Chapter 12
Designing Virtual Worlds for Learning History: The Case Study of NetConnect Project

Assunta Tavernise and Francesca Bertacchini

Abstract The possibility of exploring archaeological sites from a distance, visualizing historical monuments that are ruined or no longer exist, as well as the manipulation of specific 3D historical finds from the learner's point of view (thanks to an avatar having an I-vision), can enhance students' contextualization of the abstract knowledge of the school subject "history". In this view, in the international project "Connecting European Culture through New Technology – NetConnect", promoted by Culture 2000 European programme, three 3D virtual worlds (VWs) were realized according to a technology-enhanced constructivist offer of historical contents. The VWs are the ancient Biskupin (Poland), Glauberg (Germany) and the site of Lokroi in Magna Graecia (Italy). This chapter aims at presenting some results of learning linked to these three virtual worlds.

Keywords Learning • Education • Virtual world • Cultural heritage • Learning of history • Design of technology-enhanced settings • Educational paths • Teaching-learning methods

12.1 Background

In recent years, a growing field of studies has suggested that a learning focus on spatial thinking skills can support achievements in learning some specific subjects, because the attention to numbers and letters in a universe as flat as the page of a book represses the natural human skill of 3D thinking (Newcombe and Shipley 2015). Hence, several studies in multimedia and web technology have given rise to different kinds of educational virtual worlds (VWs), where learners can think and act as in the real physical world, manipulating 3D virtual objects. In fact, in accordance with the instructional principles derived from Piaget (1971) and Vygotskij (1974), learning is the result of a process of construction of knowledge based on a hands-on approach; the reference theory is constructivism (Kafai and

A. Tavernise (✉) • F. Bertacchini
Laboratory of Psychology and Cognitive Science, University of Calabria, Rende, Cosenza, Italy
e-mail: assunta.tavernise@unical.it; francescabertacchini@live.it

M. Ma, A. Oikonomou (eds.), *Serious Games and Edutainment Applications: Volume II*, DOI 10.1007/978-3-319-51645-5_12

Resnick 1996) that promotes the manipulation (also virtual) of objects for the increment of retention, involvement and a positive sense of success (Um et al. 2011; Verhagen et al. 2011; Bertacchini et al. 2013a, b; Bertacchini et al. 2012a). Moreover, 3D virtual exploration offers the important chance to carry on immersive experiences through personalized activities supporting learners' interests (Kuznik 2009; de Freitas and Neumann 2009; Ferguson 2011). In this view, the learning approach mixing "education" and "entertainment" has been called "edutainment" (Bilotta et al. 2009).

The implemented 3D environments have been mainly "serious video games" (Frye 2012; Connolly et al. 2012; Mayer 2012), where learners are actively engaged in the process of skill development (Merchant et al. 2014; Bertacchini et al. 2013a, b). However, in general, VWs have demonstrated a great potential for learning and teaching practices, as well as for the reaching of a wider public (Bertacchini et al. 2012a, b; Hughes 2012; Verhagen et al. 2012; Adamo et al. 2010; Beomkyu and Baek 2011). Regarding VWs based on historical subjects, virtually environments linked to cultural heritage have been dedicated to the faithful reconstruction of historical finds using 3D digitalization and scanning techniques. In fact, a great deal of research has been driven to an increasing effort in the realization of cultural VWs primarily dedicated to the archaeological site modelling. Furthermore, the use of three-dimensional computer modelling to virtually reconstruct monuments, buildings and finds refers to the concept of "virtual heritage" (Roussou 2002; Styliadis et al. 2009). A number of video games have also been realized, but their potential as learning tools is still under consideration. In order to support and promote knowledge transfer related to historical periods, the main consequence of these studies has been that learning has begun to be thought not depending on static 2D images, but it has started to be based on the exploration and manipulation of historical reconstructions (Bertacchini and Tavernise 2016). In these virtual worlds, visitors are not only allowed to witness history and cultural expansion through 3D objects, but they have access to a hands-on approach, attracted by technology (Kafai 2006; Mason and McCarthy 2006). Hence, in the view of supporting the learning of history, three immersive VWs have been realized in the project called "Connecting European Culture through New Technology – NetConnect", promoted by Culture 2000 European programme. These historical VWs can be enjoyed also by mobiles and iPads (Cutri et al. 2008; Naccarato et al. 2011; Linaza et al. 2008).

12.2 Main Aim of the Chapter

This chapter illustrates how the three immersive NetConnect VWs have been designed in order to offer a technology-enhanced constructivist setting endowed with virtual manipulation (Gärdenfors and Johansson 2005), as well as the results of two researches on learning. In the first one, 208 users (Biskupin 127, Glauberg 43, Lokri 38), aged between 12 and 30, have evaluated the VWs answering to an ad hoc-built questionnaire including the following sections: ergonomic factors

(comfort during the system use), human factors (human-computer interaction, HCI), content (quality of the contents/animations and interactivity) and suitability for the task (appropriateness for learning).

In the second research, 50 Italian subjects from 15 to 18 (secondary school students) have studied the topic "Magno-Greek colonialism in Italy" using the VW "Lokroi", developed in NetConnect project. In particular, the learning was measured in a 12-hour laboratory course through a quantitative entry and post-questionnaire; then, 24 items from the Intrinsic Motivation Inventory (IMI), a seven-point Likert scale, were used to assess students' motivation. Finally, descents' opinions on positive/negative aspects of the experience were collected.

12.3 NetConnect Virtual Worlds

12.3.1 Historical Details and 3D Reconstruction

Three immersive VWs have been realized in NetConnect project: the reconstruction of ancient Biskupin in Poland, Glauberg in Germany, and the site of Lokroi in Magna Graecia (Italy) (Fig. 12.1). They represent the important result of the collaboration of an international team consisting of archaeologists, psychologists, modellers and computer scientists (Bertacchini et al. 2007). The expertise coming from various disciplines and five different European countries has also been integrated: Italy (Evolutionary Systems Group (ESG) of the University of Calabria and the Centre for Advanced Computer Graphics Technologies (GraphiTech)), Germany (Fraunhofer Institute for Computer Graphics and Roman-Germanic Commission), Spain (Visual Communication and Interaction Technologies Centre (VICOMTech)), Poland (Institute of Archaeology of Warsaw University) and the United Kingdom (Glasgow School of Art). In the project, an interactive version of three virtual archaeological sites has been distributed through DVDs to schools and divulgated through a web-based version.

In these VWs, visitors have an active role thanks to the possibility of following different levels of educational paths (Tavernise 2012; Tavernise and Bertacchini 2016), including the manipulation of different 3D objects. In fact, they can look for cultural heritage artefacts on the basis of their archaeological characteristics, recognizing and manipulating them in a 3D setting (Bertacchini et al. 2012b) (Fig. 12.2).

This manipulative construction of knowledge cannot be replicated in the physical world, because the finds could be partial or fragmented and certainly stored in a museum. Moreover, regarding buildings, users can learn their temporal set, spatial relations (e.g. the specific and related position in the city) and use (e.g. the building called Stoà was used by pilgrims). In a specific path, the interchangeable view of the virtual object or building, as well as the circumstance of the real one, increase learning.

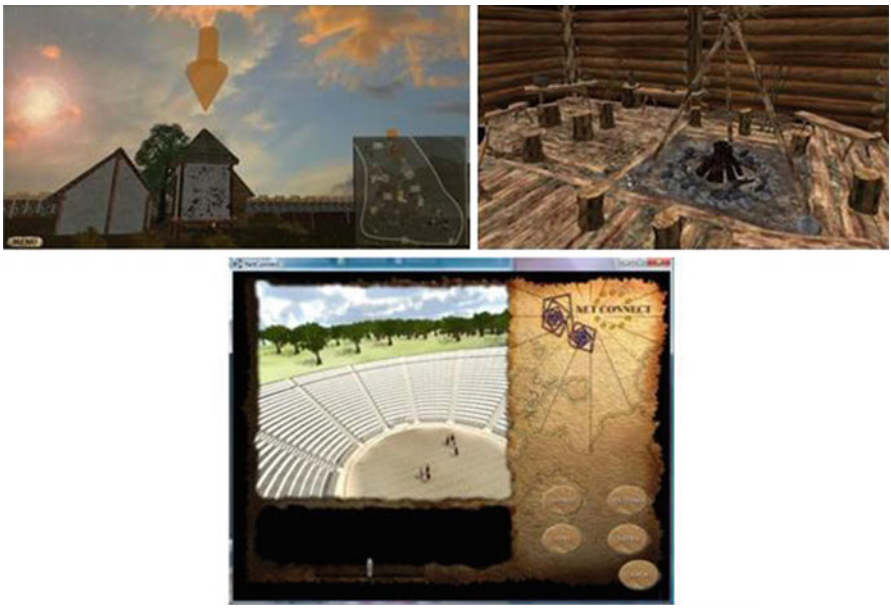

Fig. 12.1 Scenes from the three NetConnect virtual worlds: Glauberg, Biskupin, and the multimedia section of Lokroi (NetConnect project, 2009)

Regarding historical details, daily life scenarios are reconstructed on the basis of a detailed ancient documentation. In fact, the reconstruction of Lokroi scenes is based on those represented on Magno-Greek vases and votive tablets in terracotta called Pinakes, dated back to the period between 490 and the 460 BC. For example, the scene of the tuna seller in the market square is modelled on the basis of an ancient vase stored in a window of the "Mandralisca Museum" in Cefalù (Sicily, Italy) (Bertacchini and Tavernise 2012). The 3D modelling of specific farmyard animals and pets originates from their presence in Pinakes, and the chosen vegetation is typical in Southern Italy (scholars affirm olive trees were present in the selected historical age).

Regarding navigation in VWs, users can use a map clickable on the right side of the screen or a menu situating user's point of view in some selected places of interest. Visitors can also explore the city (virtually) walking in the streets: big red arrows show interesting buildings, and the avatar can move as a character in a video game to reach them (i.e. jump and run). Finally, in order to enhance history learning, users can access videos, pictures and texts in a multimedia section (Chowaniec and Tavernise 2012).

Fig. 12.2 An example of 3D objects that it is possible to manipulate in Lokroi VW (NetConnect project, 2009)

12.3.2 Design, Edutainment and Gaming Features

NetConnect design involves standard desktop set-ups instead of immersive and expensive virtual environments, encouraging low-cost robust approaches, more suitable for large number of visitors as in the case of archaeological sites (Bertacchini et al. 2007). Such navigable environments have a long technological tradition, based on the diffusion of multiplayer games and virtual communities, and the activities for their realization were the following:

- Selection of archaeological and historical materials devoted to be an integral part of scenarios (e.g. buildings and cultural finds)
- Definition of educational paths to insert in VWs
- Multimedia analysis and choice of unity platform
- Design of the immersive environments
- Implementation and experimentation
- Creation of an international network among educational institutions in order to divulgate VWs

Agents consist of a small quantity of polygons (less than 2000), and their details are due to textures at a resolution of 1024x1024 pixels applied to the mesh with UV maps (Bilotta et al. 2011).

Regarding gaming features, the exploration of the environment follows an approach very similar to video games (e.g. visitors can go through a door only if they open it), and actions can be performed using the mouse, the keyboard, a joystick or a Wii™ wireless controller based on gestures. However, user's surrogate persona is not showed in the VW (there is not an avatar acting for the user, substituted by an "I-vision"), and it cannot interact with "atmosphere agents" populating the immersive environment (Bilotta et al. 2011; Corvello et al. 2011).

Finally, NetConnect VWs can be considered edutainment environments because they incorporate entertaining/instructional activities linked to history learning; from a didactic point of view, these 3D environments provide the possibility to virtually access educational contents in an easy and appealing way, by focusing on a comfortable user-computer interaction and the incorporation of information about the culture and the society of ancient periods in the technology-enhanced product. Moreover, users can select different digital materials as texts, pictures, audios, multimedia files and videos on cultural heritage reconstructions. As a consequence, visitors' exploration can be considered as an advanced learning opportunity.

12.4 Research 1: Evaluation of the Virtual Worlds

12.4.1 Research Participants and Questionnaires

Research took place in three different countries (Poland, Germany and Italy). In particular, 208 participants, aged between 12 and 30, evaluated NetConnect VWs: 127 for Poland, evaluating the VW "Biskupin"; 43 for Germany, navigating the VW "Glauberg"; and 38 for Italian "Magna Graecia", exploring ancient "Lokroi". Materials included a personal computer with the VW and an ad hoc-built questionnaire (a five-point Likert scale with 1 being "disagree" and 5 being "agree"). The questionnaire included the following sections: user's personal profile (age, gender, education and familiarity with computers, 3D graphics and video games), ergonomic factors (comfort during the system use), human factors (human-computer interaction, HCI), content (quality of the contents/animations and interactivity) and suitability for the task (appropriateness for learning). The section on ergonomics was composed by three questions (e.g. "I feel high comfort during the system use") and that on HCI by six questions (e.g. "The interface is highly user-friendly"). Contents and appropriateness for learning were evaluated by five and four questions (e.g. "The animations are highly realistic", and "The presentation of the information on the screen supports me in performing my task"). The last part of the questionnaire was devoted to comments on the experience.

12.4.2 Procedure

Research had the following four steps:

1. Subjects' compilation of personal data
2. Navigation in NetConnect VWs without time limit
3. Compilation of an online questionnaire
4. Analysis of results

12.4.3 Results

Regarding ergonomic factors (comfort during the system use) and human factors (human-computer interaction, HCI), the 90% of the sample felt high comfort, estimating the navigation as highly intuitive. Only in two scenarios (Biskupin and Lokroi), the test of the Wii use was carried out, and the 52% of Polish users, as well as the 39% of Italian ones, agreed that the Wii use provided a high comfort possibility. However, regarding content (quality of the contents/animations and interactivity), only the 27% of participants declared to be satisfied (Bertacchini and Tavernise 2014). The majority of users affirmed to be enthusiastic on the possibility to have NetConnect worlds as support for learning, and, in general, comments remarked a positive instructional experience.

Regarding negative remarks, they were used for improving the system: bugs and errors were fixed.

12.4.4 Limitations and Future Works

Evaluation results showed a low satisfaction regarding 3D contents, maybe due to users' common use of advanced video games. Future developments will involve students' video recording during the system use for the realization of an interaction taxonomy. In particular, the communicative value of the various applications and the different charge of the different environments/contents in a single scenario could be measured. Results could be correlated with studies on manipulation and non-verbal communication in the learning of different subjects (Bilotta et al. 2007, 2008). New "virtual tours" in other historical cities could be designed and realized, guaranteeing a stimulating journey in ancient daily life. Moreover, this embodiment of information about the culture and the society of the period, also through the display of ad hoc-built contents, could be connected thanks to additional educational paths, developing a net of information like in a hypertext (Bertacchini and Tavernise 2014; Pantano and Tavernise 2009, 2011).

VWs could also provide the opportunity to "corrupt" the world, changing its shape according to the preferences of the "prosumer", a term that indicates

consumer and producer coalescing into the same person (Febbraro et al. 2008; Tychsen et al. 2008). In this context, a huge quantity of active users ("prosumers") could produce and enjoy the contents according to the technological paradigm of Web 2.0. Further improvements could also involve on-site experimentations.

12.5 Research 2: Learning Through VWs and Motivation

12.5.1 Research Participants

The experimental sample consisted of 50 Italian secondary school students aged between 15 and 18; 25 subjects were male and 25 were female. Participants' ethnical provenience (all the subjects were Caucasian and Italian) and demographic make-up (socioeconomic characteristics) were homogeneous. All students had an equal school curriculum, guaranteed by the school educational plan, called "Three-year Plan for the Formative Offer – PTOF".

The sample included students from six classes of the same secondary school, randomly assigned. As entry requests of information on familiarity with computers confirmed, all participants were comfortable with computers, already used in other instructional activities.

12.5.2 Procedure

Research had the following six steps:

1. Collection of participants' data using an entry questionnaire (age, sex and familiarity with computers)
2. Assessment of the entry level of knowledge on Magno-Greek history through a learning questionnaire consisting of 15 multiple-choice questions (pretest): 1 point was attributed for each correct answer and 0 for each incorrect one, for a maximum of 15 points
3. Navigation in NetConnect VWs without time limit
4. Assessment of the acquired level of knowledge on Magno-Greek history through a learning questionnaire consisting of 15 multiple-choice questions (post-test)
5. Compilation of a motivation questionnaire (the Intrinsic Motivation Inventory, IMI), reported as reliable and valid by McAuley, Duncan and Tammen (1987), and analysis of results
6. Qualitative evaluation of the learning experience (Iqbala et al. 2010; Thompson 2011)

Regarding the fifth step, IMI consisted in a seven-point Likert scale (with 1 being not all true and 7 being very true), and, in this research, only twenty-

four items were used in order to measure students' interest/enjoyment, perceived competence, effort/importance and value/usefulness. Their Cronbach's alpha values for the sample were the following: interest/enjoyment (seven items =a = 0.87), perceived competence (five items =a = 0.81), effort/importance (five items =a = 0.85) and value/usefulness (seven items =a = 0.77). IMI as a whole had an alpha value of 0.82 (Bertacchini and Tavernise 2016).

12.5.3 Results

Regarding knowledge, Greek history is a topic of Italian secondary school curriculum, but Magno-Greek colonialism in specific areas is a subject almost unknown among students: this is confirmed by pretest results. However, correct responses increased significantly from pretest to post-test: the mean score 1.36 out of 15 (SD = 1.08) (pretest) became 13.38 out of 15 (SD = 1.18) (post-test), and a Wilcoxon matched-pair signed-rank test showed that the scores after the visit to the virtual world were significantly higher than the scores of the pretest ($Z = -2.054$, $p < 0.001$) (Bertacchini and Tavernise 2016). Hence, results suggest that the realized virtual world can be an effective support in the study of an unfamiliar subject.

Regarding motivation, the relationship between the scores obtained in the post-test knowledge questionnaire and those attained in the motivation test, in relation with the pretest, was investigated using a multiple regression analysis. In particular, a significant R^2 of 0.65, $F(2, 28) = 22.5$, $p < 0.01$, was found, and the subscale "interest/enjoyment" resulted as the strongest predictor (Bertacchini and Tavernise 2016). Results are in line with the outcomes obtained by Verhagen et al. (2012).

Regarding qualitative analysis on the positive and negative aspects of the learning experience using NetConnect VWs, students' comments were extremely positive. The major part of learners commented the feeling of play as the best part of the assignment, while the tests after the navigation were considered as boring. Moreover, the majority of students suggested the use of computer and VWs for studying other school curriculum subjects.

12.5.4 Limitations and Future Works

Since the majority of virtual worlds connected to history learning are simple 3D reconstructions of archaeological sites, without the possibility of 3D manipulation, an adequate comparison with other studies cannot be reported here. Furthermore, the examined data are partial with respect to a more complex research, in which all the three NetConnect VWs are involved. However, data collected in secondary school could be compared with additional data collected in primary school laboratory, as well as in courses with a synchronous version with multiple users' presence.

12.6 Conclusions

NetConnect scenarios represent an advanced learning opportunity related to the learning of history, because learners are not only allowed to look back into time witnessing history, but they also have access to an effective hands-on approach able to support a deep understanding. In particular, NetConnect VWs give the opportunity of exploring and manipulating within the 3D environments, allowing users' picking up of objects and investigation. Furthermore, the immersion in a 3D environment as an avatar with an I-vision allows engaging learning experiences.

This chapter highlights the use of 3D technologies that can support the learning of history by secondary school students, thanks to the creation of the global vision of a fragmentary archaeological cultural heritage and the motivating possibility to play with the virtual finds as in a video game. Moreover, regarding the efficacy of NetConnect VWs as user-friendly environments, they were evaluated by more than two hundred students that have affirmed that the use of the system is easy and that the 3D contents are enjoyable and of high quality. Negative remarks by users were not considered as limitations but as suggestions for further improvements: they allowed the fixing of bugs and errors in the system and, as a consequence, the enhancement of the project results. However, outcomes will be improved by new data coming from forthcoming experimentations.

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