Learning in serious virtual worlds: Evaluation of learning effectiveness and appeal to students in the E-Junior project

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Abstract

The objective of this study is to present and to evaluate the E-Junior application: a serious virtual world (SVW) for teaching children natural science and ecology. E-Junior was designed according to pedagogical theories and curricular objectives to help children learn about the Mediterranean Sea and its environmental issues while playing. In this study, we present data about the E-Junior evaluation. A class in a serious virtual world (virtual group) was compared with a traditional type of class (traditional group) that contained identical learning objectives and contents but lacked a gaming aspect. Data collection consisted of quantitative and qualitative measures on a sample of 48 children. With regards to learning effectiveness, the results showed that the serious virtual world does not present statistically significant differences with the traditional type of class. However, students from the virtual group reported enjoying the class more, being more engaged, and having greater intentions to participate than students from the traditional group. The plausible explanation for this can be found in the qualitative data. The implications of these results and improvement proposals are also discussed in this work.

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1. Introduction

In recent years it has been recognized that computer games are enjoyed by millions of people around the world and that they have become an integral part of our social and cultural environment (Oblinger, 2004). Even though there are numerous fields of computer game applications, successful computer games all have one important characteristic in common: the capacity to draw people in (Janett et al., 2008). This effect is hard to obtain by a teacher during the traditional teaching process. Indeed, student motivation continues to be defined as one of the most difficult aspects of teaching (Ames, 1992). Student attitudes while playing games are very different from their attitudes toward classroom instruction (Prensky, 2003). Furthermore, classes taught at school often have recourse to extrinsic motivational factors such as rewards, praise, and punishment, while computer games seem to resort to intrinsic motivational factors. The work by Lepper, Lyengar, and Henderlong Corpus (2005) shows that children who reported a desire for easy work and wanted to pleased the teacher (extrinsic motivational factors) performed worse on standardized tests and in regular classroom assessment than students who reported a desire for challenging, independent mastery, and curiosity (intrinsic motivational factors). These results confirm what theorists have long argued: being interested and engaged in the curricular content results in better learning and achievement (Lepper et al., 2005; Prensky, 2003). Besides the motivational factors, a crucial aspect for learners during the learning process is to construct knowledge from the foundation that he/she already has in order to reach a more complex level of understanding. This construction of knowledge can be based on perceptual exchanges and experimental interactions between subject and object (Piaget, 1954) or on social interaction, cultural background, and mediation between subjects and object (Vygotsky, 1978). A wide range of possibilities for new technologies and the ability to engage people while playing computer games has captured the attention of educators to create new environments that permit learners to observe, experience, and interact individually or collectively. Their aim is to create learning environments by using new interactive technologies that provide an opportunity to actively involve students in problem solving (Garris, Ahlers, & Driskall, 2002), to directly experience the physical proprieties of objects such as shape, size, distance, and time duration (Antonietti & Cantoia, 2000), and to be physically engaged in the task (Price & Rogers, 2004).

The combination of curricular content and computer games can be defined as serious games (SGs). Specifically, SGs are games that integrate gaming elements with learning or training objectives (de Freitas, 2006). When used for educational purposes, these games represent a...
powerful and effective learning environment for a number of reasons (Kebritchi & Hirumi, 2008). First, they use actions instead of explanations and create personal motivation and satisfaction. Second, they reinforce skill mastery and accommodate multiple learning styles and abilities. Finally, they provide a context for interactive decision-making. Besides the learning effectiveness, playing computer games gives learners a “mental workout” that can develop numerous cognitive skills (Robertson & Howells, 2008). More specifically, some researchers (Garris et al., 2002; McFarlane, Sparrowhawk, & Heald, 2002) present game-playing activity as an opportunity to develop skills in decision-making, design, strategy, cooperation, and problem solving. In the same way, several studies have examined serious virtual worlds (SVWs), which can be defined as 3D environments combined with learning or training objectives (de Freitas, 2008). The SVWs also have great potential in the educational field, and many researchers have collectively yielded a list of their positive capabilities (e.g. de Freitas, 2006, 2008; Jarmon, Traphagan, Mayrath, & Trivedi, 2009; Kalyuga, 2007; Lai-Chong Law, Kickmeier, & Holzinger, 2008).

Many studies in recent years have demonstrated that SGs and SVWs make the learning of curriculum content effective, engaging, and inspiring. In the SG field, games were designed to help learning in surgical diagnostic management (Mann et al., 2002), biology and biomedical problem solving (Cai, Snel, Bharathi, Klein, & Klein-Seetharaman, 2003), and mathematics (Holzinger, Pichler, & Maurer, 2006). Moreover, games were evaluated as an effective educational tool to learn the Theory of Structures for Civil Engineering (Ebner & Holzinger, 2005) and computer science concepts (Papastergiou, 2009). In the same way, researchers (e.g. de Freitas, 2008), cite examples in which the SVWs engage and motivate students, and increase their performance and retention of knowledge; for example, the solar system (Ang & Wang, 2006). They also cite examples in which the SVWs improve the effectiveness for supporting distributed research communities and international collaboration for interdisciplinary groups of scholars (Hut, 2007) and reproduce incidents related to chemical exposure or trauma injuries in a safe context (Heinrichs, Youngblood, Harter, & Dev, 2008). Other researchers (Monaham, McArdle, & Bertolotto, 2008) also cite several examples of virtual reality applications in the educational field that are used to teach different procedures and mechanisms: the tour of Hanoi (Nijholt, 2000), the role of the individual on the training team (Rickle & Johnson, 1999), or electrocardiography (Ryan, O’Sullivan, Bell, & Mooney, 2004). In addition, Virvou, Katsionis, and Manos (2005) describe a virtual reality educational game that motivates students and improves their knowledge of geography, especially for those who used to have poor performance in geography.

As the above literature review indicates, SG and SVW applications are numerous and varied. However, as pointed out by some authors (e.g. de Freitas, 2008; Egenfeldt-Nielsen, 2006), while there is little doubt about the potential of games to achieve educational objectives, empirical evidence using a rigorous experimental approach is still missing. Indeed, several methodological criticisms have been addressed in order to improve the design and evaluation of both SGs and SVWs: first, the need for further empirical studies regarding motivational aspects as well as learning outcomes in relation to the concrete curricular objectives (e.g. Lai-Chong Law et al., 2008; Papastergiou, 2009); second, the alignment of computer games with national curricula has been identified as one of the important issues to study (de Freitas & Oliver, 2006; Lai-Chong Law et al., 2008); third, the use of control group to evaluate their learning effectiveness (e.g. Egenfeldt-Nielsen, 2006; Harrington, 2006); and third, the use of pedagogical foundations in the design of the games. In fact, of 55 educational games studied between 2000 and 2007 by Kebritchi and Hirumi (2008), the pedagogical foundation of only 18 were based on learning theories, four were classified by the authors as established instructional strategies, and two were reported as not having any learning theory or instructional strategy base. For the rest of the games (31), no information concerning their pedagogical foundation was found. According to the authors, even if the literature calls for the use of learning and instructional theories in educational game design, less than half of all designers follow these recommendations. This point of view is also shared by Lai-Chong Law et al. (2008), who confirm that the lack of pedagogical standards and didactical methods is a weakness of most educational games.

As previously shown, there are still several issues that need to be investigated in the field of serious games and serious virtual worlds. The aim of the study presented in this paper is to fill in some of the gaps in the literature review presented above. The study assesses the learning effectiveness and appeal to students of the E-Junior application (a serious virtual world) that follows the curricular objectives of Spanish primary schools and the pedagogical theories.

2. E-Junior

E-Junior is a serious virtual world (SVW) that conforms to the Spanish natural science and environment curriculum as well as to specific pedagogical theories. The goal of E-Junior is to introduce students to the basic notions of natural science and ecology, and more particularly, to one of the ecosystem of the Mediterranean Sea: Posidonia oceanica.¹ The Mediterranean Sea was chosen as a topic for the project because of its close geographical, social, and economical relationship to the Valencian community (Spain). The E-Junior was placed in L’Oceànogràfic of Valencia, Spain (one of the largest aquariums in Europe). Its purpose is to encourage active learning within a highly immersive and interactive environment in a fun, innovative, and easily accessible way. Since it is often difficult to organize a field trip to visit a Mediterranean Sea ecosystem due to high costs, safety, and organizational logistics, the objective of E-Junior was to easily transport children from a traditional room setting in the museum to an underwater environment without even getting their toes wet.

2.1. Description of the narratives of E-Junior

E-Junior encourages active learning in an immersive and interactive virtual aquatic world (see Fig. 1). While navigating in the environment, the students have the opportunity to discover information about the Mediterranean Sea, engage themselves in collaborative and competitive play, and test their understanding about explained scientific concepts.

The narratives of the game include the scientific concepts (parts) described in details in Appendix 1. E-Junior is structured around narratives that described above concepts. The first part (a) is an immersive introduction to the universe, the earth and the environment. The second part (b) is an immersive introduction to the ecosystem of the Mediterranean Sea. It includes an interaction exercise to allow students to try the navigational input device (a paddle). The third part (c) includes an explanation of the scientific concept (the dynamic of the Posidonia oceanica) followed by an explanation of the game rules (under what conditions the elements can be collected) and an

¹ Posidonia oceanica is a marine plant (a species of seagrass) that grows only in the Mediterranean Sea and that is considered to be of high importance to the environmental conservation of the region.
interactive-gaming part. In this way the students participate in the photosynthesis of the Posidonia oceanica. In the parts omitted in the evaluation (d and e) the same presentation structure as in c is used. Students distinguish among different types of animals, seagrass, seaweed and plants and they judge the positive or negative actions that human beings can have on the ecosystem.

In E-Junior, children interact with the system collectively; four students participate together in all parts of the game. Each student is assigned a fish avatar that represents a different species of fish: Sea Bream, Mediterranean Rainbow Wrasse, Ornate Wrasse and Painted Comber. With these avatars, each student can explore, experience, and interact with the virtual aquatic world (see Fig. 2). To successfully complete each interactive-gaming part, the students must find and collect some elements in the aquatic virtual world according to the rules previously established by the virtual tutor, which is a fish that represents Brown Grouper specie. The Brown Grouper guides the students through the different stages of the game.

2.2. Pedagogical foundations of E-Junior

The design of E-Junior was inspired by various pedagogical theories. The following theories were used: the experiential learning theory of Kolb (1984); the De la Cruz theory of leisure as an educational tool (2002); and Gardner’s Theory of Multiple Intelligence (1983).

The purpose of experiential learning theory is based on engaging learners in direct experience. Experiential learning as defined by Kolb (1984) consists of the cycle constructed by following sequences of events: a concrete experience (feeling), a reflective observation (watching), an abstract conceptualization (thinking), and an active experience (doing). The basic idea of using the learner’s experience to facilitate the process of learning is used in E-Junior. Players assume the role of Mediterranean Sea inhabitants (fish) and participate in the usual activities of the Mediterranean Sea. For instance, students learn about the photosynthesis and nutrition of Posidonia oceanica by: collecting elements in the aquatic virtual world such as photons, carbon dioxide, oxygen, nitrogen, and phosphorous (concrete experience); reflecting on the game feedback (reflective observation); creating a concept about the issue (abstract conceptualization); and actively experimenting with their concept during the game (active experience).

The second pedagogical theory that inspired the E-Junior project is De la Cruz’s theory of leisure as an educational tool (2002). This theory presents leisure as an activity that not only improves the knowledge of the learners but one that also lets them acquire self confidence, define themselves in relation with others, and connect with each other. In our opinion, the collaborative and competitive character of E-Junior provides these characteristics. In fact, this serious virtual world not only teaches students within the leisure context to discover their potential and skills during the game and compare them with other players while competing, it also allows them to share and learn during collaborative play.

In addition, the E-Junior development team attempted to apply Gardner’s Theory of Multiple Intelligence (1983) by stimulating other types of intelligence than just logical-mathematical and linguistic intelligence. According to Gardner, these two types of intelligence are the ones most evaluated in schools. However, there are five more types of intelligence (musical intelligence, bodily-kinesthetic intelligence, spatial intelligence, interpersonal intelligence, and intrapersonal intelligence) that can be explored as different potential pathways of teaching the same information. In the E-Junior project, the researchers attempted to stimulate these other types of intelligence by implementing the following characteristics: first, by creating the wide room-space in which children could move around as fish in the water to stimulate the bodily-kinesthetic intelligence that involves using the whole body to solve problems; second, by integrating and associating sounds in each action to stimulate the musical intelligence that implies the appreciation of musical patterns; third, by procuring a
collaborative character of the game to stimulate the interpersonal intelligence that allows people to work with others; finally, by creating a competitive character of the game to stimulate intrapersonal intelligence and help students to understand their strong and weak points.

2.3. Curricular foundations of E-Junior

The definition of the Spanish national curriculum for the 3rd cycle of Primary School (10–12-year-old students) is contained in the L.O.G.S.E. law (2005). Specifically, the curricular specifications for the natural, social, and cultural environment in the Valencian community promote three types of content: first, specific knowledge about the natural, social, and cultural environment represented by different scientific concepts; second, procedures that teach students to know how to behave; and third, general attitudes (see Appendix 1). E-Junior was created taking these objectives into account in order to facilitate the execution of educational curricula.

2.4. Technical description

The game runs on Intel Core 2 Duo E6000, 2 GB RAM and Geforce 8600 GTS 320 MB computers. The hardware corresponds to stereoscopic projection screens, tracking cameras, and projectors placed in a 6 x 5-m room. Each child used polarized glasses to perceive a scene stereoscopically and utilized paddles with an augmented reality marker to navigate in the aquatic world. Each student handled the paddle that corresponded to an assigned fish avatar. The movement of the paddle let the children move the fish and interact with the virtual aquatic world (see Fig. 3).

3. Method

3.1. Research design

The study compared two different types of natural science and ecology classes. The traditional class corresponding to the control group and the virtual class corresponding to the E-Junior application. The two classes included identical learning objectives and content and were located in the same place (L'Oceanogràfic aquarium of Valencia). Any differences in student learning outcomes and appeal to students should be attributed to the class type factor.

Based on the literature review, the hypothesis formulations were the following:

- Students from the virtual group would have significantly greater learning performance in natural science and ecology than students from the traditional group.
- Student evaluations would show that the virtual classes have significantly greater appeal to students than the traditional classes.

3.2. Participants

The participants for this study were selected randomly from the list of Valencian Primary Schools, located on the eastern Mediterranean coast of Spain. In total, 48 children participated in this study (20 boys and 28 girls) all aged from 10 to 11 years old. They all attended the 6th grade and had the same learning objectives related to natural science, geography, and ecology. Each child was randomly assigned to one of two groups (the virtual group or the traditional group) after filling out the pre-test knowledge questionnaire about natural science and ecology.

3.3. Materials

Classes about the Mediterranean Sea and its ecological issues were developed by the research team; the E-Junior corresponded to the virtual class and the traditional class was based on lecture presentation. In the design of both classes, the learning objectives and the subject matter contents were the same. A human tutor led the traditional class and a virtual tutor (the Brown Grouper) led the virtual class.
3.3.1. Description of classes
A detailed description of the virtual class (E-Junior) can be found in the Section 2. The traditional class was a lecture presentation developed by the educational team of L'Oceanogràfic. Its learning contents and objectives were identical to those of E-Junior: (a) the universe, the earth, and the environment; (b) the ecosystem of the Mediterranean Sea; and (c) the dynamics of one of the ecosystems of the Mediterranean Sea (Posidonia oceanica). The first two parts (a, b) were an introduction to the general scientific concepts. The third part (c) was a presentation of specific scientific concepts related to photosynthesis and alimentation in Posidonia oceanica. The traditional class corresponded to an interactive traditional lecture presentation without using any educational materials or media. The teacher during the traditional class explained the scientific concepts, by asking students some questions, informing them about the curiosities and inviting them to share their opinion about the subject.

In order to compare traditional teaching with virtual teaching, we decided to keep each teaching context the same. The traditional class was recreated by simulating the traditional teaching context (a large group of students in a traditional classroom space with a traditional lecture presentation). However, in order to diminish the influence of new, exciting place outside of school (an aquarium) both of the classes (the traditional class and the virtual class) were organized in the same place: L'Oceanogràfic. The learning contents were presented by a human teacher (Educator form L'Oceanogràfic) in the traditional class and by a virtual teacher (Brown grouper virtual fish) in the virtual class. All the students from the traditional group participated in the traditional class at the same time as their usual learning session at their primary school. The virtual classes were held at different times, since only four students could play at any given time.

3.4. Instruments

The intention of the research team was to collect both qualitative and quantitative data. Therefore, three paper-based questionnaires were developed: a pre-test questionnaire containing two parts (biographical information and a knowledge test on natural science and ecology); a post-test questionnaire containing a knowledge test on natural science and ecology; and a post-test feedback questionnaire containing two parts (an open-ended questionnaire and a close-ended questionnaire). In addition, informal observation of the children during the two types of classes was performed.

The biographical information included the following questions: gender, age, school grade, frequency of computer use, frequency of computer gaming, and enjoyment of computer games. More specifically, the students were asked to write their gender, age, and school grade and to indicate how often they use the computer, and how often they play computer games. A Likert scale was used with the following time frequencies: never, several times per month, several times per week, everyday. They were also asked if they enjoy computer games using a Likert scale, with the following levels of enjoyment: not at all, a little, quite a lot, a lot, and very much.

The pre-test questionnaire about natural science and ecology aimed to assess students' knowledge of the scientific concepts before the study began. It included questions developed by the research team, whose validity was examined by a panel of experienced natural science educators from L'Oceanogràfic. The knowledge test comprised 11 multiple-choice questions on natural science and ecology concepts, which were derived from the learning objectives and the subject matter contents used to create both the traditional and the virtual classes. Thus, all the information that the student would need to remember in order to be able to answer the questionnaire were included in the same way in both classes.

The post-test questionnaire aimed to measure, after the study, students' knowledge of the scientific concepts presented during the classes. Similar to the pre-test questionnaire, however with different questions, the pre-test questionnaire comprised eleven multiple-choice questions on natural science and ecology concepts with the same difficulty level. The evaluation of validity and difficulty level of this questionnaire was done by the panel of the same experts.

The close-ended questions of the post-test feedback questionnaire aimed to assess appeal to students and included eighteen items that studied six dimensions: (a) perceived usefulness; (b) intention to use; (c) perceived educational value; (d) engagement; (d) intrinsic motivation; and (e) enjoyment. Specifically, students were asked to rate on a 5-point Likert scale (not at all, a little, quite a lot, a lot, very much) the degree to which they agreed with the statement that related to one of these six dimensions (see Appendix 2).

The open-ended questions of the post-test feedback questionnaire aimed to obtain students' opinions about positive and negative characteristics as well as improvement proposals for both types of classes.

The objective of the informal observation of children was to collect all the possible information that researchers could observe regarding student engagement, attention, implication, enjoyment and other variables considered to be relevant.

3.5. Procedure

The students that participated in the study were chosen from two 6th grade classes from Nuestra Señora de Loreto Valencian Primary School. All the students completed the pre-test questionnaire individually in their respective classrooms, in the presence of the researcher and their teacher. They were then randomly assigned to one of two groups: the traditional group or the virtual group. The week after filling out the pre-test questionnaire, and without any previous instruction about the Mediterranean Sea, all students from the traditional group participated in the traditional class at L'Oceanogràfic. The rest of the students attended the virtual class in group of four on the same day. At least one researcher was present at each class session. Each class session lasted 25 min, the time needed to fill out the questionnaires was approximately 5 min for the pre-test biographical information, 15 min for the knowledge pre-test, 15 min for the knowledge post-test and 10 min for the post-test feedback questionnaire.

3.6. Data analysis

In order to explore the potential differences between the traditional and the virtual group regarding the personal information collected in the pre-test questionnaire, the following two analyses were performed: a gender comparison of two groups with \( \chi^2 \) test for independence; and a two-group comparison related to other personal information (age, computer use, etc.) using one-way between-group variance analysis (ANOVA). In each questionnaire (pre-test and post-test) the total of correct answers was calculated and presented as a total score ranging from 0 to 11 points. To investigate the effectiveness of the virtual class on student knowledge of natural science and ecology, the ANOVA was
also used. In order to study the appeal to students, in both the traditional and virtual group, the mean score of three questions (on the Likert scale ranged from 1–5) related to the same dimension was calculated. Finally, in order to compare the scores between two groups, the repeated measures ANOVA was used. All of the analyses were performed using the SPSS 16.0 application with the significance level set at 0.05. With regard to the qualitative measures, for the open-ended questionnaire, the children’s answers were grouped into categories according to their common themes. The informal observations performed by the researchers during the classes were presented in the same way.

4. Results

4.1. Comparison of the two groups with regard to biographical variables

The analysis of biographical data showed that the random distribution of the two groups resulted in no statistically significant difference between them. The descriptive statistic data can be seen in Table 1.

For the gender distribution in two groups, the analysis did not show any statistically significant difference ($\chi^2 = 1.33, df = 1, p = 0.25$). The only difference found was that of greater enjoyment of computer games by boys than by girls ($F(1, 46) = 9.99, p = 0.003$). However, there was no significant interaction between gender effect and group assignment [$F(1, 46) = 0.564, p = 0.457$].

4.2. Comparison of the two groups with regard to the knowledge tests

The analysis of the pre-test showed no statistically significant differences [$F(1, 46) = 0.022, p = 0.884$] between the traditional group ($M = 5.42, SD = 1.99$) and the virtual group ($M = 5.33, SD = 1.93$). This indicates that the two groups had similar background knowledge about natural science and ecology.

The results for the pre-test and the post-test, showed a statistically significant difference [$t = -2.10, p = 0.041$] between the pre-test ($M = 5.37, SD = 1.94$) and the post-test ($M = 6.10, SD = 1.89$). Thus, it can be concluded that the children learned some new information during the two types of classes. However, the post-test comparison analysis that evaluated the learning effectiveness of two types of classes showed no statistically significant difference [$F(1, 46) = 0.699, p = 0.408$] between the traditional group ($M = 5.88, SD = 1.54$) and the virtual group ($M = 6.33, SD = 2.20$). These results can be explained by the qualitative measures presented in the following sections.

4.3. Comparison of the two types of classes with regard to appeal to students

In order to study the impact of groups on appeal to students, six scores were calculated for each participant. Each score (the mean of student’s answers to three items) corresponded to the dimensions stated above (perceived usefulness, intention to use, perceived educational value, engagement, intrinsic motivation, and enjoyment). The results showed that on the general level there is a statistically significant difference between two groups with regard to the appeal to students ($F(5, 220) = 2.859, p = 0.027$). More specifically, the results showed the following: the students reported being significantly more engaged ($post \ hoc, p = 0.031$) in the virtual class ($M = 3.68, SD = 0.77$) than in the traditional class ($M = 3.08, SD = 1.01$); the students reported enjoying the class significantly more ($post \ hoc, p = 0.004$) in the virtual group ($M = 4.31, SD = 0.89$) than in the traditional group ($M = 3.37, SD = 1.17$); and the students reported greater intention to participate ($post \ hoc, p = 0.010$) in the virtual classes ($M = 3.90, SD = 0.68$) than in the traditional classes ($M = 3.20, SD = 1.02$). The rest of the items did not show any statistically significant differences.

4.4. Observation of the children during classes

In accordance with the informal data from the researchers’ observations, the virtual group seemed very enthusiastic about the idea of having a 3D lesson. During their interaction with the game, children were deeply engaged, involved, and absorbed. During the virtual class, the majority of the students collaborated collectively, helping each other to understand the game rules and to navigate in the aquatic world (“Look at the legend to see what you are collecting”; “You are the oxygen”). Moreover, the children seemed to be quite immersed during E-Junior. The students frequently asked if the room was moving and screamed with excitement when the image rapidly changed (i.e. to produce the feeling of immersion into the water).

With regard to the input device, the researchers did not observe any particular problems during navigation and interaction with the virtual aquatic world. In fact, students from only one group out of the six groups had visible problems and could not manage the paddle properly or were too close to the screens. The children were relatively well-behaved during the game; however their involvement was visible and audible. They interacted with the virtual tutor (the Brown Grouper) by responding to it and expressing their satisfaction by screaming and jumping while playing. Nevertheless, their level of attention to what the Brown Grouper was explaining was not very high. The innovative character of the application (3D effects or the possibility of moving the fish avatars) seemed to engage the children more than the explanations of the scientific concepts. Instead of concentrating on the game rules or the virtual tutor’s theoretical clarifications, they were running around trying to move their fish avatars in the virtual aquatic environment. This did not influence their enjoyment; in the majority of cases, the children were disappointed when the researcher informed them that the class had ended.

### Table 1

Comparison of the two groups with regard to biographical variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Traditional group</th>
<th>Virtual group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>10.29 (SD = 0.46)</td>
<td>10.17 (SD = 0.38)</td>
</tr>
<tr>
<td>Frequency of computer use</td>
<td>2.79 (SD = 0.58)</td>
<td>2.62 (SD = 0.58)</td>
</tr>
<tr>
<td>Frequency of game use</td>
<td>2.17 (SD = 0.64)</td>
<td>2.33 (SD = 0.64)</td>
</tr>
<tr>
<td>Enjoyment of computer games</td>
<td>2.54 (SD = 1.29)</td>
<td>2.83 (SD = 1.40)</td>
</tr>
</tbody>
</table>
The traditional group, however, showed a high level of attention and involvement only at the beginning stage of the class. They actively participated in the class by responding to the human tutor or by asking their own questions. They seemed to be interested in the subject and listened to the tutor carefully. However, as time passed, more students started to talk and present signs of restlessness, weariness, and tiredness. Their level of attention was also lower and by the end of the class, they were happy to leave the classroom space.

4.5. Written comments about two types of classes

According to the children's opinions that were collected in the open-ended questionnaire, the virtual class generally received very good comments. The children were pleased with the game, especially when they were collecting elements to let Posidonia oceanica breathe and feed (“I liked the most catching the oxygen and all that stuff”). Another frequently cited point concerned the virtual tutor (the Brown Grouper) and the fish avatars that the children could move through the virtual Mediterranean Sea (“I liked to help the fish”). The other aquatic animals and 3D effect were also appreciated (“I liked the most seeing the animals in the water,” “It is real”). The learning aspect of the application was mentioned less frequently, but still a few students showed their interest (“I liked the most) learning about interesting things and how plants live”.

In contrast, the traditional group visibly appreciated what they could learn during the class. The children expressed most of their happiness about all the things they could learn about the sea. The class seemed to be interesting and useful for them (“I liked the most) that they have taught us a lot about the Posidonia,” “That we learned a lot of interesting things that are very fun and pleasant”). In addition, a few students mentioned the importance of the dialogues they had with the human tutor (“I liked the most) all the information that we learned and also that we could talk about and discuss curiosities”).

The negative points indicated by children from the virtual group were not numerous. However, the most frequent commentary made concerned the length of the speeches by the virtual tutor (the Brown Grouper), which in their opinion spoke too much (“I did not like when the fish was talking to us all the time”, “I did not like that the fish was talking so much”). These comments were confirmed by the improvement proposals made by the children. In fact, the students proposed reducing the talking time of the fish (“I would change that he (the Brown Grouper) stop talking so much and give us more time to play”,” That the fish not talk so much”). Moreover, a few students did not appreciate the first part of the narratives concerning the introduction to the universe and the earth (“I did not like) some of the explanations at the beginning about space”).

The negative characteristics extracted from the students’ comments from the traditional group were also not very numerous. The children explicitly expressed their weariness (“I did not like that it started to get long and a little bit boring”). Furthermore, they proposed some improvements like: (a) visually demonstrating some concepts; (b) reducing the lecture time; and (c) adding some additional activities like games.

5. Discussion

This study presents and evaluates E-Junior, a serious virtual world based on pedagogical theories and the curricular objectives of Spanish primary schools. The virtual class was compared with the traditional class in order to study its learning effectiveness and appeal to students. The main findings and their implications are discussed below.

The evaluation showed no statistically significant differences in the learning performance between the traditional group and the virtual group. This result can be interpreted as being due to a distraction that the innovative environment produced on the children. As certain authors suggest (e.g. Papastergiou, 2009), the attractiveness and complexity of the environment might be a distraction from the learning objectives. We think that this assumption could be an explanation for what happened during the virtual class. Certainly, the innovative way of navigating, the realistic 3D graphics, and the immersive world might distract the students. By focusing on graphics and stereoscopic effects, as well as running around with the paddle, the students appreciated the visual features and navigational way more than the information presented about natural science and ecology. This is confirmed by both the observations of the researchers and the commentaries made by the children. We noticed that the children made many more comments about the aesthetical characteristics of the virtual class than its learning benefits. This is in contrast to the traditional group in which students frequently mentioned the learning dimension.

On the other hand, the students that participated in the virtual class reported enjoying the class more, being more engaged, and having greater intention to participate again in this type of classes than students from the traditional class. These results were confirmed by the informal observations made by the researchers during the experiment. In fact, the children in the virtual group seemed to be more satisfied and engaged than in the other group. According to the authors (Lepper et al., 2005; Prensky, 2003), this aspect is crucial during the learning process. This makes us think that once the new innovative technology effect has passed, the children will not only enjoy the virtual class but will also learn from it.

This study has certain limitations. As we have already mentioned, the evaluation of E-Junior only considered three of the five integral parts of the project. Therefore, a full evaluation of the application must be done before drawing the final conclusions. Moreover, the study involved short-term retention of natural science and ecology knowledge. We consider that a long-term retention evaluation would be appropriate for future research.

Other limitation of the study corresponds to the difference between two tutors in the traditional and the virtual classes (human tutor and virtual tutor, respectively). Although the scientific contents explained by both tutors were controlled in order to keep it exactly the same, the fact that the scientific concepts were not presented by the same tutor in both groups could influence the results.

Furthermore, the fact that the control group performed their learning class in one large group and the experimental group existed as a group of 4 could as well influence the perception and experience of students. The different size of groups was due to the time limitations. We consider that the same group size (four students in both traditional and virtual class) should be applied in future experimental design.

The evaluation process also gives a lot of interesting information for improving both the application and the evaluation methodology. First, it should be noted that the most frequent negative comments about the virtual class concerned the long concept introduction given by the virtual tutor (the Brown Grouper). Apparently, the children did not appreciate the passive form of instruction presented before the
active form of learning (game). The experiential learning theory involves some passive instruction but it soon progresses to an experiential form of learning (Kebritchi & Hirumi, 2008). Thus, we should improve the application of this pedagogical theory by reducing the lecture parts of the virtual tutor and by transforming some more of the important information into an interactive game.

It should also be noted that other issues related to the evaluation of the learning effectiveness should be studied further. In our study, only a declarative type of knowledge (facts) was taken into account. However, the learning process not only concern facts but also procedures of how to do the described action (procedural knowledge) as well as attitudes that correspond to transferring of learned information to other situations (strategic knowledge). In this sense, learning about the Mediterranean Sea is not only learning about scientific information, it is also about how to preserve it and how to apply this knowledge to other environmental issues. Moreover, the curricular objectives of the Spanish primary schools that were taken into account in the development of the E-Junior narratives, precisely define both general attitudes and procedures. These more “affective” characteristics cited in the curricular objectives (e.g. to promote respect, to promote the protection and conservation of the environment) should also be taken into account in both short-term and long-term evaluation.

Finally, some authors suggest (Virvou et al., 2005) that if a traditional class is used as the control group in order to compare it with the new technology (e.g. virtual class), it assumes that the new technology is destined to replace traditional instruction rather complementing it. In our case, E-Junior application is not meant for classroom use, but rather more as a complement to an aquarium or a natural science museum visit. A real field trip, such as the Posidonia oceanica depths expedition would be very difficult or even impossible to organize. According to Spicer and Stratford (2001), a virtual field trip should not replace a real field trip, but it can be a very effective tool in preparing it or in reviewing it. If there is absolutely no possibility of organizing a real field trip, the aquarium visit with the additional interactive game sessions could be an interesting option to consider. Nevertheless, another interesting topic to study would be to compare not only the traditional and virtual types of classes but also the classes given by museum educators, which are usually very interactive, engaging, and enjoyed by students. This certainly might be a challenge for serious virtual worlds and an interesting point to evaluate.

6. Conclusion

This study shows that the serious virtual world is an effective tool for satisfy and engage students. This result is one of the crucial aspects in the learning process, especially when the application is directed at school-aged children, which is a very demanding demographic. However, the lack of statistically significant learning effectiveness confirms the need for improvements in this area. New technologies used in education must be carefully chosen and applied in order to help students not only enjoy the aesthetical aspect but also to learn while playing. Many times impressive hardware and software can be too innovative to allow students to concentrate on the content that the application is really designed for.

Evaluations are the best way of confronting the developed application with reality. By using children as experimented critics we are sure that once the improvements are incorporated, E-Junior will not only let students enjoy the game more but also help them learn more about the Mediterranean Sea and its environmental issues.

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Appendix 1

Curricular objectives related with the contents and characteristics of E-Junior application. Links between curricula and contents in terms of specific knowledge

<table>
<thead>
<tr>
<th>Curricular objectives</th>
<th>Contents of E-Junior</th>
</tr>
</thead>
</table>
| The environment and the universe | • The universe, the earth, and the environment  
 o The position of earth in the universe  
 o The organization of the biosphere  
 o The lithosphere, hydrosphere, and atmosphere  
 o The geographical position of Europe and Spain  
 o The Mediterranean Sea  |
|                        | • The ecosystem of the Mediterranean Sea  
 o The definition of ecosystem  
 o The terrestrial and aquatic ecosystem  
 o Introduction to the Posidonia oceanica ecosystem  |

(continued on next page)
Appendix 2

Questionnaire measuring the appeal to students

Dimension 1: Perceived usefulness

- I think that this type of class is useful in order to improve my knowledge about the Mediterranean Sea ecosystem.
- I can easily improve my knowledge about Mediterranean Sea ecosystem with this type of class.
- The participation in this type of class brings me some interesting and useful information.

Dimension 2: Intention to participate

- Based on my experience, I would like to participate more in this type of class.
- I want to participate more in this type of class as soon as it possible.
- If it would be possible I would like to participate in this type of class shortly.

Dimension 3: Perceived educational value

- This type of class let me learn about the Mediterranean Sea ecosystem.
- Participating in this type of class let me understand the basic notions of presented information.
- I learned some interesting information in this type of class.

Dimension 4: Engagement

- I forgot about time passing while participating in the class.
- I become unaware of my surroundings while participating in this type of class.
- I temporally forget worries about everyday life while I participated in this type of class.

Dimension 5: Intrinsic motivation

- After this class I want to learn a lot about the Mediterranean Sea ecosystem.
- After this type of class I will learn more about the Mediterranean Sea ecosystem to find out a lot of things I've been waiting to know.
- After this type of class, if I had homework to do, I would like to do it without any help.

Dimension 6: Enjoyment

- This type of class is fun.
- I had fun during this type of class.
- It is nice to participate in this type of class.

Appendix 1 (continued)

<table>
<thead>
<tr>
<th>Curricular objectives</th>
<th>Contents of E-Junior</th>
</tr>
</thead>
</table>
| Material and energy   | • The dynamics of one of the ecosystems of the Mediterranean Sea (Posidonia oceanica)  
                         • The components of Posidonia oceanica  
                         • Solar energy, nutrients, and carbon dioxide  
                         • Photosynthesis  
| Living organisms     | • The classification of living organisms in Posidonia oceanica  
                         • Different Posidonia oceanica grasslands  
                         • Habitat in the Posidonia oceanica  

Links between curricula and contents in terms of attitudes and procedures

To promote respect
To promote the protection and conservation of the environment
To demonstrate acceptance and respect for oneself and others
To foment social interaction by respecting social norms
To stimulate the cooperative and the competitive spirit
To collaborate in games and group-related activities
To stimulate imagination and creativity
To be able to think about one’s own behavior

• Preservation of the environment  
  • Positive actions on the environment  
  • Negative actions on the environment  

• The character of the E-Junior application (interactive game, collaborative character of the game, competitive character of the game)
### References


De la Cruz Ayuso, C. (2002). Educación del ocio: propuestas internacionales. BILBAO.


