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Teaching Students to Build Historical Buildings in Virtual Reality: A Didactic Strategy for Learning History of Art in Secondary Education

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Abstract

This article is a summary and conclusions of a field study carried out in a secondary education classroom with the aim of experimenting and observing how 13-year-old students learn the history of architecture by using complex virtual reality software. Within the framework of autonomous and active learning, students act as builders of some of the historic landmarks studied during the course. Thus, students learn, for instance, the features of Romanesque and Gothic architecture as they are asked to build block by block –and with the aid of a computer equipped with virtual reality software– various buildings of the periods concerned. The student-centered approach which concentrates on students' learning also allows for a high degree of student autonomy and creativity. At the same time, this method fosters interactivity, and the spectacular results of virtual recreation and its stimulating activities are highly motivating and contribute to improve student concentration and achievement alike.

Why use virtual reality in teaching?

The real world the students live in is governed by completely different parameters from those which traditional pedagogy is based on (Baricco, 2008). Among the innovative advantages of virtual reality we can highlight are its spectacular nature, the search for constant stimuli, autonomy of movement, and immediate effort-result satisfaction. The students are involved in multiple sensorial experiences where all their senses play a part in the learning process, and they enjoy being the protagonists, or at least active participants, in the activities being carried out. For them, learning should be fun, exciting and active.

Although a methodology based solely upon these values would obviously lead to banality and triviality, it is possible to find a compromise, and in this aspect, virtual reality can be useful in so far as, due to its spectacular nature and its enormous appeal, it contains all the new values, while at the same time, as an educational tool, it enables significant learning, both of competence and content.

Virtual reality is a technology with important applications in the teaching world (Pantelidis, 1997). In a subject like History, and more specifically History of Architecture, the fact that students can in real time freely move around historical spaces and scenes virtually reconstructed by computer is undeniably advantageous (Sanders, 2008). In this way, thanks to virtual reality, the student can understand the architecture of a building and the elements that comprise it in a more natural and intuitive way, using all the senses as if on a real visit. However, although the students obviously have an active and autonomous role on their visit – they can enter the building on their own accord, make their own decisions regarding itinerary, the pace, the time they wish to devote to the visit, the aspects they want to pay attention to and the angle they wish to view from – evidently they cannot change the elements that make up the virtual reality or modify what they see, and of course, they have not taken part in its design. In most cases, in primary and secondary education, the students play the role of consumers of worlds previously developed and produced by companies or cultural centers.

Following from this, going one step further, we could ask ourselves what would happen if the students could become the actual designers of virtual architectural monuments object of study in their respective syllabuses. That is, what didactic implications could be observed by allowing the students to construct a historical monument piece by piece using virtual reality software. Would their level of content learning improve? What dynamics would be established inside the classroom between the students and the teacher? How would the students' interest and motivation be affected? What difficulties would the students encounter with the virtual reality software? The following research attempts to answer all those questions.

Methodology

This article is the result of field work carried out at Barcelona University. It consists of designing and experimenting with an educational project based on the use of virtual reality as a learning tool for History of Architecture, and was developed in a secondary school classroom at IES Eugeni d'Ors in Vilafranca del Penedès, Catalonia, Spain.

The work was carried out over three whole school years, from 2004 to 2007, for three school terms each year, and was integrated in the organizational structure of the school as an optional three-month subject. The total number of students involved was 133, with an average of 14 per term, and the educational level chosen was 2nd year of E.S.O. (Educacio'n Secondaria Obligatoria, Compulsory Secondary Education), which corresponds to 13-year-old students.

The didactic method applied in the field work was based on autonomous and collaborative work, and for this reason, the group/class was divided into pairs of students with one computer each.

As can be seen in Figure 1 and Figure 2, the place where the work was carried out was a classroom equipped with a minimum of 10 conventional PC computers (without external devices such as headphones or gloves), with an internet connection and the presence of an interactive digital whiteboard.

The observation and feedback related to the development of the fieldwork was carried out through a session journal, three reports by external observers and recorded video interviews with all the students.

Figure 1. The classroom.

Figure 2. Pair of students working.

This research is experimental and is a kind of case study where the investigator is not only an observer but also an active participant in the object of the study, and is responsible for the trial and experimentation of different strategies, activities and materials necessary for the project (López-Barajas, 1995). In this way, the field work was carried out with the daily presence in the classroom, as the teacher in charge, of the author of this article, who is a staff member of the educational centre where the research took place. Apart from the necessary teaching qualities, it must also be mentioned that due to his adequate familiarity with virtual reality software at a professional level, external technical support was unnecessary.

The main objective of the study was to observe the nature and the dynamics of the learning process in the classroom when a methodology with the student as designer of historical monuments is put into practice.

The methodology derives from the following parameters.

Firstly, in order to build a virtual world it is necessary to learn and master the workings of an appropriate software, which in most cases is a complicated development tool, not designed for didactic aims but for professionals and companies dedicated to the design and production of virtual worlds. Consequently, the first challenge was that of turning such software into a teaching tool for classroom work for 13-year-old students, which made it compulsory to take into account two considerations:

The first was the need for a software which did not need costly and specific equipment outside the budget of a secondary school. In this case, the software chosen was Superscape 3D Webmaster, which although not designed for teaching purposes, offered the advantage of easy installation and user-friendly functionality within a classroom with conventional PC computers.

The second consideration was that of the difficulty that 13-year-old students might encounter in its use. For this reason, due to the complexity of learning how to use the software for students of this age, it was necessary to design didactic strategies so as to make its use feasible. This was an important and basic factor in order to carry out the experiment, and was solved by choosing one of the modules that made up the software. In this way, the students had to learn how to use only one of the modules, the World Editor, which allowed them to construct the buildings by placing and moving the pieces in a fairly intuitive fashion.

At the same time, a specific tutorial was designed, adapted to the ability of the students and the objectives of their fieldwork, in order for them to learn how to operate the module. This tutorial was not included in the software due to its habitual use by professionals. The new tutorial consisted of a guide which led the students step by step through the process of construction of a small Romanesque chapel, during which the students became familiar with the basic menus and commands of the software.

Another important aspect of the methodology was to decide which buildings were to be chosen for the work, and which resources could be used by the students for their construction. For the first point, it was decided to include the most representative monuments of the historical periods studied in the syllabus of the corresponding educational stage, namely Roman and Medieval times, which will be covered in detail in the following pages.

Regarding the resources at the students' disposal, it was decided to purpose-design them, due to the lack of existing suitable educational material on the Catalan or Spanish market, or in those cases where they did exist, due to the difficulty of adapting them to such a specific educational purpose.

The resources were the following:

a) A drag-and-drop warehouse of three-dimensional pieces for each of the buildings and styles (Figure 3). These warehouses consist of a collection of three-dimensional architectural elements typical of each style, and make up the construction material for the monuments, like, for example, arches, vaults, columns, capitals, domes, windows, walls, etc., which the student can select, move and modify in order to construct the building.

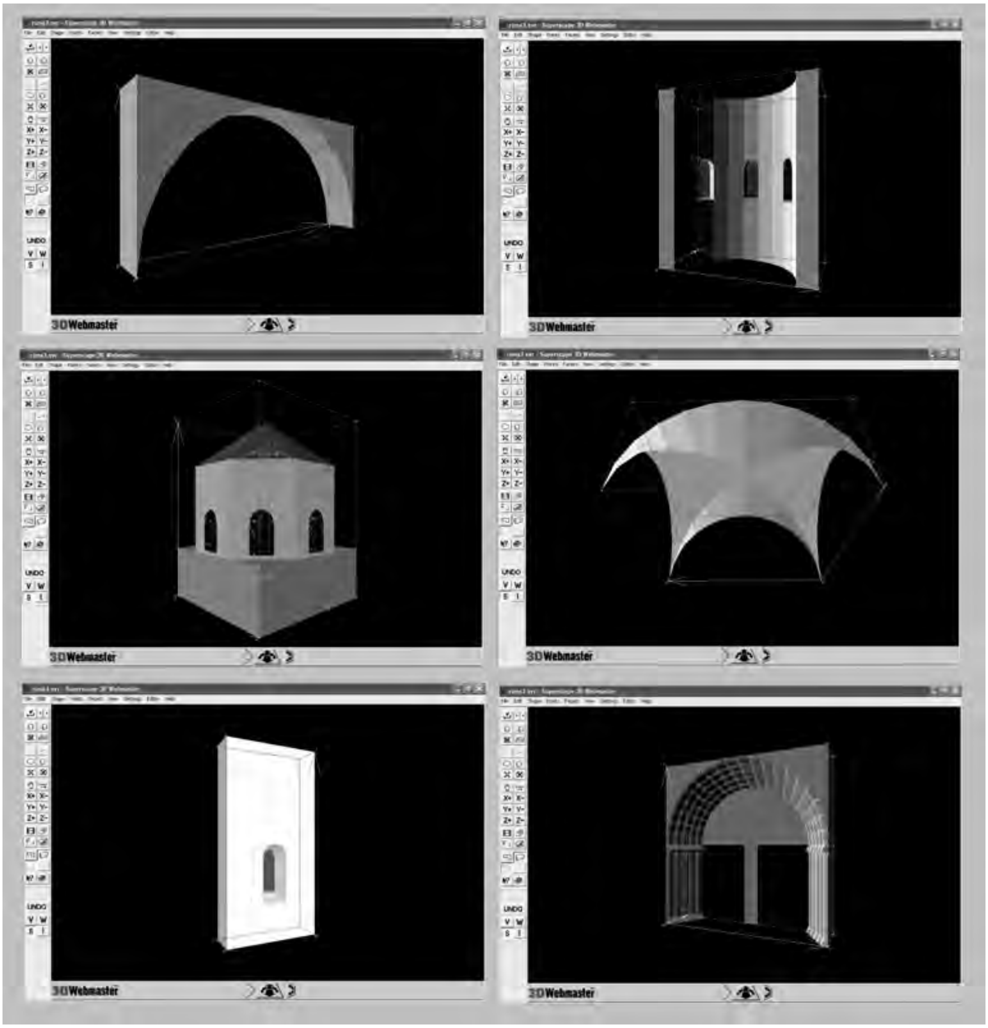

Figure 3. Warehouse of Romanesque architectural elements.

b) Two virtual reality historical buildings, the Roman Temple in Barcelona and a Romanesque church, both of which were presented in ruins, with missing, incomplete or half-destroyed pieces. The aim of the material was for the students to reconstruct the historical buildings *in situ* and with the original appearance they had before the destruction. Working on a ruin has undeniable educational potential, since it forces students to identify elements still standing, replace the half destroyed part with complete ones (which involves identifying what the original pieces might look like and deciding on a suitable replacement piece) and add the missing pieces and parts through the observation of other constructions.

In this way, basic competences related to observation, interpretation and deduction are developed.

c) Some reference materials were designed with the objective of facilitating the access to essential information on the architectural style and the historical context of each monument so that the students could know the characteristics and construction techniques of the buildings they had to construct. These digital materials consisted of two videogames and two slide presentations, where the visual aspect had a much greater role than the textual content. In the first case, the videogames offered the possibility of finding out the information as part of the game, in a fun and participative way, and allowed the students to observe the process and building techniques of two historical buildings: the Roman Temple in Barcelona and a Romanesque church. In the second case, the slide show offered purely visual information about Gothic and Byzantine architecture, with less possibility of interaction on the part of the user.

With these resources and following the methodology previously described, the central core of the students' work consisted in the realization in virtual reality of four historical buildings. If the reader wishes to enter and walk around the inside of the buildings constructed by the students or consult the teaching resources employed, he or she may do so at http://www.xtec.cat/~ebiosca/tesi/arxius/indexa.htm. A sample of the student's works is presented as follows:

- The reconstruction of a Romanesque church in ruins (Figure 4, Figure 5 and Figure 6), in which, from the existing remains, the student had to restore *in situ* a Romanesque church to its original appearance.

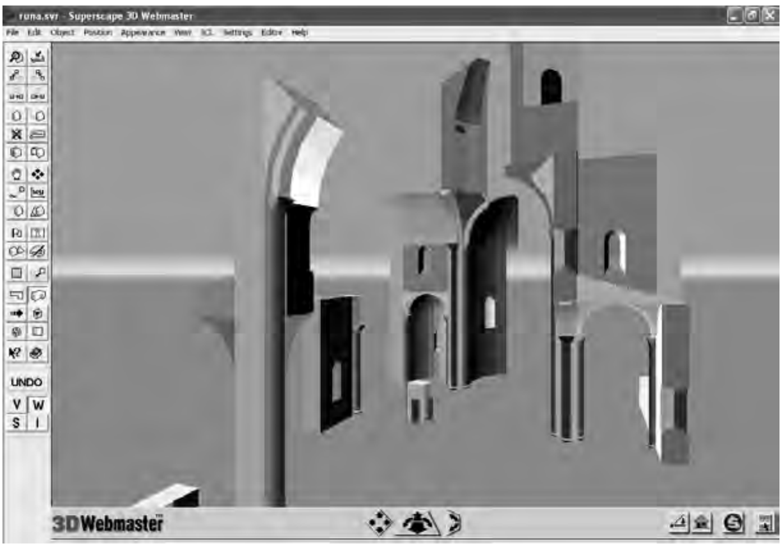

Figure 4. Virtual ruins of a Romanesque church.

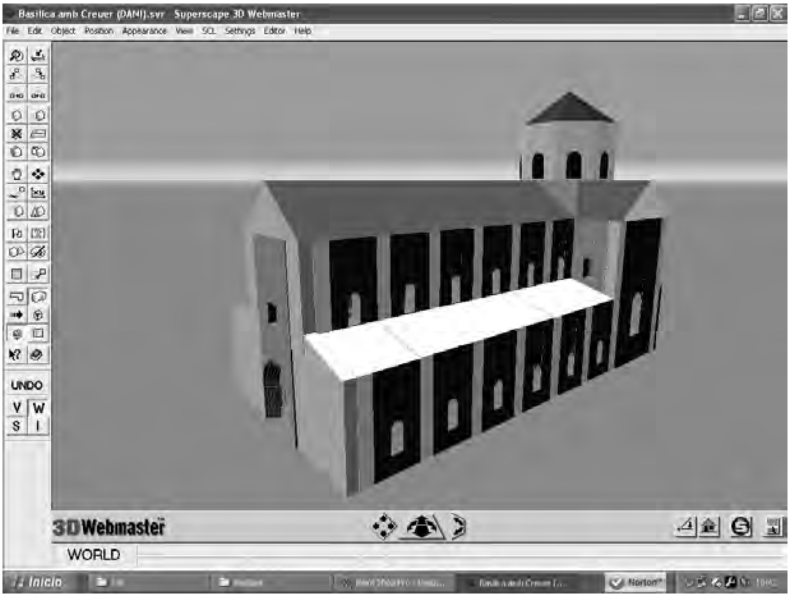

Figure 5. Reconstruction carried out in situ. View of the exterior.

Figure 6. Reconstruction carried out in situ. View of the interior.

- The construction of a Gothic church (Figure 7, Figure 8, Figure 9 and Figure 10) where the students had to build a Gothic temple from scratch, choosing type, form and dimensions.

Figure 7. Exterior of a French Gothic style church.

Figure 8. Interior of a French Gothic style church.

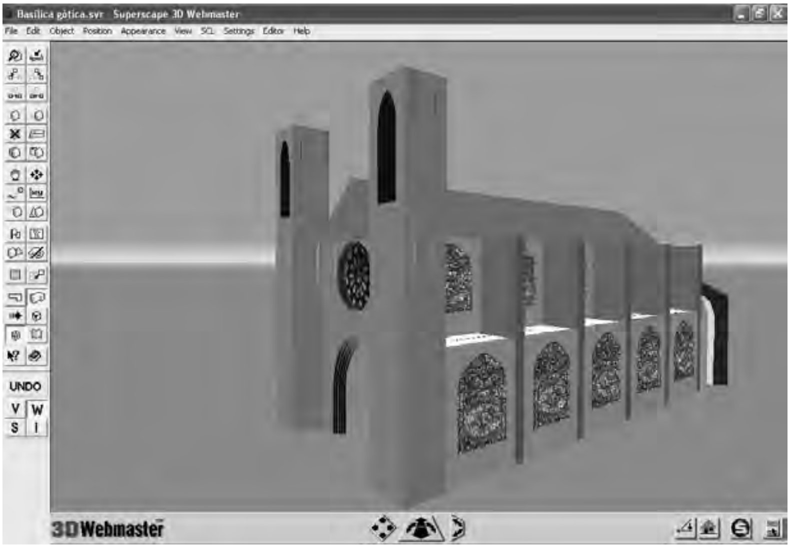

Figure 9. Exterior of a Catalan Gothic style church.

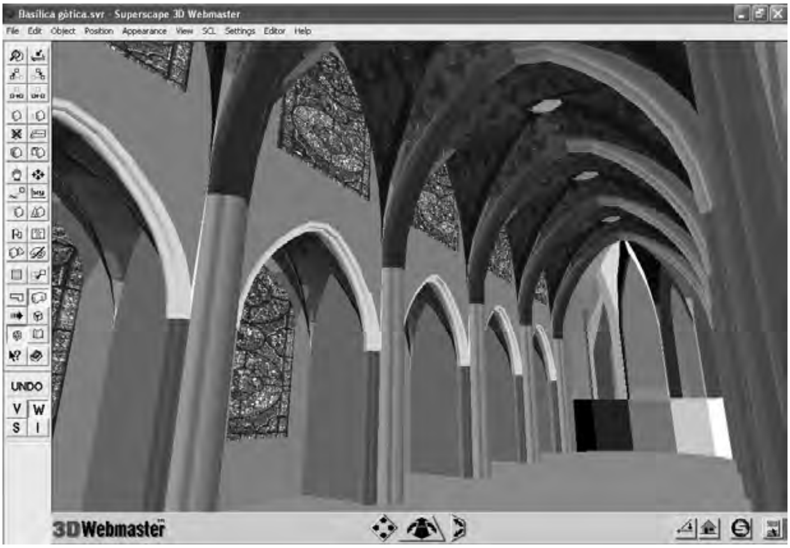

Figure 10. Interior of a Catalan Gothic style church.

- The reconstruction of the Roman Temple in Barcelona (Figure 11 and Figure 12), a similar activity to the first.

Figure 11. Virtual ruins of the Roman Temple.

Figure 12. Virtual reconstruction of its possible original appearance.

- The construction of Agia Sofia in Istanbul (Figure 13 and Figure 14), where the students had to make a replica of the most representative temple in Byzantine architecture.

Figure 13. Exterior of Agia Sofia.

Figure 14. Interior of Agia Sofia.

Results and conclusions

The application of innovative technology in educational practice affects both the quality and quantity of the content which is learnt, and especially how the knowledge is obtained, and which competences the students develop (Coll, 2003). For this reason it is important to assess the pros and cons in the following aspects involved in a learning environment based on the educational use of virtual reality.

What is learnt and how?

In this kind of learning environment, the objective is not to learn exhaustive structured content delivered by the teacher, but rather for the students to acquire that knowledge through carrying out the task of building a virtual historic monument. The students learn the concepts and content in an autonomous way through constant interaction between the source of information and the practical activity of constructing the building. The idea is that the student encounters the structural challenges of the building, and so must adopt strategies in order to solve the challenge, drawing from the reference material to obtain information, formulating hypotheses and deciding which new piece should replace the damaged one, which elements are missing, and where and in which position they should be placed in. In this way, not only are the students able to deliberate on the possibilities available, but they also subject them to experimental verification and draw conclusions, which enables them to test their initial hypotheses in order to reject them or propose new ones.

This constant interaction is what produces meaningful learning: students acquire knowledge about a building and the historical style being studied, and the curricular content of History of Art is studied in more depth than what can be expected from a traditional class, and in addition with very satisfactory results (Ausubel, Novak, & Hanessian, 1983).

In this way, taking into account the difficulty and complexity involved in constructing a virtual building in an autonomous learning environment where the student must search for the necessary information, we can consider that the work performance was considerable, averaging 3.5 virtual buildings a term, corresponding to between 6 and 8 hours of work each building. In addition, the architectural quality of the buildings was also very satisfactory in 89% of the projects, and the average mark of all the building was also quite high, with a 7.2 out of 10.

On the other hand, analysis of the students' statements in their interviews reveals that the level and quality of the content learnt are clearly perceived as more satisfactory than what would have been the case in a traditional class. This is due to the fact that the student can expand his or her own knowledge during the process of carrying out highly meaningful activities (Ausubel et al., 1983).

What type of students benefit the most?

Among students who usually got good marks in other subjects, the academic results obtained in virtual construction were also high, averaging slightly higher (0.5 points difference in favor of the latter); however, among students of medium, poor or deficient average performance, the marks obtained in virtual construction showed an even bigger difference as compared to their other subjects (1.5 points higher). Therefore, coinciding with the conclusions of Osberg (1997) and Marchesi and Martin (2004), the average and poor performance students are those most benefited by this methodology. In this sense, taking into consideration that one of the challenges of pedagogy is precisely that of improving global performance and helping weaker students achieve higher marks without bringing down the level of requirement, we can conclude that the evaluation of the field work is very positive.

On the other hand, regarding gender issues, the analysis of the results conclude that the only clear differences are related only to initial motivation. That is, although this experience was part of an optional subject, more interest was detected among boys, who made up 68% of the students enrolled, than among girls, 32%. This greater initial interest is related to the boys' particular curiosity for virtual reality and greater predisposition towards the more technical and graphical side of working with computers.

However, the sessions journal and the students' statements in their interviews allow us to complement this data and observe how, regarding everyday class work, motivation among the minority of girls taking part was just as high as that of the boys, and increased throughout the term, although it must be said that the only expressions of lack of interest or dissatisfaction came from the girls' group. Likewise, it was symptomatic that only the boys took an interest in installing the software at home in order to be able to build their own virtual worlds, which reinforces the idea of the boys' greater predisposition towards that kind of technology.

All in all, regarding academic performance, the conclusions do not observe a significant difference between the boys' and girls' results. In addition, in the case of this field work it must be taken into account that the disparity between the number of boys and girls attending the class, both globally and for each term (two boys to one girl), makes it difficult to establish gender comparisons between their respective performances.

Virtual reality is a great motivating factor

This field work corroborates what experiments with virtual reality in the classroom have indicated: the great motivation that it arouses in students (Youngblut, 1998). Motivation is a decisive element in learning: more motivation equals more learning. This was clear from the students' declarations, where the degree of interest and satisfaction while carrying out the didactic activities was considered essential and fundamental to positive learning.

This interest led to a relaxed and pleasant atmosphere in class, where order or discipline problems were rare, and a collaborative and mutual-help attitude and a favorable set of mind predisposed the students towards learning.

Among the factors to be taken into account, previous and initial motivation must be emphasized, since among the students enrolled, 78% confessed to having enrolled due to their interest in virtual reality technology, the content object of study and the methodology employed.

What is the ideal teaching method for working with virtual reality?

As the student is the actual constructor of the historical building object of study, the most suitable environment in which to carry out the activities is within a methodology of autonomous, collaborative and active learning. The use of virtual reality within this learning environment explains the good work performance and level of results obtained, while also being the main foundation for the students' motivation.

The advantages of the method are the following:

- The learning started from scratch. The complexity and difficulty involved in using software not directed at the general public or for learning purposes made all the students start from the same point of ignorance regarding its use. This aspect was especially important in those students who showed lack of development or knowledge throughout previous school years, as in this case they were free of the sensation of always lagging behind.
- As a software program is a tool, learning to use it is an ongoing process. This enables students to observe and be aware of their own progress regarding the use and mastery of the software, during the whole process.
- The learning process caused instant and immediate satisfaction. Each little effort made towards operating the software, each step in the virtual construction of a building, was rewarded by a clear graphic result, which at the same time required a quick assessment on the part of the student in order to decide if the move was right or not, without the need for depending on the teacher's opinion. Each little success and the evident visual verification of their own progress (the students were active agents in the construction of the buildings and were able to see them growing before their very eyes) had a positive feedback effect on their motivation and interest, and these emotions were fundamental to the students' perception of the work and learning process as pleasurable activities.
- Coinciding with the observations that Gee (2007) and Johnson (2005) have made about the causes of the enormous interest aroused by videogames, the activities tended to push the student to his or her own limit of ability, meaning that the intellectual challenges that they faced in the building process and the level of competences developed were neither beyond the students' cognitive abilities

nor below them, but rather just at the right point where the student was obliged to make an effort, but not an excessively difficult or impossible one. In a construction activity, the students had to alternate between, on the one hand, moments of observation and reflection which led to risk taking and facing a certain level of difficulty, and on the other hand, more monotonous situations where the student carried out more repetitive and mechanical tasks. In both cases the students were obliged to make an effort, albeit of a different nature (in the first case, related to cognitive exercises inherent to a scientific method and the need for decision making, and in the second case, related to operating complex software with a generous dose of patience and perseverance) which, although significant, was well within their ability, and allowed them to combine moments of different levels of difficulty which complemented each other without ever reaching a point where the students would have found the difficulty or excessive ease demoralizing, which would obviously have caused them to lose interest and motivation.

- Work autonomy. Each group was allowed to work at their own pace, without constant instructions from the teacher, who took on the role of a guide who advised, corrected and encouraged them.

Is it possible to turn a complex virtual reality development program into a learning tool at the disposal of a secondary school?

The possibility of operating the development software gave the students the same degree of freedom and creativity that professionals enjoy when they design their virtual products. On the other hand, regarding the degree of difficulty that 13-year-old students encountered while learning to operate the program, although the students initially found it hard to operate due to lack of experience and to insecurity, in the later stages this initial difficulty disappeared, replaced by a high level of understanding and familiarity with the use of the software, which caused them to want to learn about other modules of the software which were not part of the course plan. The students' mastery of the software was also shown in their work performance, which was better than initially expected.

Was it possible to find a suitable assessment system?

Osberg (1997), Youngblut (1998), Roussou (2006) and most studies and experiences to date mention the difficulty of finding a suitable system when attempting to assess what content has been learnt and what competences have been developed within a learning process based on the use of virtual reality as an educational tool. They highlight the need to find a specific method which can be adapted to the new learning environment, where a traditional assessment system is too limited.

As the learning process is based on the construction of different historical buildings in virtual reality, the assessment of the knowledge acquired and the competences that the students have developed is based on two factors that refer exclusively to the assessment of the practical side of the learning process, and more specifically to the results of the construction activity. On one hand, the assessment is based on observing the way that the students work and administer the information, and on the other, the architectural assessment of the resulting virtual buildings. In the first case, the following factors were taken into consideration: the way the students administered the resources at their disposal, the reflection and reasoning process involved, and the interaction and participation within the group; and in the second case, other aspects, such as the number of buildings produced, the accuracy in architectural style and the level of architectural quality were taken into account.

In the evaluation process, we thought it is important to bear in mind what Carretero (1993) names "accumulative experience". This concept derives from the specific constructive dynamics of a building in virtual reality within an autonomous learning environment, and consists in a process whereby the student gradually comes to understand aspects of architectural style (as, for example, the distribution of space and structural elements), as he or she is constructing the building, and which produces an interaction between the experience that he or she acquires through operating the software and the information provided by the reference materials.

However, although the students' overall mark was based exclusively on continuous assessment of the tangible results of the practical activity (the virtual buildings) and on daily observation and monitoring of the students' work, other traditional elements of assessment were also used, consisting in tests both at the beginning and at the end of the term, and whose objective was to provide complementary information from a different viewpoint, which allowed a comparison between the different assessment methods, although these results were not taken into consideration and had no influence on the overall mark.

The tests consisted of a set of photographs of different buildings corresponding to the different architectural styles studied by the students, in which they had to identify and name the different elements they could see. The analysis of the results once again shows the difficulty of assessing autonomous learning based on the use of virtual reality as educational technology when using assessment techniques from other teaching methods. For example, while the average mark for all the building activities was 7.2, that of the tests was lower, 5.5, a clear difference of 1.7 points.

One interpretation of this result is the possibility that, in some cases, the fact that the student has shown ability in the construction of the virtual buildings does not imply that he or she has acquired a similar level of knowledge about the architectural content. This would be the case of those students who obtained a much higher mark in the building activities than in the test.

Nevertheless, regarding this point it must be taken into account that the interpretation of the results faces an initial difficulty arising from the comparison of results stemming from two different assessment methods of different natures: that of the test, of a more individual and specific nature, which only appraises the students' ability to identify architectural elements that he or she has at a particular moment, and that of the building activities, of a collective nature, resulting from collaborative work (as seen before, while the test was answered individually, the virtual buildings produced were the result of pair work) and continuous evaluation which assessed especially the results of the work, and the competences developed by the work group throughout the task.

Other factors related to the group dynamics that take place in all collaborative work must not be underestimated: the personal involvement and the effort made by the students were not always the same for each member of the pair nor in all cases, meaning that in some cases the high mark obtained was not the result of a similar effort made by each member of the pair. This factor, except in some flagrant and visible cases, is very difficult to assess due to the lack of more precise evaluation observation techniques.

Another factor to be taken into account is related to the way of working within a learning environment of great autonomy. Some students showed a slower, erratic or incorrect way of solving the challenges involved in constructing a virtual building, along with less frequent consultation of the reference material, a greater inclination towards a trial-and-error approach, or they revealed themselves to be more dependent on the teacher's help and the solutions provided by other groups. In these cases, it is possible that the students may not have acquired complete understanding of the content, in spite of being able to complete the building correctly.

To sum up, although we consider that within a learning environment of this kind the ideal system of evaluation consists of an assessment of the practical results obtained (the buildings constructed) and the daily work carried out by the students in class, more traditional tests reveal the need to define and specify the assessment and observation techniques required.

What challenges does the teacher face in his or her work?

It is well known that in an autonomous and active learning environment the teacher is no longer the main transmitter of knowledge, but rather a guide, a problem-solver that assesses, leaving the students ample room for creativity and autonomy (Coll, 2007). At the same time, if we introduce into this framework the operation of virtual reality development software, the teacher must take on the added challenge of understanding the technology in depth and showing mastery in its practical use. In this case, the challenge was solved by the ability of the teacher to use the software adequately; otherwise, a technical support team or a specific training course would be needed. Regarding this point we feel it necessary to mention the need to research new types of software which would enable the construction of virtual buildings, with the same level of performance but more accessible and user-friendly, which would not require the users to have specific technical training.

The students' response

The satisfaction with this type of experience is practically unanimous among students, with very few exceptions. The most highly valued aspects of the methodology were the following:

1) Practical learning: the students consider that they make the most of their time, they perform the work better and they acquire more knowledge on the history of art in an active and practical learning environment, as compared to a more traditional didactic approach. Being able to virtually experience the construction of a building and the need to place all its parts correctly following a logical architectural order, allows the students to remember the names of the elements and to understand space and architecture better.
2) Collaborative and autonomous work: the fact that the students were working without being constantly directed by the teacher forces the students to accept responsibility in their work and allows them to plan according to their own preferences, with their own priorities and pace. The possibility of working in pairs is also valued. The main reason is that they have the benefit of mutual help, and feel comfortable and at ease, which more than makes up for the sacrifices they have to make regarding personal autonomy and individual creativity.
3) Learning is related to fun: the expression "it's fun" appears often in the interviews in all kinds of contexts and as a general response. It is a general and vague term but for the students also implies important values, since it relates to the satisfaction felt in experiencing the high degree of interaction of virtual reality and with the intensity and the nature of the stimuli they have received. In this way, although our educational culture tends to establish a big difference between what is fun and actual learning (Baricco, 2008), the students consider that the best didactic approach is one that includes and combines both elements.

Who does virtual reality appeal to?

Lastly, it seems necessary to ask ourselves why virtual reality appeals so strongly to the students. I believe that in some way virtual reality promotes a series of attitudes and addresses certain needs that are becoming more important in our society nowadays, especially among the younger generations. The tendency towards spectacular, beautiful and realistic virtual images and effects; the autonomy that the user enjoys, which allows him or her to become the protagonist of what is happening; the stimuli for creativity; the immediacy of response, and therefore immediate satisfaction; the development of certain cognitive abilities related to mental agility, logical thinking and decision taking; the similarity with the world of games; and in conclusion, the possibility of a kind of learning that, although not effortless, was perceived by the students as being stimulating and fun, are characteristics of virtual reality technology which may be the starting point of the road that leads to the education of the future.

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