PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
ESCUELA DE INGENIERIA

CO-LOCATED COLLABORATIVE LEARNING VIDEO GAME WITH SINGLE DISPLAY GROUPWARE

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Thesis submitted to the Office of Research and Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Science in Engineering.

Advisor:
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To my family and friends, who supported me through this investigation.

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RESUMEN

Role Game es un juego de video CSCL donde juegan tres estudiantes sentados uno al lado del otro frente a una pantalla común, cada uno con su propio mouse. Inspirado en juegos de video, Role Game permite a los estudiantes aprender realizando actividades e ir adquiriendo habilidades sociales y personales en un contexto de colaboración con sus compañeros. Primero se describe la estructura del juego y los elementos lúdicos de éste. Para posteriormente presentar un experimento que se realizó en un kindergarten, cuyos resultados fueron usados en un estudio de usabilidad. Nosotros concluimos que un juego de video educativo como Role Game puede ser utilizado por niños de seis años sin problemas, a pesar de que previamente no sabían usar un computador. Los juegos multijugador diseñados para la educación mostraron ser dispositivos poderosos para el trabajo colaborativo en la sala de clases y mantener el atractivo para los jugadores. Estos juegos son consistentes con la necesidad de alinear el software educativo con el currículo escolar, Y la manera de hacerlo es creando un ambiente técnico (editor y juego) que facilite el trabajo del pensamiento y en grupos en los colegios. Nuestros resultados confirman la visión de McFarlane: que ellos “proveen un ambiente donde el aprendizaje surge como resultado de tareas estimuladas por el contenido del juego, el conocimiento es desarrollado a través del contenido del juego y se desarrollan habilidades como resultado de usar el juego”.

Palabras Claves: Colaboración, Juegos de video, Múltiples mouses, CSCL, SDG

ABSTRACT

Role Game is a co-located CSCL video game played by three students sitting at one machine sharing a single screen, each with their own input device. Inspired by video console games, Role Game enables students to learn by doing, acquiring social abilities and mastering subject matter in a context of co-located collaboration. After describing the system's ludic and gaming structure, we present an experiment conducted in a kindergarten situation, whose results are subjected to a usability analysis. We conclude that a console video game for learning applications such as Role Game can easily be operated by six-year-old students who have yet to learn to read or operate a computer. Console multiplayer games designed for learning are shown to be a powerful device for collaborative work in the classroom while maintaining its attractiveness to the gamer. They are consistent with the need to align learning software with the school curriculum, creating a socio-technical environment that can support meta-design and social creativity in an educational setting. Our findings thus confirm McFarlane´s view that they "provide a forum in which learning arises as a result of tasks stimulated by the content of the games, knowledge is developed through the content of the game, and skills are developed as a result of playing the game".

Keywords: Collaboration, video games, multiple mice, CSCL, SDG

1. INTRODUCTION

1.1. Motivation

Today's children are surrounded by technology: internet, cell phones, computers, chats and blogs. With one single click they can surf the web and communicate with the world. But, when they go to school, they have to sit down, remain quiet and listen to a teacher, just like children living one hundred years ago. This kind of situation make us think how to use technology to make the classroom more fun, so the children be more motivated to learn, not only the curricula's contents, but also social skills, such as collaboration. These skills are essential for children's successful development in the society.

1.1.1. Games

Playing games is important to build social skills. Huizinga (1950) observes that playing is a common way to form new groups. Also, playing games in any form constitutes an important part of children's cognitive and social development (Provost, 1990). In 1976 Vigotsky stated that a child learns through playing with others, creating and improving his or her zone of proximal development, because playing often involves more complex activities than those the child experiences in daily life. Playing games is a natural activity for children and it is critical for their social development. It is mandatory to use game's benefits in order to improve learning and social skills.

Video games are an attractive technological solution to improve motivation and learning in the classroom: Brown et al. (2004) suggests that gamers experience different levels of commitment with a game. The first stage of immersion is engagement and its barrier is the gamers' preference. An engaged gamer wants to keep playing and is willing to concentrate on the game tasks. Since engagements, and possibly obsession, are necessary parts of the learning process, an engaged player in a school context will be better able to concentrate on learning tasks (Bransford, Brown & Cocking, 1999). Also, advances in neuroscience reveal that emotions have a direct connection to learning. Research shows that the brain structures that underlie learning and memory are the same ones that regulate many kinds of emotions. Video games in particular can provide story-driven entertainment that engage children to connect with the content while learning critical thinking skills (Crocker, 2003).

Games should be introduced in schools because they make learning meaningful to students, creating a learning culture that is more in correspondence with their interests (Papert, 1995; Provenzo, 1992). Games can make the matters of school curriculums more interesting and relevant to them: "(Computer) games offer teachers enormous resources they can use to make their subject matter come alive for their students, motivating learning, offering rich and compelling problems, modeling the scientific process and the engineering context and enabling more sophisticated assessment mechanisms" (Jenkins, 2002). Also video games strengthen and support school achievement, cognitive abilities, motivation to learn, attention and concentration (Rosas et al., 2003).

Introducing video games in schools is not easy. They are considered by many teachers and parents as a problem for children's development. Children can spend up to 10,000 hours with Video Games when they arrive to the age of 21 (Pre, 2003). Also, a general opinion holds that computer gaming has an anti-socializing rather than socializing effect in children (Raybourn, 2004). Others allude games' violent, sexist and addictive characteristics may become transferred to people who play with them. Fortunately, these are unfunded opinions only. As de Aguilera and

Méndiz (2003) states: “Many experts have shown that is impossible to attribute negative effects to video games, except in rare cases and under unusual circumstances.”

There is also ample empirical evidence supporting the positive effects of computer games as instructional tools (Kulik, 1994). The video games can strengthen and support: school achievement (McFarlane et al, 2002), cognitive abilities (Keller, 1992), motivation towards learning (Kulik, 1994), and attention and concentration. Video games contribute additional value by creating their own micro world in which players act based on their natural tendencies towards learning (Rieber, 1996). Therefore, learning occurs during video game playing (Baird & Silvern, 1990). The learning process that occurs has to do with the created immersion effect (Hubbard, 1991), that is, an environment into which the players submerge themselves, progressively increasing their levels of attention and concentration on the goal to obtain. This effect has commonly been interpreted as alienating; however, it can be understood as a genuine opportunity to take advantage of children’s concentration for introducing educational contents (Lepper and Malone, 1987). The games model not only the principles, but also the dynamics of cognitive processes and particularly those of complex systems. Even video-game programming is considered a highly valuable tool for the development of higher order skills. As McFarlane et al., 2002 state, “computer games provide a forum in which learning arises as a result of tasks stimulated by the content of the games, knowledge is developed through the content of the game, and skills are developed as a result of playing the game”.

1.1.2. Learning with games

The learning process changed in the 1900s with the introduction of color printing, radio, movies, television and video. These new technologies provided new opportunities to reshape stories for children. In 1980s the computers made their appearance. The first steps were to use the existing texts documents to bring stories to children. These were rapidly replaced by animated picture books and then by edutainment programs, which use the instructional capabilities of the computer, and adventure video games that provide an immersive and visual representation. Both of them were much more interesting to the audience than animated picture books (Madej, 2003).

Video games incorporate a whole new set of learning principles, yet to be discovered, that can be used in other settings. Game players learn different skills: to fly airplanes, to operate theme parks, to build civilizations, to drive cars, etc. They are learning to search and use information from many sources and make decisions based on it; they deduce game's rules from playing rather than by being told; they create strategies for overcoming obstacles; to understand complex systems through experimentation (Gee, 2003). Kids who are used to play video games, enter the first grade being able to do and understand so many complex things, from reasoning to flying, that the curriculum they are fed in school often feels to them like a depressant (Prensky, 2003).

Video games are a good medium for learning: as state before, an engaged player can be a concentrated student (Bransford et al., 1999) and because video games can provide story-driven entertainment that engages kids to connect with the content while learning critical thinking skills (Crocker 2003).

People who play video games learn from three different levels (Sisk, 1995): from contextual information, from an organic process generated by the game and from the outcome of strategies that are result from decision making. Game players can operate in these levels simultaneously, showing that decision making and applying newly learned tools are a complex and multilevel social process (Raybourn and

Waern, 2004). Players learn from a game when they build connections between game actions and the underlying knowledge (Conati and Lehman, 1993). The ability of a person to do so depends on individual differences in meta-cognitive skills, relevant to learn from autonomous exploration (Shute, 1993). The introduction of video games in schools can be a powerful tool to promote learning when teachers use them along with other instructional activities (Rosas et al., 2003), and since educational games have a high level of engagement, they do not remind students of traditional activities of the school (Conati and Zhao, 2004).

The last thing about learning is to understand the motivation. Maslow (1954) argued that using computer games in learning is intrinsically motivating. He developed a pyramidal model to understand hierarchy of needs. The needs of the lower levels of this pyramid must be fulfilled before the needs of the higher levels. In the bottom level are the needs of understanding the basic rules of games, the middle level is the need to comprehend all the information required to achieve game's goal. Once they have fulfilled these needs they move to the last level: Satisfaction, which involves to feel in control of the game, to expect challenge, different outcomes, and to be able to build strategies to achieve the goal.

To ensure that a game can promote learning, all motivational issues mentioned before must be taken into account. And one of the most relevant subjects is to find a solution that won't scare teachers just because it involves technology and games. Teachers are the key to bring educative games into the classroom successfully. Also games should focus on children of first grade because at this age a child determines his/her auto academic concept and his attitude to learning (Heussler et al., 2005).

1.1.3. Collaboration

Social interactions are important for sharing ideas and constructing and shaping understanding, and are fundamental to educational development (Cole & Stanton, 2003). When individuals work together on a common problem they communicate and mobilize knowledge, energy, and motivation (Zurita & Nussbaum, 2004). In addition, creative activity grows out of the relationship between individuals and their work as well as their interactions with others (Fischer, 2005). These social interactions are essential to achieve the desired learning. “As early as 1890, social psychology literature discusses the social facilitation effect on learning, concluding that under collaborative face-to-face interaction conditions, group members working on a common problem communicate to one another a sense of urgency that tends to heighten their mobilization of energy, and as an ultimate result their motivation” (Newcomb, Turner, & Converse, 1965; cited in Zurita & Nussbaum, 2004). Clearly, social interaction and collaboration between peers is critical for a successful development of children.

Collaborative learning (CL) environments have proven to confer many benefits in achieving learning objectives, social results, positive interdependence and motivation, with students acquiring new skills, ideas, and knowledge through working together (Zurita & Nussbaum, 2005a).

However, CL has also been shown to suffer from certain problems of coordination, communication, organization, and synchronization. One way of solving these problems is by using computers. Littleton (1999) suggests that the computer is not only capable of supporting collaborative behavior, but it is unique among the various possible solutions because it can transform the way in which collaborative activity is structured (Stanton, Neale & Bayon, 2002).

Computers can be a great tool to improve collaboration because their use grows exponentially in homes, works and schools. There are two major lines of investigation in Computer-Supported Collaboration (CSC): one is known as Computer Supported Cooperative Work (CSCW), which studies how computers can support and coordinate collaborative activities, commonly at a distance. The other one is Computer Supported Collaborative Learning (CSCL), which uses collaborative activities to obtain better academic results (Johnson et al., 1999).

Computer supported collaborative learning (CSCL) (Lipponen et al., 2003; Zurita, Nussbaum & Salinas, 2005) encourages cooperation, discussion of ideas and resolution of cognitive conflicts as well as promoting problem-solving and higher-order thinking skills (Bricker et al., 1995).

CSCL employs technology to control and monitor interaction between participants; supply information; regulate tasks, rules and roles; and finally, mediate the acquisition of new knowledge.

1.1.4. Game design

There are different guidelines for game design, but to ensure that video games improve learning, two important characteristics must be present:

a) The first is a high level of user satisfaction, which is what motivates players to progress and learn more. To achieve this, the user's preferences, needs and expectations must be included in the video game design (Fabricatore, Nussbaum and Rosas, 2002). They also offer a model that provides an empirical basis for design guidance by way of a comprehensive study of actual player behavior. This model helps to understand the elements that must be dealt when designing games.

b) The second characteristic is alignment with the school curriculum and the environmental conditions that favor learning (Gros, 2000). The challenge is thus to achieve a mix of recreation and learning in a single entity (De Aguilera & Méndiz, 2003).

The model proposed by Fabricatore, Rosas and Nussbaum (2002) focused mainly in commercial games (non educational games). There is also several design features in video games that affect students learning more strongly (Avezedo et al., 1995):

a) Adequate and adaptive feedback.

b) The embedding of cognitive strategies such as repetition, rehearsal, paraphrasing, outlining, cognitive mapping, and the drawing of analogies and inferences.

c) Animated graphics, which increase achievement and/or reduce task time.

According to De Aguilera and Méndiz (2003) the differences according to sex, age, socio-economic status, discourse on technology, educational context and models of use, have to be considered. Also to design games for small children, Good and Robertson (2004) propose a few characteristic that are important in games to them and Lepper et al. (1987) and Kafai (1995) give a list of elements to make an educational game more enjoyable:

a) Audience awareness: the game is expected to be different each time it is played.

b) Non-deterministic stories: the player wants to be an active actor of the action.

c) Interactive story structure: the children have to think about choices, respecting the story and environment constraints.

d) The character development: the story must include appearance and motives, and has to be in line with the character's nature.

e) The child actions must have consequences: these have to be explicit so the player perceives that he is an agent of the action.

f) Challenge: clear, meaningful and multiple goals, uncertain outcomes, variable difficulty levels, randomness, and constant feedback.

g) Fantasy: use of metaphors and emotionally appealing imagination directly linked to the activity, with character with which players can identify.

h) Explode two types of curiosity: sensory curiosity, audio and visual effects, and cognitive curiosity, surprises and constructive feedback.

None of these authors provide a specific instruction on how to provide feedback. The answer is in behavioral learning (Hopson, 2001): Most games use some kind of trial and error learning. During trial and error learning process, punishers or unpleasant consequences given to weaken behavior should be minimized to keep high motivation of the player, while reinforces should be given frequently and appropriately. The feedback must be given instantly, as concerned in immediacy of consequences, else the player cannot associate their behavior with the reinforcement or punishment. Players pay attention to information if they have to retain it. The working memory of attention is formed by sensory registers, which hold it for a very short period of time (Lloyd, 2000). Within a game, stimulus have to be interesting enough to move form sensory registers to long-term memory, storing the links to new and old data in order to be meaningful.

Another key concept in game design is the usability. Several games that are in the market would do much better if they were more usable (Pagulayan et al., 2003). Microsoft Game Studio in Washington is in an impressive endeavor regarding to usability (Jørgensen, 2004).

Finally, to develop educational games that can be used in a school, several key guidelines have to be taken under consideration: it can be said that user's preferences, usability, a good story and proper feedback are the key components to keep the attention of the user. And to be able to introduce the game into the school, its contents must be aligned with school curriculum.

1.1.5. Platform

Which platform should be use to run the game is a critical question since some platforms support CSCL better than others. Also schools have a major hardware limitation that must be taken in consideration in order to introduce the game in schools successfully.

CSCL programs can be operated either at a distance or face to face in a co-located or co-present setting such as a classroom. Co-located collaboration "allow students to interact directly, see each other's expressions and gestures, therefore communicate more effectively" (Bricker et al., 1995). It also facilitates interactivity and simulation (building virtual words).

Co-located CSCL can be implemented through a wireless network of handheld devices (Zurita & Nussbaum, 2004) or single-display groupware (SDG) (Tse & Greenberg, 2004).

The case of handhelds devices using a wireless network has several advantages: Children appreciate taking the handhelds with them instead of being seated behind a PC because they can be more close to other children. They also feel a capacity of appropriation with handhelds due to their size (Zurita et al. 2005). Also Tremaine et al. (2005) inform that collaboration among partners using small handhelds was more cooperative and friendly in a comparison with PCs. The use of handheld devices is better than PCs, according with Brukman et al. (2002), who states that children have problems with keyboards, because they might not understand letters, numbers and the symbols of the keyboard. Also keyboard don't explain button's functions, therefore children cannot understand their use.

The difference between handheld devices and SDG is that with handheld devices, each child interact with his device and in SDG, a small group of co-located users collaborate by sharing one computer with a single display and simultaneous use of multiple input devices (Stewart, Bederson & Druin, 1998). With SDG, co-located users collaborate through a single computer with multipoint or multiple mouse technology (Pawar, Pal & Toyama, 2006). Video games have been using Single Display Groupware (SDG) from the beginning: many users, each with his own joystick connected to a single console, sharing the same screen on which they interact. This provides an opportunity to improve collaboration, because there is some evidence that SDG improves motivation and effectiveness of task completion through co-operative work (Stanton et al., 2002; Pawar et al., 2006). As Inkpen et al. (1995) states: "In some situations, learning is not necessarily the best when one student works on a single computer. Rather, the environment of multiple students collaborating around a single computer provides unique interactions that can result in improvements both in achievement and in attitude towards the task. One way this can happen is through students having to verbalize their ideas in order to work together. This elaboration reinforces the learning process".

With SDG, "children immediately understand the idea of multiple mice and cursors, are not confused by multiple cursors on screen, and with mice remain engaged throughout" (Pawar et al., 2006). Pawar also states that children react in favor of multiple mouse, children want to engage in the games, therefore each of them want a mouse.

Considering the low resources that schools have to acquire new hardware, the handheld devices are too expensive and delicate to be use in a classroom. SDG has an advantage in this case because multiple co-located persons, each with their own input device, can interact simultaneously on a single communal display, thereby multiplying the amount of interaction per student per PC for the cost of only a few extra mice (Pawar, Pal, Gupta & Toyama, 2007). This is highly attractive for schools in developing countries where high student-computer ratios are a common problem. An SDG game should not use keyboard for two reasons: as explain before, children have problem with keyboards and the second reason is that multiple keyboards use more physical space.

The following applications were found reviewing the SDG learning games for small children. Pawar's application (Pawar et al., 2006) was a competitive game and he observes that some children did not like competitiveness. This game was about identifying images correctly. Inkpen's application was to solve puzzles using mice but with only one cursor that has to be toggled between them (Inkpen et al., 1995). This game is not really a full SDG software, because almost the same result can be achieve just by interchanging one mouse between the users. Bricker

(1998) develop a simple application, in which three users must change RGB component's to match a color.

The current SDG applications are far from being a collaborative video game; they are only prototypes and they lack of an environment to allow the teacher a proper alignment of the game content with the school curriculum. There is still no good user interface design on SDG applications to avoid user interference (Tse et al., 2004). This investigation is the first one to use an SDG application with pre-school students, where is possible to support collaborative work using only one computer.

1.2. Hypothesis

It is possible to use a collaborative and educative video game, based on Single Display Groupware, to teach basic skills to pre-scholar children.

1.3. Objectives

The main objective is to develop a video game for pre-scholar children that force them to work collaboratively while learning academic content. The design of the video game must avoid interference between children when they are playing the game. It is also important to achieve a high level of motivation and concentration of the children on the game task, so the teacher can concentrate only on groups with problems. Finally it is mandatory to develop an environment, where the teacher can modify the game content in order to align them with the school curriculum.

1.4. Methodology

A three player game model was design to achieve the objective of this thesis. In the game each player has a unique ability that they have to use to get around the game obstacles. If a player doesn't have the ability to surpass an obstacle, he must ask the player, who has that ability, to help him. These abilities are: climbing walls, swimming through water and putting dangerous animals to sleep. A game editor was developed in order to allow teachers to align the game contents with the school curriculum. This editor has a graphical user interface to promote his use by people without programming skills. The video game and the editor design were validated by psycho-pedagogic experts. At the end of the implementation of these two applications, the video game was used in a real classroom. Also several usability tests were performed during this experiment.
The following pages describe how the game and editor were design and implemented:

On the first semester of 2005, a prototype of a collaborative game for Pocket PC was developed (SDG technology with multi-mouse was only available at the end of 2006). According to Zurita and Nussbaum (2004), Computer Supported Collaborative Learning (CSCL) can be implemented using handheld devices on a wireless network. This game was named "Role Game" and it is a three player collaborative game as described before. The software architecture is based on a layer model shown in TableTable **1-1**.

Table 1-1: Layers

Interface
GAPI
Game Engine
Network
Wi-Fi

The game was implemented in C# Language using the Compact Framework 1.1 .Net and the Game API library (GAPI). This library provides graphical support for games in Pockets PC.

The prototype was analyzed with psycho-pedagogic experts during the second semester of 2005. In this analysis, the elements of the game were evaluated if they were able to maintain a high level of user satisfaction in order to keep high levels of concentration on the game tasks. All necessary interactions were defined to force the students to collaborate and to work in a team. The behavior of the avatars, enemies and obstacles, the objective and score system of the game were modified according to the suggestions made by the psycho-pedagogic experts. All these elements define any level of the game and they are explained in detail in chapter 2.2.

On fall of 2006 the video game model (with the changes proposed by the psycho-pedagogic experts) was implemented successfully. To allow the contents of the game to be aligned with school curriculums, the application must load all contents dynamically. All elements of the video game, described before, were parameterized, so they can be loaded to the video game from an XML file.

The next step was testing the video game in a real classroom, meaning a massive use. For such a purpose, the game was modified to work with Eduinnova's[1] network. This network provides automatic group creation and support recovery if any machine failed. Thanks to the layers-model used to implement the video game, this change was made easily. The original network layer was not removed because Eduinnova's network was too slow for a real-time game. It was only used to form groups and to recover failed machines.

On the first semester of 2006, an experiment with 12 first graders was conducted to analyze their motivation and the functionality of the game during one session. The game in Pocket Pc was difficult to use for the students, because of their age: they had a hard time trying to understand that individual actions have an effect on the group. Children of 5 to 7 years are in their preoperational stage. According to Piaget (1970), that means they think bipolar, intuitive and hardly in terms of causal relationships. They are also egocentric, causing more difficulties when they work in groups and trying to understand that any individual action on the game has an effect on the group. One of the reasons they found it difficult to understand was they worked on individual screens and they couldn't see their peers' screens. They wanted to continue playing without interruption, are competitive, try to be dominant and are unhappy when they lose, and they do not know how to accept failure. On the positive side, children at this age start to think about their own behavior and sharing with friends. Therefore, a collaborative game can potentially strengthen children social behavior and be a bridge for learning (Sluis et. al, 2004). The performance of the video game was also not good: the Pocket Pc's CPU was too slow to run the game, the screen was too small to show big maps and they missed a lot of network messages, resulting in an unpleasant lag on the game.

[1] Eduinnova develop new usage models for mobile technologies in the classroom.

More powerful Pockets Pc were release on spring of 2006, but GAPI library was discontinued on these machines. Fortunately, a new version of Compact Framework (CF 2.0) was also released. This version provided more extended support for graphics, so the GAPI library was replace with CF 2.0. The GAPI library allows a direct access to the video memory of the Pocket Pc and the CF 2.0 not, but there really was no distinction, because the upgrades on the hardware compensate this difference.

On the beginning of 2007 Microsoft Research Lab from India release an experimental driver to connect several mousses on one Pc. Even though the network problems and the performance of the game improve with the new hardware, the size of the screen was still an important limitation. The only solution to that problem was the use of computers using SDG with multiple mice.

SDG has been used by video game since the beginning: one console with multiples joysticks on one shared screen. With SDG, multiple co-located persons can interact simultaneously on a single display, thereby multiplying the amount of interaction per student per PC (Pawar, 2007). Also children immediately understand the idea of multiple mice and cursors, and they are not confused by multiple cursors on screen (Pawar et al., 2006).

Therefore, the game was modified to be used in a PC with multiple mice on the first semester of 2007. Now users share a single screen and they move their avatar with their own mouse. Also the psycho-pedagogic experts were asked about how to improve the alignment of the game content with the school curriculum. To facilitate this process, a game editor was designed, in which the game elements can be defined to build custom levels. Actually most of the teachers know very little about the digital world: from online exchanging, sharing, meeting, coordinating, searching and customizing to real time gaming and socializing (Pre, 2003). So anyone trying to introduce technology inside the classroom must find ways to involve teachers in the digital world without sacrificing state of the art technology (Cortez et al., 2005b). Therefore, the editor must be a graphical application that allows teachers, who lack programming skills, to create of content for the game. The video game and the editor conform a full environment, in which the school can create their own content in order to keep them align with the school curriculum.

On winter of 2007, an experiment was conducted to analyze if first graders understood the SDG version of the game. The students were not confused at all with several cursors on the screen and they immediately understood the logic of the game in one session. The children were able to interact better than with mobile devices, because they shared the same screen, on which they interacted better. The shared screen reduced the egocentric problem of small children, allowing them to get involved in a more social behavior. After this experiment was conducted, a larger experiment was prepared: test the game in a classroom of an underfunded school with a sample of 36 kindergarten pupils, all aged six, who had yet to learn to read or use a computer. To ensure the activities prepared were aligned with the school curriculum, the teacher specified the different mathematics and reading activities for each game session. The experiment was successfully conducted on the second semester of 2007. The details and results of this experiment are described on chapter 2.3.

1.5. Results

A model of a collaborative game based on Single Display Groupware was the result of this thesis. This model and the editor to build game's contents were successfully implemented. Both of them makes a whole environment, on which teachers can create contents, aligned to the schools curriculums, and use them with their students.
On the project side, the results were that the students were highly motivated to use the game and they were capable to work in teams without teacher's intervention.

The results of the experiment conducted in the school are described in detail in chapter 2 (2.3).

1.6. Future Work

A mayor step would be the introduction of a network. Having the computers on a network makes possible to watch students progress on real time in the teacher's computer. The teacher would be able to identify groups with problems quickly, without actually going to every group. Also, it will be easy to record student's progress in time, which can be analyzed by the teacher on his computer.

The editor could be a more graphical application, facilitating even more the teacher's job. Also it is important to build a library of pre-made contents, so teachers can select some of them and eventually modify them too. This will make the adoption of the game more easily for them.

Furthermore, it is expected that teachers would be capable of appropriate the editor and that they would use the game, not because they are force to do so, but because of its effectiveness to motivate children to work in teams.

1.7. Conclusions

Several conclusions are drawn from the experiment conducted in the school.

If children don't know how to use the mouse, the first game levels must be really easy, almost without ludic difficulties until they become used to the mouse. As soon as they mastered the use of the mouse, some difficulties should be introduced in order to teach them that any individual action has a repercussion on the group and that they have to work in teams to reach game's goal. As soon as they know how to play the game, more complex level should be introduced to force them to work collaboratively and to think on strategies to achieve the goal.

The game was able to improve collaboration on the students. At the beginning, students attempted to act on their own, but once they realized their actions did not achieve their goals, they understood they had to negotiate among them and to help each other to make some progress on the game. The communication in the groups was also improved because they were force to work with different peers every session.

The game sets rules for interaction so the teacher doesn't have to intervene in order to force the children to collaborate and work in teams. If a student leaves the computer, his group will force him to return to them, since they couldn't play the game without him. The same cannot be achieved so easily with board games, because usually, one student ends stealing the game and making the whole work alone. This won't happen with video games because children are very possessive with the mouse and they won't let anyone steal their mouse.

Even with very difficult levels, children didn't lose their motivation to play the game. This tells us that Role Game is a powerful tool to improve motivation and attention of students in a classroom.

The team, who made the game contents for the experiment, was guided by psycho-pedagogy experts to adapt the difficulty of the game to children capabilities and the content to schools curriculum. Even though, many troubles were found using these contents in the school. Teachers don't follow the curriculum exactly, they have to repeat lessons if children have difficulties understanding them. And another problem was that is quite hard to know how difficult the contents are a priori. Because all of these problems, it is mandatory to deliver a whole environment in which teachers can adapt the contents and difficulties of the game to match their students capabilities. The teachers know which levels of difficulty are appropriate to children and they know which content match their lessons, because they work with the children every day. They can use the game editor and achieve a better alignment of the game to school's curriculum and to children's capabilities than pre-made contents.

The development of the game and editor gave us much experience managing an investigation project. It began with the development of a prototype, which was analyzed with psycho-pedagogic experts, teachers and engineers to build a model; this model was later implemented and used in a school. Also the team that created the contents was managed and coordinated with the school successfully.

The experience in the school was satisfactory, because they are actually using the game and the editor to improve children's collaboration. Another conclusion is that it is very hard to introduce technology in a school: you have to create an appropriate environment: train the teachers to use the game and the editor, show them they can modify or create contents to match their needs, so they don't feel replaced by technology and understand the game is a tool to enhance their lessons.

The game was implemented using a layer architecture, which facilitated the introduction of Eduinnova's network and the replace of the graphic layer. This architecture also made very easy to modify the game from a mobile application to a Single Display Groupware application using multi mice. The use of an interpreted language like C# made this transition almost trivial.

2. CO-LOCATED COLLABORATIVE LEARNING VIDEO GAME WITH SINGLE DISPLAY GROUPWARE[2]

2.1. Introduction

Game playing in its diverse forms constitutes an important part of children's cognitive and social development, and more specifically, of their learning experience. A child learns through playing with others, creating and improving his or her zone of proximal development (Vygotsky, 1976), because such play tends to involve more complex activities than those the child experiences in daily life. Games in schools make learning meaningful to students and help to create a learning culture more in tune with their interests.

An engaged gamer wants to keep playing and is willing to concentrate on the game tasks. Since engagement and possibly obsession are necessary parts of the learning process, an engaged player in a school context will be better able to concentrate on learning tasks (Bransford, Brown & Cocking, 1999). Also, advances in neuroscience reveal that emotions have a direct connection to learning. Research shows that the brain structures that underlie learning and memory are the same ones that regulate many kinds of emotions. Video games in particular can provide story-driven entertainment that engages children to connect with the content while learning critical thinking skills (Crocker, 2003).

There is ample empirical evidence supporting the positive effects of computer games as instructional tools. Many of these positive elements are also found in video games, which contribute additional value in that they create their own micro

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world in which players act based on their natural tendencies towards learning (Rieber, 1996). Learning therefore occurs during video game playing (Baird & Silvern, 1990). The games model not only the principles, but also the dynamics of cognitive processes and particularly those of complex systems. Even video-game programming is considered a highly valuable tool for the development of higher order skills. Video games strengthen and support school achievement, cognitive abilities, motivation to learn, and attention and concentration (Rosas et al., 2003).

Of course, not all video games improve learning. To ensure they do, two important characteristics must be present. The first is a high level of user satisfaction, which is what motivates players to progress and learn more. The user´s preferences, needs, and expectations are essential considerations in video-game design (Fabricatore, Nussbaum & Rosas, 2002). The second necessary characteristic is alignment with the school curriculum and the environmental conditions that favor learning (Gros, 2000). The challenge is thus to achieve a mix of recreation and learning in a single entity (De Aguilera & Méndiz 2003)

Social interactions are important for sharing ideas and constructing and shaping understanding, and are fundamental to educational development (Cole & Stanton, 2003). When individuals work together on a common problem they communicate and mobilize knowledge, energy, and motivation (Zurita & Nussbaum, 2004). In addition, creative activity grows out of the relationship between individuals and their work as well as their interactions with others (Fischer, 2005). The role of interaction and collaboration with others is therefore critical.

These social interactions are essential to achieve the desired learning. “As early as 1890, social psychology literature discusses the social facilitation effect on learning, concluding that under collaborative face-to-face interaction conditions, group members working on a common problem communicate to one another a sense of urgency that tends to heighten their mobilization of energy, and as an ultimate result their motivation” (Newcomb, Turner, & Converse, 1965; cited in Zurita & Nussbaum, 2004). Collaborative learning (CL) environments have proven to confer many benefits in achieving learning objectives, social results, positive interdependence and motivation, with students acquiring new skills, ideas, and knowledge through working together (Zurita & Nussbaum, 2005a).

However, CL has also been shown to suffer from certain problems of coordination, communication, organization, and synchronization. One way of solving these problems is by using computers. Littleton (1999) suggests that the computer is not only capable of supporting collaborative behavior, but is unique among the various possible solutions in that it can transform the way in which collaborative activity is structured (Stanton, Neale & Bayon, 2002). Computer supported collaborative learning (CSCL) (Lipponen, Rahikainen, Lallimo & Hakkarainen, 2003; Zurita, Nussbaum & Salinas, 2005) encourages cooperation, discussion of ideas and resolution of cognitive conflicts as well as promoting problem-solving and higher-order thinking skills (Bricker, Tanimoto, Rothenberg, Hutama & Wong, 1995). CSCL employs technology to control and monitor interaction between participants; supply information; regulate tasks, rules and roles; and finally, mediate the acquisition of new knowledge.

CSCL programs can be operated either at a distance or face to face in a co-located or co-present setting such as a classroom. Co-located collaboration “allow students to interact directly, see each other’s expressions and gestures, therefore communicate more effectively” (Bricker et al., 1995). It also facilitates interactivity and simulation (building virtual words). Co-located CSCL can be implemented through a wireless network of handheld devices (Zurita & Nussbaum, 2004) or single-display groupware (SDG) (Tse & Greenberg, 2004). In the latter case, a small group of co-located users collaborate, sharing one computer with a single display and simultaneous use of multiple input devices (Stewart, Bederson & Druin, 1998).

Today's computers are designed on the assumption that a single person interacts with the display at any given moment, manipulating the mouse exclusively while the others present are passive onlookers with no operational control of the machine. With SDG, co-located users collaborate through a single computer with multipoint or multiple mouse technology (Pawar, Pal & Toyama, 2006). Each individual using their own mouse but sharing the communal display.

In video games, SDG has been employed from the beginning. Two or more users, each with their own joystick connected to a single console, share the same screen on which they interact. From a CSCL perspective, SDG provides an opportunity to improve support of existing forms of collaborative work, introducing computing capabilities through a ubiquitous channel. Multiple co-located persons, each with their own input device, can interact simultaneously on a single communal display, thereby multiplying the amount of interaction per student per PC for the cost of only a few extra mice (Pawar, Pal, Gupta & Toyama, 2007). This is highly attractive for schools in developing countries where high student-computer ratios are a common problem.

Much research has been conducted on the advantages of SDG in school learning Abnett, Stanton, Neale & O´Malley. (2001), Bier and Freeman.(1991), Bricker et al. (1995), Inkpen, Booth, Gribble and Klawe. (1995), Pawar et al. (2006), Stanton and Neale. (2003), Stanton et al. (2002), Stewart et al. (1998), Tse and Greenberg (2004), Pawar et al. (2007), Scott, Mandryk and Inkpen. (2003), Patra, Pal, Nedevschi, Plauche and Pawar. (2007), "The necessity of sharing can promote communication amongst the students. Physically separating students to work individually on computers tends to discourage communication" (Bricker et al., 1995). "In some situations, learning is not necessarily best when one student works on a single computer. Rather, the environment of multiple students collaborating around a single computer provides unique interactions that can result in improvements both in achievement and in attitude towards the task. One way this can happen is through students having to verbalize their ideas in order to work together. This elaboration reinforces the learning process" (Inkpen et al. 1995). With SDG, "children immediately understand the idea of multiple mice and cursors, are not confused by multiple cursors on screen, and with mice remain engaged throughout" (Pawar et al., 2006). "There is some evidence that the use of multiple input devices improves motivation, effectiveness of task completion (through parallel or co-operative work), equity of activity and time on task (Stanton et al., 2002).

This research presents a SDG video game application called Role Game. Its purpose is to support elementary school students as they strive to master course content while also learning to work collaboratively in small groups. Because of the students' young age, the process has not only to be educational but fun and simple as well. To achieve these objectives, a number of mathematics and language goals were defined within a collaborative ludic environment. The corresponding game activities were organized in such a way as to align with the scheduling of the course curricula set by the schools. To ensure the emphasis was on collaboration over competition, the following meta-goals for the game were also defined:

a) All members of a given group have the same goal, which can only be reached by all of them simultaneously. No member can "win" by defeating their group peers.

b) No group member can achieve the objectives of the activity on his or her own. Reaching the game's goals requires the participation of all members. Thus, the objectives can only be accomplished through collaborative work.

The collaborative game application was tested twice a week for an entire semester on the kindergarten class of an underfunded school in Chile's poorest urban area. The participating students had not yet learnt how to read or use a computer. In the remainder of this paper, Section 2.2 introduces Role Game, Section 2.3 presents a theoretical framework followed by a usability analysis, and Section 2.4 sets out our conclusions.

2.2. Role Game

2.2.1. Objectives

Role Game's pedagogical objectives are to count, recognize and order objects. Such skills facilitate a wide range of specific basic mathematics and language learning goals. A complementary objective of the game is to develop social and communication abilities.

Because Role Game is implemented with SDG, players can to play face to face, a work mode that promotes communication between the group members. The collaborative game activity is designed in such a way that the children must plan a strategy and then distribute the various tasks among themselves in order to reach the game objective.

Figure 2-1: Co-located Computer-Supported Collaborative Learning with SDG.

2.2.2. Description

Role Game participants are divided into groups of three co-located players. With only two members in a group, the players tend to merely converse while with four or more, too many viewpoints emerge and convergence to a group consensus is difficult. In groups of three, however, a momentum develops in the conversation and the peers (*i.e.*, fellow group members) are obligated to arrive at an agreement. Peers must interact and play together in such a way as to overcome ludic barriers and achieve the academic objectives. Each player has their own mouse that moves an avatar with abilities differing from those of their peers' avatars. These abilities allow them to support their peers in getting around obstacles. For example, the Hipno avatar can put monsters to sleep, the Alpi avatar can climb and help the others climb hills and rocks, and the Rafti avatar can cross and help the others cross rivers.

As with any video game, Role Game moves the players through increasingly more complex levels as they get better at playing it, posing ever more difficult ludic obstacles The game itself takes place in a space consisting of a map with zones defined by objects that illustrate flow, like a river, objects that block, as a rock, and objects that are at different levels, like mountains; enemies, like monsters or animals; pedagogical objects that must be captured to attain the pedagogical objectives, like letters, signs, and numbers; and elements called blockers that block and unblock the objects to be captured, like keys and flags. The avatars move within this map as they work collaboratively towards the objectives. Group achievement is measured in terms of energy (collaborative points) while pedagogical achievement is scored in terms of points. All of these game elements are listed and defined in Table 2-1.

Table 2-1: Elements of Role Game

Elements	Description	
Objective	Each level has a specific pedagogical objective, which is to capture pedagogical objects in a specified manner.	There are three kinds of objectives and activities : - Sequence: objective is to capture objects in a specific sequence; *e.g.*, capture letters of a word in the correct order. - Count Objects: objective is to capture a specific number of objects in any order; *e.g.*, capture five apples. - Recognition: objective is to capture specific objects; *e.g.*, capture the circles in a universe with different geometric shapes.
Map	Set of zones with different rules determining how the avatars move through them.	
Zones	Zones define the obstacles on the map: rivers, mountains, rocks.	There are five types of zones: - Green: Neutral ground; avatars can walk through it safely. - Blue: Avatars entering this zone die unless they have the specific ability to pass through it. - Brown: Avatars cannot enter this zone from another zone. An avatar that is in the brown zone can move freely within it, but cannot leave it without the specific ability to do so. - Black: Avatars cannot enter this zone. - Red: All avatars entering this zone die.
Enemies	Enemies are characters that walk across the map in a specific way. An avatar that touches an enemy dies.	- Any animated character: dragon, dog, etc.
Avatar abilities	There are three avatars in the game, each with a specific ability different from those of the other two. These abilities can be constructed in such a way that the three avatars must work together according to a specific plan in order to reach the defined objective.	The three specific avatar abilities are: - Putting an enemy to sleep by touching it, thus eliminating a threat to the other avatars. - Walking through blue zones and helping the other avatars without this ability move across them as well. - Entering and leaving brown zones and supporting the avatars without this ability to enter or leave.
Pedagogical objects	Entities represented by images that can be captured by the avatars.	- Letters - Signs - Numbers
Blockers	Pedagogical objects can be blocked or unblocked. Only when unblocked can	- Keys - Flags

	they be captured. An object is unblocked when an avatar is placed over its corresponding blocker.	
Points	Determines ranking of groups' success.	Two types of points can be won: - Collaborative: Awarded for group energy. Every avatar death or error made in capturing objects is considered an erroneous collaboration and decreases group energy. If the group loses all its energy it must start over. - Pedagogical: One positive point is won for every pedagogical object captured.

The following example illustrates the various components of Role Game and how it is played.

Imagine that a game is underway and that the pedagogical objective of the current level is to capture the three letters forming the word "ICE" in the proper order, with an additional letter, "S", as a distracter. The map for this level, shown in Figure 2-2, contains the four letters plus a key that acts as a blocker and is divided in two by a river. These and the remaining elements can be summarized as follows:

a) Objects to be captured: the letters "I", "C" and "E", with "S" as a distracter.

b) Avatars: the three avatars are located on the right bank of the river. Their abilities are defined such that Avatar 1 can capture the letters "I" and "S", Avatar 2 can capture the letter "C" and Avatar 3 can capture the letter "E".

c) Abilities: Avatar 3 has the ability to cross blue zones and Avatar 1 the ability to put enemies – in this case, the dog – to sleep.

d) Blocker: located on the left side of the river; blocks the four letters. It is represented as a red key.

e) Obstacles:

i) Blue zone: a river in the middle of the map running north to south.
ii) Brown zones: two elevated zones, one in the top right corner and the other in the bottom right corner.
iii) Green zone: the rest of the map.
iv) Enemy: a dog patrolling the letter "C".

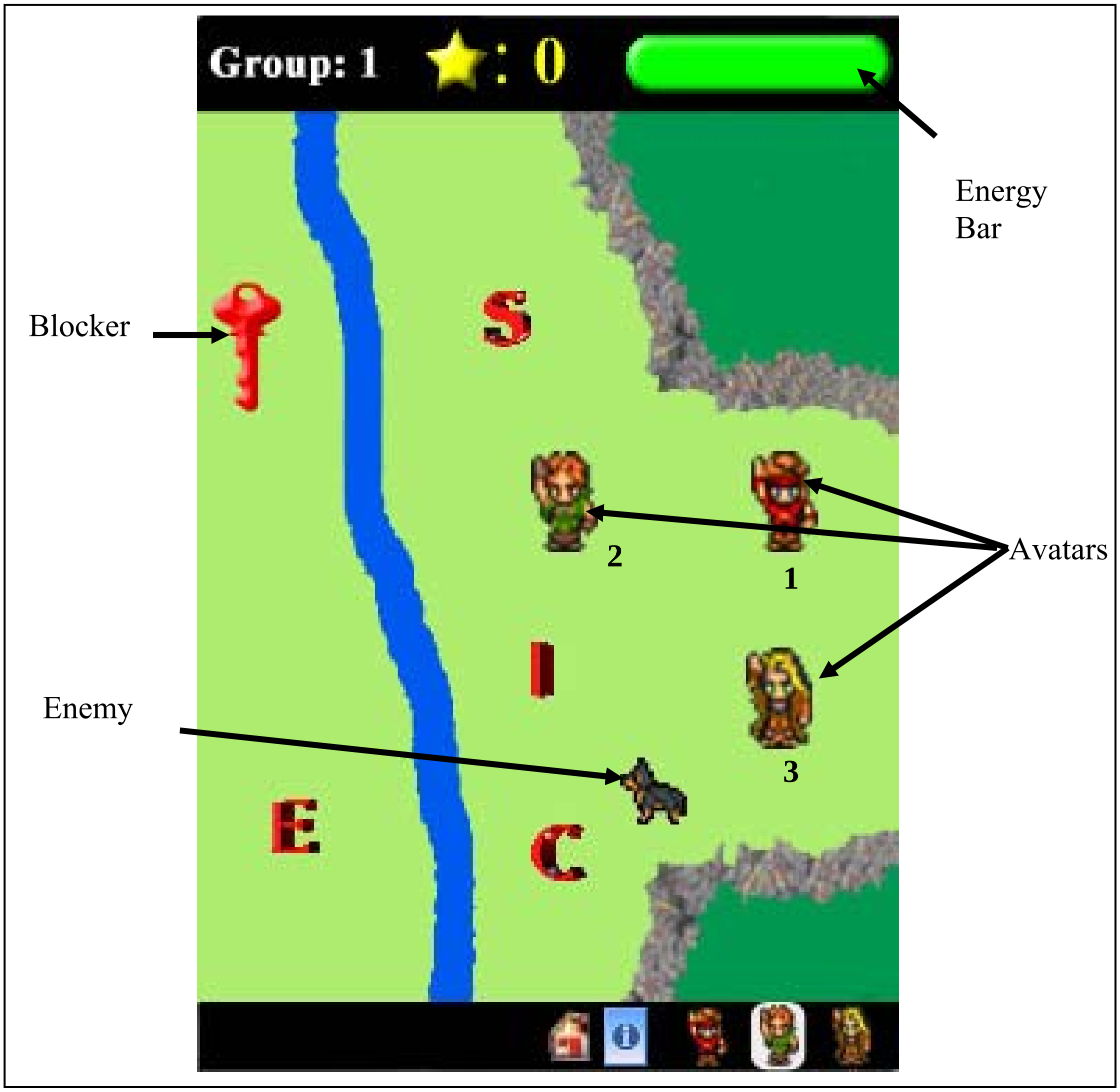

Figure 2-2: Screenshot of Role Game

Each player can only control their own avatar using their own mouse. The only way the players can move their avatars is to click on the desired location. The many possible interactions in the game are set forth in

Table **2-2**. Each one is described in terms of a result that depends on certain preconditions and is realized through a specific action.

Table 2-2: Interactions among elements

Result	Preconditions	Action
Capture of a pedagogical object	• Pedagogical object unblocked. • Avatar is able to capture this object.	Avatar is placed over pedagogical object
Unblocking of a pedagogical objects	None	Avatar is placed over corresponding blocker
Death of an avatar	Avatar does not have ability to put enemies to sleep	Avatar touches an enemy
	Avatar does not have ability to cross blue zones	Avatar enters blue zone
	Pedagogical object blocked	Avatar touches a blocked pedagogical object
	None	Avatar enters red zone
Enemy put to sleep	Has this ability	Avatar touches enemy
	Does not have this ability	Other avatar that does have this ability puts enemy to sleep so it is no longer a danger to others
Crossing of blue zone	Has ability	Being in the blue zone.
	Does not have ability	Touches other avatar that has ability to cross blue zone until safely out of it.
Entering and leaving of brown zone	Has ability	Enter brown zone from another zone or leave it to enter another zone
	Does not have ability	Touching the avatar that has this ability while entering or leaving brown zone.

The design of the game levels must be such that the players are forced to collaborate in order to overcome barriers and evade dangers and thereby achieve the pedagogical objective. It must also promote the development by the players of a collaborative strategy and prevent attempts by individual players to isolate themselves or play alone. Progress should only be possible through mutually supportive actions.

As an example, Figure 2-3 shows how the players plan and carry out a collaborative action to overcome the barrier posed by the river. Avatar 2, which does not have the ability to cross blue zones, is helped across with the support of Avatar 3, which does have that ability.

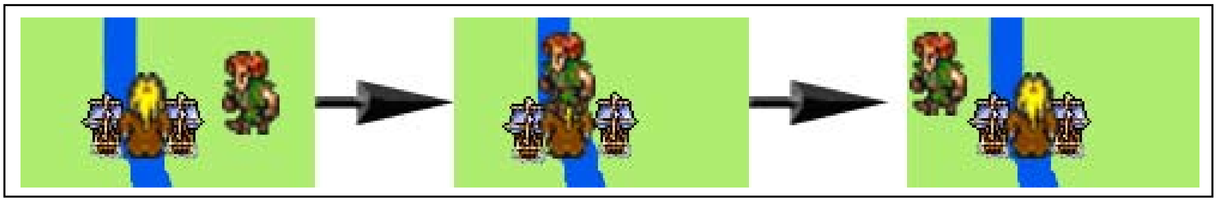

Figure 2-3: Collaboration between players to cross blue zone.

Another example is shown in Figure 2-4. There, the pedagogical objects are unblocked by Avatar 3, which is placed over the blocker. This allows Avatar 1 to capture the letter “I”, scoring one pedagogical point for the group (show at the top of the screen as a star). An “I” is then indicated at the bottom of the screen.

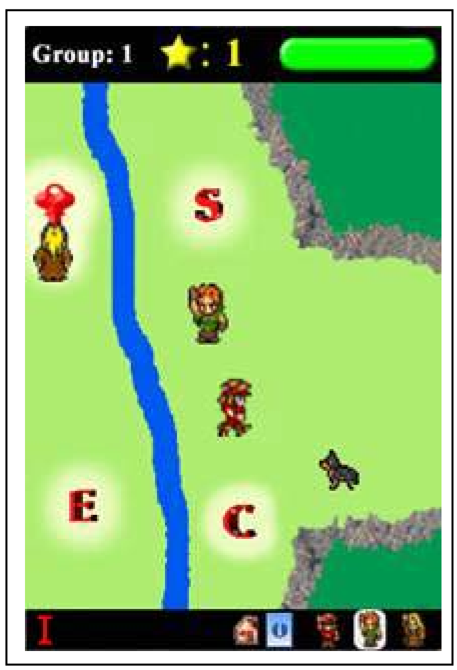

Figure 2-4: Collaboration between players to capture a letter: avatar unblocks letter by touching key.

2.2.3. Role Game activities editor

As well as a video game, Role Game also provides a system development environment for building collaborative educational video game activities. This is done via a high-level Editor that is easy to use and affords considerable flexibility. Activities can be created and educational content adapted without having to actually program the different levels or ensure compatibility with Role Game's files.

A screen shot of the Editor is shown in Figure 2-5. After specifying the game activity level in a drop-down box, the various elements of the activity are then defined using a series of seven tabs for the different element types and configuration functions: Initial State, Objects to Capture, Blocking Objects, Actors, Objective, Enemies, and Advance Configuration. Working the tabs from left to right, the teacher constructs the various interactions that make up the activity. This ordering of the tabs reflects a logical sequence that ensures the definitions necessary for the options on any given tab have already been made on the previous ones. As an example, in Figure 2-6 the map image would have to be defined before an avatar or object could be located.

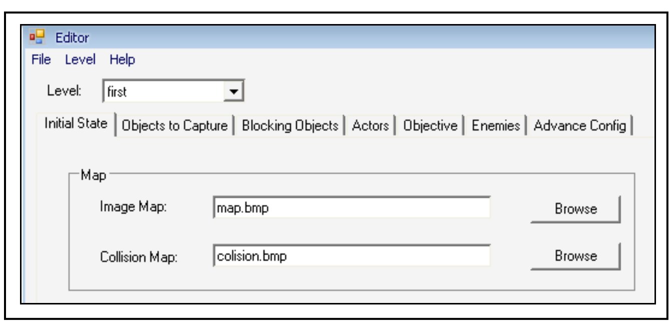

Figure 2-5: Editor

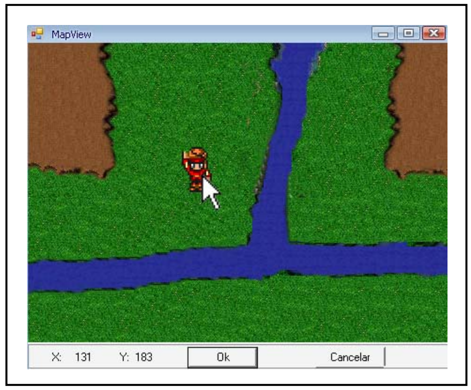

Figure 2-6: Locating an avatar in editor

Once all of the activity elements have thus been defined, the level is complete. A level can be modified later by the Editor where required. This capability means that a repository of levels can be created, any one of which can then be reused or adapted to new educational content by editing only those elements that need to be changed, thus simplifying the teacher's task. As an example, a new level could be built merely by reusing a previously designed map and elements with a different defined objective.

2.3. Usability Analysis

2.3.1. Research framework

As noted briefly in the Introduction, Role Game was applied twice a week over an entire semester (31 sessions of 45 minutes each) at an underfunded school in Chile's poorest urban district to a sample of 36 kindergarten pupils, all aged six, who had yet to learn to read or use a computer. To ensure the activities prepared were aligned with the school curriculum, the teacher specified the various mathematics and reading activities for each game session.

A usability analysis was performed to assess the results of this experiment on the basis of three sets of observation guidelines. The first set measured the level of user satisfaction, covering both the motivational elements that make the game attractive to the users and the essential elements of the user's expectations of video games following the framework proposed by Rouse (2001). This framework, which applies generally to all types of video games, consists of a set of elements describing why gamers play and what they expect from the games.

The second set of observation guidelines measured the system's user efficiency, analyzing the effort required to master the software, hardware, and the game strategies (Nielsen, 1994). With players of such a young age the ability to master the system is essential, as any significant complexities in its operation would render the activity unusable. Our purpose, therefore, was to understand which parts of the game were easily mastered by the children and which ones were not.

Finally, the third set of guidelines measured collaboration in the building of common strategies to accomplish the games' objectives. They were based on the framework given in Zurita, Nussbaum and Sharples (2003), which defines coordination, communication, organization, negotiation, and interactivity as key elements of a collaborative process.

These findings were complemented by the observations in the teacher’s logbook and an interview with the teacher at the end of the experiment.

2.3.2. Analysis of user satisfaction

Table 2-3: Analysis of user satisfaction

Main elements motivating people to play video games (Rouse (2001))	Experimental observation
Players want a challenge	RG challenges players both in its ludic and its pedagogical objectives Even though the experiment was embedded in an educational context, it was evident the students were very willing to meet the challenge of reaching the gaming and pedagogical objectives. Although the groups worked independently and no comparisons of their achievement levels were performed, some degree of competition was observed between them as they attempted to reach their objectives and finish earlier than the other groups.
Players want a dynamic experience in which they can be in control inside an interactive environment	RG allows players to interact with the game and with each other. They can make decisions about what to do and when to do it. The teacher observed that the children mastered the game elements (abilities, levels, points, and enemies) and found them fun. It is important, however, that the activity difficulty level be well adapted to the groups’ success in achieving both the gaming and the pedagogical objectives.
Players want bragging rights: the satisfaction of reaching objectives and being recognized by others.	RG awards points when pedagogical objectives are achieved, and allows successful groups to move up to the next level. Students expressed satisfaction when they overcame obstacles, completed an activity level, and won points.
Players want an emotional experience	RG encourages social relationships between players (Zurita & Nussbaum, 2005a) by obligating them to negotiate, build common strategies, collaborate and debate among themselves. All of the students were keen on participating in the activity, and enjoyed working closely with their peers. However, gender problems emerged between group members that required intervention by the teacher to resolve.
Players expect a consistent world where they can interact and understand the actions they can perform and their effects.	RG’s consistent world is made up of five zones that define the avatars’ range of movement and their actions. Both elements have clearly defined effects that the students easily understood. The students intuitively understood the game rules. However, they associated more power with one of the avatars than the others due to the avatars’ defined abilities, which created problems between group members that were difficult to resolve.
Players expect to understand the game world´s bounds.	

Players expect reasonable solutions to work so that every problem posed by the game can be solved.	In RG there are many ways to achieve the game's objectives depending on the players' strategies and the agreements they make. In general, students came up with reasonable solutions. Crossing the river was difficult for many since it required coordination and synchronization among members.
Players expect direction.	Instructions regarding objectives and abilities are displayed at the beginning of each level. Information on the game outcome, group energy level and accomplishment of pedagogic objectives is provided continuously. Students continuously monitored the information on their outcomes, which helped them understand what they were doing and achieving. Some levels turned out to be no more difficult or challenging than the preceding one. Game difficulty depends on the group members' abilities to master their individual roles, and the complexity of successive pedagogic objectives did not always increase.
Players expect to accomplish a task incrementally and be able to understand by means of rewards or checkpoints whether their actions are correct.	
Players expect to be immersed	As can be seen in Figure 1, only one student is seated directly in front of the screen. Students seated on either side of the one in the centre were exposed to distractions such as talking with members of other groups. Striking the right balance between ludic and pedagogical difficulty is a key element not easily achieved. We observed that if an objective was beyond the children's ability, they lost their concentration.
Players expect some setbacks in order to make the game more fun and challenging. It is not fun if the game is too easy.	
Players expect a fair chance to solve problems and overcome obstacles.	Certain activities required more training to overcome the obstacles they contained, such as crossing the river. Until they mastered these tasks the children expressed some frustration.
Players expect not to have to repeat themselves.	The different game levels combine increasingly difficult gaming pedagogical goals. If a mistake is made, the player must return to the previous level. The children found this to be very frustrating. When this occurred more than once in the same level, the children tended to begin arguing and interfering with each other's roles and play would often deteriorate into an improvised game of killing avatars.
Players expect not to get hopelessly stuck and have to start over, losing everything already gained.	
Players expect to participate, not just to watch. They want to be active players in the game.	Our observations confirmed that one of the main accomplishments of RG is that all players become protagonists in the game, each through the use of their own mouse.

2.3.3. Analysis of user efficiency

Table 2-4: Analysis of user efficiency

Observed element	Experimental observation
Time spent understanding the game's dynamics	According to the session logbook, students found it difficult at first to understand the game's dynamic because they had no instructor to introduce them to it. However, after a few sessions all students understood the game intuitively.
Multiple mouse use	Most of the students were able to use the mouse and integrate themselves quickly into their group without problems.
Ability to move avatar	Although the students understood the system and were able to use the mouse, many of them did not grasp the logic of the avatar movements, clicking repeatedly in a pointless attempt to increase the avatar's speed. Also, crossing the river was a difficult goal for many and was not always achieved.
Ability to develop strategies for reaching objectives	Since the groups were formed randomly and changed from session to session, the students had to learn to build strategies with a varying combination of peers. This was not always easy due to their age.

2.3.4. Analysis of the collaborative process

Table 2-5: Analysis of the collaborative process

Collaborative process elements (Zurita, Nussbaum & Sharples, 2003)	Experimental observation
Coordination: The design of the activity should force participants to perform one task at a time and carry out each group action in a specific sequence.	The game incorporates barriers that have to be overcome in a specific order for the goal to be achieved. The students had difficulties coordinating their actions with their peers. But since the software gave them no choice, in the end they learned to coordinate and were thus able to proceed with the game.
Organization: Each participant's machine should provide all required information for the activity. No additional material should be necessary.	The design of the different levels was always clear and the players' roles were immediately understood.
Negotiation: All participants have the same rights and must agree to proceed.	No advance is possible in RG until the group members come to an agreement. Negotiation occurs both in the ludic and the pedagogical aspects. At the beginning students attempted to act

	on their own, but once they saw their actions did not achieve their goals, they realized they had to negotiate them.
Interactivity: Agreement must be built through peer interaction.	RG forces students to interact in order to reach agreement on their actions. When a student was unsure what to do, their first reaction was to seek help from a peer. Since the groups were different in each session, those who understood the game better assumed leadership of their group. When a student lost interest, the other two members usually took over the use of their mouse to continue the game. As long as the students remained interested, however, they all kept control of their own mice and supported each other to reach the objectives.

2.4. Conclusions

Role Game proved to be a satisfying experience for the students who participated in the study, maintaining their motivation throughout the experiment. The children enjoyed playing the collaborative game and found the objectives to be an interesting challenge. Furthermore, the activity fulfilled their expectations. They collaborated well in carrying out the tasks, and the random assignment of them into different groups resulted in successful working relationships.
A key aspect of the SDG activity was that each child identified with their avatar through their individual mouse. This created a sense of ownership that facilitated a constant and active involvement.

A significant problem that did affect their satisfaction, motivation and expectations was the level of gaming and pedagogical difficulty. The design of each lesson and game level must ensure that these difficulties are in line with abilities and knowledge of the students. Other aspects such as the complexity of the avatars' roles and avatar movement speed also have to be fine-tuned to optimize the gaming experience, taking into account the players' age level.

The console multiplayer video game is a powerful tool that can be used to advantage in the classroom. Though not designed as a learning tool, our experiment showed that for kindergarten students, these multiplayer games are both effective and attractive as pedagogical devices. Despite being generally considered as a competitive environment, we found that the games' attributes carry over to collaborative activities, maintaining students' motivation even though they had to collaborate with each other rather than compete.

Finally, console video games with a high-level application-building environment that teachers can use to specify educational activities offer the necessary flexibility to intermix gaming and pedagogic objectives and provide new ways to align learning software with school curricula. From this perspective, the games create a socio-technical environment that can support meta-design and social creativity in educational settings (Fischer, 2007). Our findings thus confirm McFarlanes' (2002) view that games "provide a forum in which learning arises as a result of tasks stimulated by the content of the games, knowledge is developed through the content of the game, and skills are developed as a result of playing the game".

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APPENDICES

APENDIX A: RECEPTION AND CONFIRMATION EMAIL

From: "cristián infante" <infantecristian@yahoo.com>
Sent: Tuesday, June 03, 2008 6:15 PM
To: <psotka@msn.com>
Cc: <mn@ing.puc.cl>; <threyes@puc.cl>; <jfweitz@puc.cl>
Subject: send paper

Dear Dr Psotka

Please find enclosed a PDF of our paper "Co-located Collaborative Learning Video Game with Single Display Groupware", that we submit to your consideration to the "Interactive Learning Environments" Journal.

If this article is not within the journal scope or you need a different sort of submission, please let me know. If the previous is not the case, please let me know if you received OK the PDF.

Thanking you in advance for your response.

Cristian Infante

From: joe Psotka <psotka@msn.com>
Sent: Tuesday, June 03, 2008 9:20 PM
To: cristián infante <infantecristian@yahoo.com>, b.c.e.scott@cranfield.ac.uk
Cc: <mn@ing.puc.cl>; <threyes@puc.cl>; <jfweitz@puc.cl>
Subject: send paper

Dear Cristian Infante,

Thank you for submitting your ms to ILE.

I will send it out for review and you should hear from me in about two months.

If you do not hear from me, pleaase do not hesitate to email me about the status of the ms.

Best

Joe Psotka
Co-Editor

APENDIX B: SUBMITION PAPER

The following pages show the original paper submitted to the "Interactive Learning Environments" Journal.

Co-located Collaborative Learning Video Game with Single Display Groupware

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Abstract

Role Game is a co-located CSCL video game played by three students sitting at one machine sharing a single screen, each with their own input device. Inspired by video console games, Role Game enables students to learn by doing, acquiring social abilities and mastering subject matter in a context of co-located collaboration. After describing the system's ludic and gaming structure, we present an experiment conducted in a kindergarten situation, whose results are subjected to a usability analysis. We conclude that a console video game for learning applications such as Role Game can easily be operated by six-year-old students who have yet to learn to read or operate a computer. Console multiplayer games designed for learning are shown to be a powerful device for collaborative work in the classroom while maintaining its attractiveness to the gamer. They are consistent with the need to align learning software with the school curriculum, creating a socio-technical environment that can support meta-design and social creativity in an educational setting. Our findings thus confirm McFarlane´s view that they "provide a forum in which learning arises as a result of tasks stimulated by the content of the games, knowledge is developed through the content of the game, and skills are developed as a result of playing the game".

Keywords

collaboration, video games, multiple mice, CSCL

I. Introduction

Game playing in its diverse forms constitutes an important part of children's cognitive and social development, and more specifically, of their learning experience. A child learns through playing with others, creating and improving his or her zone of proximal development (Vygotsky, 1976), because such play tends to involve more complex activities than those the child experiences in daily life. Games in schools make learning meaningful to students and help to create a learning culture more in tune with their interests.

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An engaged gamer wants to keep playing and is willing to concentrate on the game tasks. Since engagement, and possibly obsession, are necessary parts of the learning process, an engaged player in a school context will be better able to concentrate on learning tasks (Bransford, Brown & Cocking, 1999). Also, advances in neuroscience reveal that emotions have a direct connection to learning. Research shows that the brain structures that underlie learning and memory are the same ones that regulate many kinds of emotions. Video games in particular can provide story-driven entertainment that engages children to connect with the content while learning critical thinking skills (Crocker, 2003).

There is ample empirical evidence supporting the positive effects of computer games as instructional tools. Many of these positive elements are also found in video games, which contribute additional value in that they create their own microworld in which players act based on their natural tendencies towards learning (Rieber, 1996). Learning therefore occurs during video game playing (Baird & Silvern, 1990). The games model not only the principles, but also the dynamics of cognitive processes and particularly those of complex systems. Even video-game programming is considered a highly valuable tool for the development of higher order skills. Video games strengthen and support school achievement, cognitive abilities, motivation to learn, and attention and concentration (Rosas *et al.*, 2003).

Of course, not all video games improve learning. To ensure they do, two important characteristics must be present. The first is a high level of user satisfaction, which is what motivates players to progress and learn more. The user´s preferences, needs, and expectations are essential considerations in video-game design (Fabricatore, Nussbaum & Rosas, 2002). The second necessary characteristic is alignment with the school curriculum and the environmental conditions that favor learning (Gros, 2000). The challenge is thus to achieve a mix of recreation and learning in a single entity (De Aguilera & Méndiz 2003)

Social interactions are important for sharing ideas and constructing and shaping understanding, and are fundamental to educational development (Cole & Stanton, 2003). When individuals work together on a common problem they communicate and mobilize knowledge, energy, and motivation (Zurita & Nussbaum, 2004). In addition, creative activity grows out of the relationship between individuals and their work as well as their interactions with others (Fischer, 2005). The role of interaction and collaboration with others is therefore critical.

These social interactions are essential to achieve the desired learning. “As early as 1890, social psychology literature discusses the social facilitation effect on learning, concluding that under collaborative face-to-face interaction conditions, group members working on a common problem communicate to one another a sense of urgency that tends to heighten their mobilization of energy, and as an ultimate result their motivation” (Newcomb, Turner, & Converse, 1965; cited in Zurita & Nussbaum, 2004). Collaborative learning (CL) environments have proven to confer many benefits in achieving learning objectives, social results, positive interdependence and motivation, with students acquiring new skills, ideas, and knowledge through working together (Zurita & Nussbaum, 2005a).

However, CL has also been shown to suffer from certain problems of coordination, communication, organization, and synchronization. One way of solving these problems is by using computers. Littleton (1999) suggests that the computer is not only capable of supporting collaborative behavior, but is unique among the various possible solutions in that it can transform the way in which collaborative activity is structured (Stanton, Neale & Bayon, 2002). Computer supported collaborative learning (CSCL) (Lipponen, Rahikainen, Lallimo & Hakkarainen, 2003; Zurita, Nussbaum & Salinas, 2005) encourages cooperation, discussion of ideas and resolution of cognitive conflicts as well as promoting problem-solving and higher-order thinking skills (Bricker, Tanimoto, Rothenberg, Hutama & Wong, 1995). CSCL employs technology to control and monitor interaction between participants; supply information; regulate tasks, rules and roles; and finally, mediate the acquisition of new knowledge.

CSCL programs can be operated either at a distance or face to face in a co-located or co-present setting such as a classroom. Co-located collaboration "allows students to interact directly, see each other's expressions and gestures, therefore communicate more effectively" (Bricker *et al.*, 1995). It also facilitates interactivity and simulation (building virtual words). Co-located CSCL can be implemented through a wireless network of handheld devices (Zurita & Nussbaum, 2004) or single-display groupware (SDG) (Tse & Greenberg, 2004). In the latter case, a small group of co-located users collaborate, sharing one computer with a single display and simultaneous use of multiple input devices (Stewart, Bederson & Druin, 1998).

Today's computers are designed on the assumption that a single person interacts with the display at any given moment, manipulating the mouse exclusively while the others present are passive onlookers with no operational control of the machine. With SDG, co-located users collaborate through a single computer with multipoint or multiple mouse technology (Pawar, Pal & Toyama, 2006). each individual using their own mouse but sharing the communal display.

In video games, SDG has been employed from the beginning. Two or more users, each with their own joystick connected to a single console, share the same screen on which they interact. From a CSCL perspective, SDG provides an opportunity to improve support of existing forms of collaborative work, introducing computing capabilities through a ubiquitous channel. Multiple co-located persons, each with their own input device, can interact simultaneously on a single communal display, thereby multiplying the amount of interaction per student per PC for the cost of only a few extra mice (Pawar, Pal, Gupta & Toyama, 2007). This is highly attractive for schools in developing countries where high student-computer ratios are a common problem.

Much research has been conducted on the advantages of SDG in school learning Abnett, Stanton, Neale & O´Malley. (2001), Bier and Freeman.(1991), Bricker *et al.* (1995), Inkpen, Booth, Gribble and Klawe. (1995), Pawar *et al.* (2006), Stanton and Neale. (2003), Stanton *et al.*

(2002), Stewart *et al*. (1998), Tse and Greenberg (2004), Pawar *et al.* (2007), Scott, Mandryk and Inkpen. (2003), Patra, Pal, Nedevschi, Plauche and Pawar. (2007), "The necessity of sharing can promote communication amongst the students. Physically separating students to work individually on computers tends to discourage communication" (Bricker *et al.*, 1995). "In some situations, learning is *not* necessarily best when one student works on a single computer. Rather, the environment of multiple students collaborating around a single computer provides unique interactions that can result in improvements both in achievement and in attitude towards the task. One way this can happen is through students having to verbalize their ideas in order to work together. This elaboration reinforces the learning process" (Inkpen *et al*. 1995). With SDG, "children immediately understand the idea of multiple mice and cursors, are not confused by multiple cursors on screen, and with mice remain engaged throughout" (Pawar *et al.*, 2006). "There is some evidence that the use of multiple input devices improves motivation, effectiveness of task completion (through parallel or co-operative work), equity of activity and time on task (Stanton *et al.*, 2002).

This paper presents a SDG video game application called Role Game. Its purpose is to support elementary school students as they strive to master course content while also learning to work collaboratively in small groups. Because of the students' young age, the process has not only to be educational but fun and simple as well. To achieve these objectives, a number of mathematics and language goals were defined within a collaborative ludic environment. The corresponding game activities were organized in such a way as to align with the scheduling of the course curricula set by the schools. To ensure the emphasis was on collaboration over competition, the following meta-goals for the game were also defined:

- All members of a given group have the same goal, which can only be reached by all of them simultaneously. No member can "win" by defeating their group peers.
- No group member can achieve the objectives of the activity on his or her own. Reaching the game's goals requires the participation of all members. Thus, the objectives can only be accomplished through collaborative work.

The collaborative game application was tested twice a week for an entire semester on the kindergarten class of an underfunded school in Chile's poorest urban area. The participating students had not yet learnt how to read or use a computer. In the remainder of this paper, Section II introduces Role Game, Section III presents a theoretical framework followed by a usability analysis, and Section IV sets out our conclusions.

II. Role Game

II.1 Objectives

Role Game's pedagogical objectives are to count, recognize and order objects. Such skills facilitate a wide range of specific basic mathematics and language learning goals. A complementary objective of the game is to develop social and communication abilities.

Because Role Game is implemented with SDG, players can to play face to face, a work mode that promotes communication between the group members. The collaborative game activity is designed in such a way that the children must plan a strategy and then distribute the various tasks among themselves in order to reach the game objective.

Figure 1: Co-located Computer-Supported Collaborative Learning with SDG.

II.2 Description

Role Game participants are divided into groups of three co-located players. With only two members in a group, the players tend to merely converse while with four or more, too many viewpoints emerge and convergence to a group consensus is difficult. In groups of three, however, a momentum develops in the conversation and the peers (*i.e.*, fellow group members) are obligated to arrive at an agreement. Peers must interact and play together in such a way as to overcome ludic barriers and achieve the academic objectives. Each player has their own mouse that moves an avatar with abilities differing from those of their peers' avatars. These abilities allow them to support their peers in getting around obstacles. For example, the Hipno avatar can put monsters to sleep, the Alpi avatar can climb and help the others climb hills and rocks, and the Rafti avatar can cross and help the others cross rivers.

As with any video game, Role Game moves the players through increasingly more complex levels as they get better at playing it, posing ever more difficult ludic obstacles The game itself takes place in a space consisting of a map with zones defined by objects that illustrate flow, like a river, objects that block, as a rock, and objects that are at different levels, like mountains; enemies, like monsters or animals; pedagogical objects that must be captured to attain the pedagogical objectives, like letters, signs, and numbers; and elements called blockers that block and unblock the objects to be captured, like keys and flags. The avatars move within this map as they work collaboratively towards the objectives. Group achievement is measured in terms of energy (collaborative points) while pedagogical achievement is scored in terms of points. All of these game elements are listed and defined in Table 1.

Table 1: Elements of Role Game

Elements	Description	
Objective	Each level has a specific pedagogical objective, which is to capture pedagogical objects in a specified manner.	There are three kinds of objectives and activities : - Sequence: objective is to capture objects in a specific sequence; *e.g.*, capture letters of a word in the correct order. - Count Objects: objective is to capture a specific number of objects in any order; *e.g.*, capture five apples. - Recognition: objective is to capture specific objects; *e.g.*, capture the circles in a universe with different geometric shapes.
Map	Set of zones with different rules determining how the avatars move through them.	
Zones	Zones define the obstacles on the map: rivers, mountains, rocks.	There are five types of zones: - Green: Neutral ground; avatars can walk through it safely. - Blue: Avatars entering this zone die unless they have the specific ability to pass through it. - Brown: Avatars cannot enter this zone from another zone. An avatar that is in the brown zone can move freely within it, but cannot leave it without the specific ability to do so. - Black: Avatars cannot enter this zone. - Red: All avatars entering this zone die.
Enemies	Enemies are characters that walk across the map in a specific way. An avatar that touches an enemy dies.	- Any animated character: dragon, dog, etc.
Avatar abilities	There are three avatars in the game, each with a specific ability different from those of the other two. These abilities can be constructed	The three specific avatar abilities are: - Putting an enemy to sleep by touching it, thus eliminating a threat

	in such a way that the three avatars must work together according to a specific plan in order to reach the defined objective.	to the other avatars. - Walking through blue zones and helping the other avatars without this ability move across them as well. - Entering and leaving brown zones and supporting the avatars without this ability to enter or leave.
Pedagogical objects	Entities represented by images that can be captured by the avatars.	- Letters - Signs - Numbers
Blockers	Pedagogical objects can be blocked or unblocked. Only when unblocked can they be captured. An object is unblocked when an avatar is placed over its corresponding blocker.	- Keys - Flags
Points	Determines ranking of groups' success.	Two types of points can be won: - Collaborative: Awarded for group energy. Every avatar death or error made in capturing objects is considered an erroneous collaboration and decreases group energy. If the group loses all its energy it must start over. - Pedagogical: One positive point is won for every pedagogical object captured.

The following example illustrates the various components of Role Game and how it is played.

Imagine that a game is underway and that the pedagogical objective of the current level is to capture the three letters forming the word "ICE" in the proper order, with an additional letter, "S", as a distracter. The map for this level, shown in Figure 2, contains the four letters plus a key that acts as a blocker and is divided in two by a river. These and the remaining elements can be summarized as follows:

- Objects to be captured: the letters "I", "C" and "E", with "S" as a distracter.
- Avatars: the three avatars are located on the right bank of the river. Their abilities are defined such that Avatar 1 can capture the letters "I" and "S", Avatar 2 can capture the letter "C" and Avatar 3 can capture the letter "E".
- Abilities: Avatar 3 has the ability to cross blue zones and Avatar 1 the ability to put enemies – in this case, the dog – to sleep.
- Blocker: located on the left side of the river; blocks the four letters. It is represented as a red key.
- Obstacles:

- Blue zone: a river in the middle of the map running north to south.
- Brown zones: two elevated zones, one in the top right corner and the other in the bottom right corner.
- Green zone: the rest of the map.
- Enemy: a dog patrolling the letter “C”.

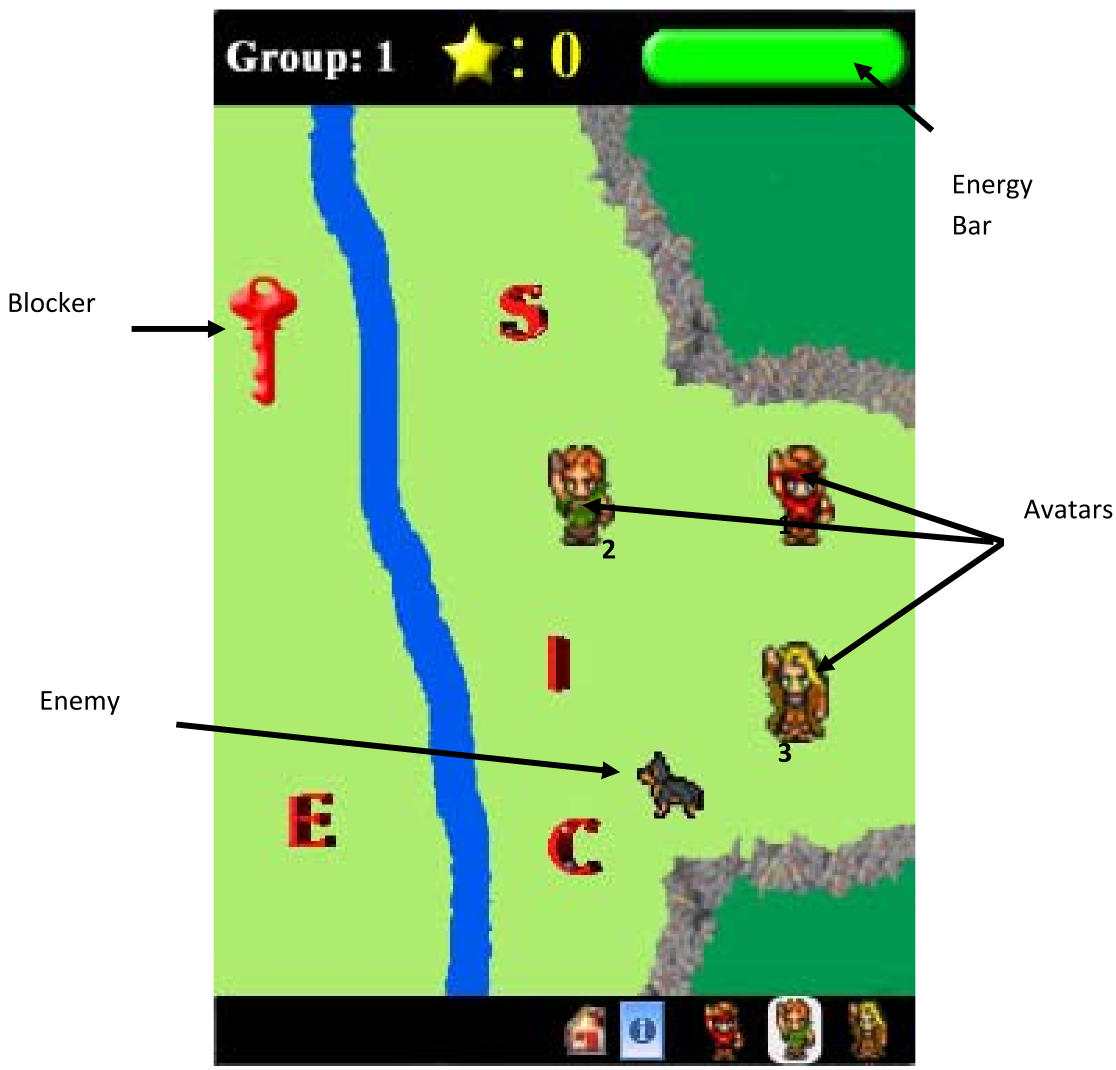

Figure 2: Screenshot of Role Game

Each player can only control their own avatar using their own mouse. The only way the players can move their avatars is to click on the desired location. The many possible interactions in the game are set forth in table 2. Each one is described in terms of a result that depends on certain preconditions and is realized through a specific action.

Table 2: Interactions among elements

Result	Preconditions	Action
Capture of a pedagogical object	• Pedagogical object unblocked. • Avatar is able to capture this object.	Avatar is placed over pedagogical object
Unblocking of a pedagogical objects	None	Avatar is placed over corresponding blocker
Death of an avatar	Avatar does not have ability to put enemies to sleep	Avatar touches an enemy
	Avatar does not have ability to cross blue zones	Avatar enters blue zone
	Pedagogical object blocked	Avatar touches a blocked pedagogical object
	None	Avatar enters red zone
Enemy put to sleep	Has this ability	Avatar touches enemy
	Does not have this ability	Other avatar that does have this ability puts enemy to sleep so it is no longer a danger to others
Crossing of blue zone	Has ability	Being in the blue zone.
	Does not have ability	Touches other avatar that has ability to cross blue zone until safely out of it.
Entering and leaving of brown zone	Has ability	Enter brown zone from another zone or leave it to enter another zone
	Does not have ability	Touching the avatar that has this ability while entering or leaving

		brown zone.

The design of the game levels must be such that the players are forced to collaborate in order to overcome barriers and evade dangers and thereby achieve the pedagogical objective. It must also promote the development by the players of a collaborative strategy and prevent attempts by individual players to isolate themselves or play alone. Progress should only be possible through mutually supportive actions.

As an example, Figure 3 shows how the players plan and carry out a collaborative action to overcome the barrier posed by the river. Avatar 2, which does not have the ability to cross blue zones, is helped across with the support of Avatar 3, which does have that ability.

Figure 3: Collaboration between players to cross blue zone.

Another example is shown in Figure 4. There, the pedagogical objects are unblocked by Avatar 3, which is placed over the blocker. This allows Avatar 1 to capture the letter "I", scoring one pedagogical point for the group (show at the top of the screen as a star). An "I" is then indicated at the bottom of the screen.

Figure 4: Collaboration between players to capture a letter: avatar unblocks letter by touching key.

II.3 Role Game activities editor

As well as a video game, Role Game also provides a system development environment for building collaborative educational video game activities. This is done via a high-level Editor that is easy to use and affords considerable flexibility. Activities can be created and educational content adapted without having to actually program the different levels or ensure compatibility with Role Game's files.

A screen shot of the Editor is shown in Figure 5. After specifying the game activity level in a drop-down box, the various elements of the activity are then defined using a series of seven tabs for the different element types and configuration functions: Initial State, Objects to Capture, Blocking Objects, Actors, Objective, Enemies, and Advance Configuration. Working the tabs from left to right, the teacher constructs the various interactions that make up the activity. This ordering of the tabs reflects a logical sequence that ensures the definitions necessary for the options on any given tab have already been made on the previous ones. As an example, in Figure 6 the map image would have to be defined before an avatar or object could be located.

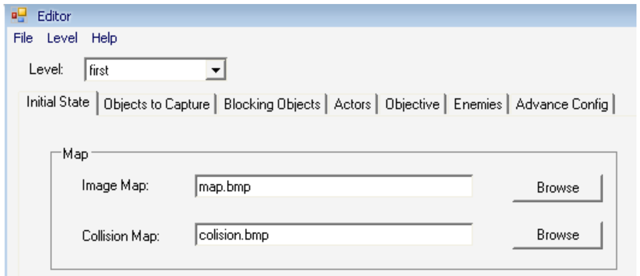

Figure 5

Figure 6

Once all of the activity elements have thus been defined, the level is complete. A level can be modified later by the Editor where required. This capability means that a repository of levels can be created, any one of which can then be reused or adapted to new educational content by editing only those elements that need to be changed, thus simplifying the teacher's task. As an example, a new level could be built merely by reusing a previously designed map and elements with a different defined objective.

III. Usability Analysis

III.1 Research framework

As noted briefly in the Introduction, Role Game was applied twice a week over an entire semester (31 sessions of 45 minutes each) at an underfunded school in Chile's poorest urban district to a sample of 36 kindergarten pupils, all aged six, who had yet to learn to read or use a computer. To ensure the activities prepared were aligned with the school curriculum, the teacher specified the various mathematics and reading activities for each game session.

A usability analysis was performed to assess the results of this experiment on the basis of three sets of observation guidelines. The first set measured the level of user satisfaction, covering both the motivational elements that make the game attractive to the users and the essential elements of the user's expectations of video games following the framework proposed by Rouse (2001). This framework, which applies generally to all types of video games, consists of a set of elements describing why gamers play and what they expect from the games.

The second set of observation guidelines measured the system's user efficiency, analyzing the effort required to master the software, hardware, and the game strategies (Nielsen, 1994). With players of such a young age the ability to master the system is essential, as any significant complexities in its operation would render the activity unusable. Our purpose, therefore, was to understand which parts of the game were easily mastered by the children and which ones were not.

Finally, the third set of guidelines measured collaboration in the building of common strategies to accomplish the games' objectives. They were based on the framework given in Zurita, Nussbaum and Sharples (2003), which defines coordination, communication, organization, negotiation, and interactivity as key elements of a collaborative process.

These findings were complemented by the observations in the teacher's logbook and an interview with the teacher at the end of the experiment.

III. 2 Analysis of user satisfaction

Main elements motivating people to play video games (Rouse (2001))	Experimental observation
Players want a challenge	RG challenges players both in its ludic and its pedagogical objectives Even though the experiment was embedded in an educational context, it was evident the students were very willing to meet the challenge of reaching the gaming and pedagogical objectives. Although the groups worked independently and no comparisons of their achievement levels were performed, some degree of competition was observed between them as they attempted to reach their objectives and finish earlier than the other groups.
Players want a dynamic experience in which they can be in control inside an interactive environment	RG allows players to interact with the game and with each other. They can make decisions about what to do and when to do it. The teacher observed that the children mastered the game elements (abilities, levels, points, and enemies) and found them fun. It is important, however, that the activity difficulty level be well adapted to the groups' success in achieving both the gaming and the pedagogical objectives.
Players want bragging rights: the satisfaction of reaching objectives and being recognized by others.	RG awards points when pedagogical objectives are achieved, and allows successful groups to move up to the next level. Students expressed satisfaction when they overcame obstacles, completed an activity level, and won points.
Players want an emotional experience	RG encourages social relationships between players (Zurita & Nussbaum, 2005a) by obligating them to negotiate, build common strategies, collaborate and debate among themselves. All of the students were keen on participating in the activity, and enjoyed working closely with their peers. However, gender problems emerged between group members that required intervention by the teacher to resolve.

<table>
<tr><td>Players expect a consistent world where they can interact and understand the actions they can perform and their effects.</td><td rowspan="2">RG’s consistent world is made up of five zones that define the avatars’ range of movement and their actions. Both elements have clearly defined effects that the students easily understood.

The students intuitively understood the game rules. However, they associated more power with one of the avatars than the others due to the avatars’ defined abilities, which created problems between group members that were difficult to resolve.</td></tr>
<tr><td>Players expect to understand the game world´s bounds.</td></tr>
<tr><td>Players expect reasonable solutions to work so that every problem posed by the game can be solved.</td><td>In RG there are many ways to achieve the game’s objectives depending on the players’ strategies and the agreements they make.

In general, students came up with reasonable solutions. Crossing the river was difficult for many since it required coordination and synchronization among members.</td></tr>
<tr><td>Players expect direction.</td><td rowspan="2">Instructions regarding objectives and abilities are displayed at the beginning of each level. Information on the game outcome, group energy level and accomplishment of pedagogic objectives is provided continuously.

Students continuously monitored the information on their outcomes, which helped them understand what they were doing and achieving.

Some levels turned out to be no more difficult or challenging than the preceding one. Game difficulty depends on the group members’ abilities to master their individual roles, and the complexity of successive pedagogic objectives did not always increase.</td></tr>
<tr><td>Players expect to accomplish a task incrementally and be able to understand by means of rewards or checkpoints whether their actions are correct.</td></tr>
<tr><td>Players expect to be immersed</td><td rowspan="2">As can be seen in Figure 1, only one student is seated directly in front of the screen. Students seated on either side of the one in the centre were exposed to distractions such as talking with members of other groups.

Striking the right balance between ludic and pedagogical difficulty is a key element not easily achieved. We observed that if an objective was beyond the children’s ability, they lost their concentration.</td></tr>
<tr><td>Players expect some setbacks in order to make the game more fun and challenging. It is not fun if the game is too easy.</td></tr>
<tr><td>Players expect a fair chance to solve problems and overcome obstacles.</td><td>Certain activities required more training to overcome the obstacles they contained, such as crossing the river. Until they mastered these tasks the children expressed some frustration.</td></tr>
<tr><td>Players expect not to have to repeat themselves.</td><td rowspan="2">The different game levels combine increasingly difficult gaming pedagogical goals. If a mistake is made, the player must return to the previous level. The children found this to be very frustrating.

When this occurred more than once in the same level, the children tended</td></tr>
<tr><td>Players expect not to get hopelessly stuck and have to start over, losing</td></tr>
</table>

everything already gained.	to begin arguing and interfering with each other's roles and play would often deteriorate into an improvised game of killing avatars.
Players expect to participate, not just to watch. They want to be active players in the game.	Our observations confirmed that one of the main accomplishments of RG is that all players become protagonists in the game, each through the use of their own mouse.

III. 3 Analysis of user efficiency

Observed element	Experimental observation
Time spent understanding the game's dynamics	According to the session logbook, students found it difficult at first to understand the game's dynamic because they had no instructor to introduce them to it. However, after a few sessions all students understood the game intuitively.
Multiple mouse use	Most of the students were able to use the mouse and integrate themselves quickly into their group without problems.
Ability to move avatar	Although the students understood the system and were able to use the mouse, many of them did not grasp the logic of the avatar movements, clicking repeatedly in a pointless attempt to increase the avatar's speed. Also, crossing the river was a difficult goal for many and was not always achieved.
Ability to develop strategies for reaching objectives	Since the groups were formed randomly and changed from session to session, the students had to learn to build strategies with a varying combination of peers. This was not always easy due to their age.

III. 4 Analysis of the collaborative process

Collaborative process elements (Zurita, Nussbaum & Sharples, 2003)	Experimental observation
Coordination: The design of the activity should force participants to perform one task at a time and carry out each group action in a specific sequence.	The game incorporates barriers that have to be overcome in a specific order for the goal to be achieved. The students had difficulties coordinating their actions with their peers. But since the software gave them no choice, in the end they learned to coordinate and were thus able to proceed with the game.

Organization: Each participant's machine should provide all required information for the activity. No additional material should be necessary.	The design of the different levels was always clear and the players' roles were immediately understood.
Negotiation: All participants have the same rights and must agree to proceed.	No advance is possible in RG until the group members come to an agreement. Negotiation occurs both in the ludic and the pedagogical aspects. At the beginning students attempted to act on their own, but once they saw their actions did not achieve their goals, they realized they had to negotiate them.
Interactivity: Agreement must be built through peer interaction.	RG forces students to interact in order to reach agreement on their actions. When a student was unsure what to do, their first reaction was to seek help from a peer. Since the groups were different in each session, those who understood the game better assumed leadership of their group. When a student lost interest, the other two members usually took over the use of their mouse to continue the game. As long as the students remained interested, however, they all kept control of their own mice and supported each other to reach the objectives.

IV. Conclusions

Role Game proved to be a satisfying experience for the students who participated in the study, maintaining their motivation throughout the experiment. The children enjoyed playing the collaborative game and found the objectives to be an interesting challenge. Furthermore, the activity fulfilled their expectations. They collaborated well in carrying out the tasks, and the random assignment of them into different groups resulted in successful working relationships.

A key aspect of the SDG activity was that each child identified with their avatar through their individual mouse. This created a sense of ownership that facilitated a constant and active involvement.

A significant problem that did affect their satisfaction, motivation and expectations was the level of gaming and pedagogical difficulty. The design of each lesson and game level must ensure that these difficulties are in line with abilities and knowledge of the students. Other aspects such as the complexity of the avatars' roles and avatar movement speed also have to be fine-tuned to optimize the gaming experience, taking into account the players' age level.

The console multiplayer video game is a powerful tool that can be used to advantage in the classroom. Though not designed as a learning tool, our experiment showed that for kindergarten students, these multiplayer games are both effective and attractive as pedagogical devices. Despite being generally considered as a competitive environment, we found that the games' attributes carry over to collaborative activities, maintaining students' motivation even though they had to collaborate with each other rather than compete.

Finally, console video games with a high-level application-building environment that teachers can use to specify educational activities offer the necessary flexibility to intermix gaming and pedagogic objectives and provide new ways to align learning software with school curricula. From this perspective, the games create a socio-technical environment that can support meta-design and social creativity in educational settings (Fischer, 2007). Our findings thus confirm McFarlanes' (2002) view that games "provide a forum in which learning arises as a result of tasks stimulated by the content of the games, knowledge is developed through the content of the game, and skills are developed as a result of playing the game".

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