each application launch.

We used some of Aldrich's (2009) suggestions to perform assessments for "grading student performance", namely to write a paper about the experience in the virtual museum, to keep a journal during the experience, and create a multimedia production, in our case weblog and Facebook postings.

We appreciate that the educational advantages of the mixed-reality experience in an immersive 3D environment was highlighted by the following:

- The visual presentation of the exhibits corresponding to different historical periods allowed a good message retention and understanding.
- The videos have increased the educational value of the learning experience since they improved the viewer's sense of reality.
- The return to the 3D environment after viewing the movies required a certain discipline and patience in exploring the museum.
- After the guided tours, the children were able to perform self-directed learning.
- We have identified cognitive (concentration, memorization) and affective (enthusiasm, a sense competition in navigation the space) components to the learning process.
- The computer literacy was enhanced with

concepts necessary to understand the new learning environment (e.g. Virtual Reality).

9 CONCLUSIONS

The mixed-reality experiment presented was designed and modelled with a well-defined educational objective. The 3D virtual museum has proved to be a creative tool, used both by teachers and children in a flexible manner that allowed learning without the constraints of the traditional learning process and in an immersive and playful manner. The 3D mixed-reality experience has allowed children to immerse in a spatial and temporal virtual environment while still maintaining the connection to real life by watching the video recordings.

This experiment led us to the conclusion that 3D virtual museums, as an intuitive exploration space, are a valid instrument of education. A 3D online virtual museum designed for education can support learning by doing and can accommodate a large and distributed learning community. The experiment showed interest and enthusiasm from the children and teachers for the novel learning environment, as a validation of the technology and approach we used.

10 FURTHER DEVELOPMENTS

In order to capitalize on the present experience we decided to develop a collaborative version of the 3D virtual museum: Vădastra participants from Bucharest, Râmnicu Vâlcea (Central Romania) or Piatra Neamț (North Romania) will have the possibility of entering the museum in real time.

The new museum will allow the teaching of traditional technologies under the form of guided tours, accompanied by explanations. The function of the "Guide" avatar will be extended providing a more complex and animated character that will deliver explanatory texts in front of each object and indicating for each object the technological video which needs to be played; the avatar movements will be determined by the teacher: for example, a professor in a remote location (our university or Vădastra school) will indicate course keywords, such as "Roman pottery" and the avatar will guide the users only on the Roman level, presenting the ceramic objects and the technology of pottery making. The children will follow each object presentation and will be able to ask questions using a chat component. At the end of each lesson, children will answer the questionnaire for learning assessment using the qualitative and semi-structured interviews presented at the Methodology paragraph (see Table 1). The children will be also evaluated by their objects and sketches made during the lessons. The learning method that we propose is usable for skills development in manufacturing of objects with low level of difficulty, but at the same time it offers the theoretical learning of making more complex objects. The future strategy mentioned above will require the design of the roles for each category of users (teachers, children), and the activation of the networking component of the Unity3D platform in order to support the development of a Multiple User Virtual Environment (MUVE) interactive application. This will also require a more powerful hardware infrastructure to ensure the required real-time performance.

The project presented will help to create a "community of learners" (Veen and Vrakking 2006). An interesting case to be discussed is how our approach generalizes in different European communities. During 2013, we presented the project to two urban communities from Portugal (Mação and Abrantes), which proved interested to use the results of the project as a pedagogical instrument for protection of local immaterial heritage. Recently, other communities from UK and the Netherlands also adhered to the project.

The 3D Virtual Museum will therefore support an extended virtual learning community, with numerous real time participants and mixed-reality lessons.

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