Problem Solving Processes and Video Games: The Sim City Creator Case

Natalia Monjelat[1], Laura Méndez-Zaballos [2] & Pilar Lacasa [3]

[1] Department of Philology, Documentation and Audio-visual Communication, Universidad de Alcalá, Alcalá de Henares
[2] Department of Developmental and Educational Psychology, Universidad Nacional de Educación a Distancia UNED, Madrid
[3] Department of Philology, Documentation and Audio-visual Communication, Universidad de Alcalá, Alcalá de Henares

Spain

Correspondence: Natalia Monjelat. San Cirilo st. s/n. Aulario de María Guzmán. 28801, Alcalá de Henares, Madrid, Spain. E-mail: natalia.monjelat@uah.es

Abstract

Introduction. Video games have proven to be a valuable resource to work different school subjects and topics. Beyond specific content, they could help to develop different abilities, like problem solving. However, not much has been studied on this topic, or many of the studies followed a perspective not entirely compatible with an educational approach.

Method. Based on the theory of information processing we analyse the problem-solving processes presented in a classroom when the commercial game Sim City Creator was introduced. The data come from an ethnographic study conducted in a secondary school in Madrid, with students of 3 º ESO, where Sim City Creator was used in Socio-Linguistic Area. Qualitative approach and case study perspective along with discourse analysis was the frame for the data analysis.

Results. When students are faced with the problems of the game, they build representations. To do so, they identify the necessary operators, located in the game menu, also considering the conditions exposed by them, the teacher or the game play, which narrow the problem space. Also, in order to solve the problems students use different strategies, among which we highlight the use of previous schemes and the establishment of subgoals.

Discussion and conclusion. Commercial video games used in educational settings can become valuable resources to develop problem-solving processes. The support of teachers and their knowledge of the game are a valuable asset when it comes to take advantage of the game, favouring the construction of representations of the different problems that appear during the game.

Keywords: Problem solving, video games, secondary school, new technologies in education

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Resumen

Introducción. Los videojuegos han probado ser un recurso válido para trabajar diferentes cuestiones escolares. Más allá de contenidos puntuales, permiten trabajar distintas habilidades, dentro de las cuales podemos descatar la resolución de problemas. Sin embargo, no mucho se ha estudiado sobre esta temática o muchos estudios toman una perspectiva no del todo compatible con un enfoque educativo.

Método. En este trabajo analizamos los procesos de resolución de problemas que se presentan en un aula al introducir el videojuego comercial Sim City Creator tomando como referencia la teoría del procesamiento de la información. Los datos provienen de un estudio etnográfico llevado a cabo en un instituto secundario de Madrid, con alumnos de 3º ESO, que utilizaron Sim City Creator en la asignatura de Ámbito Socio-Lingüístico, y han sido analizados desde un enfoque cualitativo y de estudios de casos considerando también una perspectiva del análisis del discurso.

Resultados. Cuando los estudiantes se enfrentan a los problemas que presenta el videojuego, construyen representaciones del mismo. Para ello identifican los operadores necesarios, localizados en el menú del juego, atendiendo a condiciones derivadas del docente, de los mismos estudiantes o del juego, que acotan el espacio del problema. Asimismo, para resolver los problemas los estudiantes recurren a diferentes estrategias, dentro de las cuales se destacan en nuestro estudio el uso de esquemas previos y el establecimiento de submetas.

Discusión y conclusión. Los videojuegos comerciales, utilizados en entornos educativos, pueden convertirse en recursos valiosos para trabajar los procesos de resolución de problemas. El apoyo del docente y su conocimiento del juego resultan un elemento valioso a la hora de sacar partido al videojuego, favoreciendo la construción de las representaciones de los diferentes problemas.

Palabras Clave: Resolución de problemas, videojuegos, educación secundaria, nuevas tecnologías en educación.

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Introduction

Video games have proven to be an important educational resource (Gee, 2003, 2008, Jenkins, 2003, 2006a, 2006b; Lacasa, 2006, 2011, Prensky, 2001, 2002, Salen & Zimmerman, 2004; Squire, 2003) and are used in school for different purposes, including problem solving, a subject which has been widely addressed in the field of psychology (de Vega, 1998, Duncker, 1945; Holyoak & Morrison, 2005; Robertson, 2001). However, few studies have been conducted on the specific processes employed when solving problems presented by video games. Most of the recent research on problem solving (Pizlo, 2009) has been carried out under experimental conditions where such processes are analysed from a developmental perspective or from neuroscience, and report evidence based on imaging studies, or present research related to mathematics, algebra or arithmetic. Other studies have been based on quantitative analysis, which does not necessarily focus on the problem solving process as such but rather on the outcomes (Lee, Koh, Cai, Quek, 2012).

Without detracting from these methods, we believe that the information processing approach (Bassok and Novick, 2012; Newell & Simon, 1972; Novick and Bassok, 2005; Simon, 1978) can offer a different perspective of the phenomenon studied, allowing connections to be established between the characteristics inherent in the game itself and the context in which it is used (Lacasa, 2011). On the basis of this theory, we wanted to explore the processes involved when students solved the problems presented by the Sim City Creator simulation game. We were interested in analysing the role of operators and conditions in building an adequate representation of the problems, focusing also in certain ways of solving them using schemas or setting sub-goals.

Video games and problem solving: an integrated approach

It is not easy to establish a relationship between these two fields, which at first glance appear unconnected, without first having an understanding of their individual characteristics. Thus, we will begin by presenting the problem-solving framework adopted in this study, followed by an analysis of the relationship between this theory and the characteristics of video games when they are used in a school workshop.

The problem solving process

We can say that people are confronted with a problem when they want something and do not immediately know what actions must be taken to achieve it (Newell & Simon, 1972). Thus, solving a problem implies interaction between an information processing system, the subject and the task environment (Simon, 1978). When a subject solves a problem, he or she focuses on the task and represents the situation in what is called the *problem space*, which can be defined as the person´s representation of the task environment presented by the researcher (Simon, 1978). Building an accurate and complete representation of the problem is crucial to achieving its solution (Domin & Bodner, 2012; Jonassen, 2011, Robertson, 2001). This representation includes four elements (Bassok & Novick, 2012, Novick & Bassok, 2005, Newell & Simon, 1972), presented below in figure 1:

- The initial state: what is known about the problem before attempting to resolve it
- The goal state: the desired outcome of solving the problem
- The set of operators: the possible actions or steps required to achieve the goal state
- The conditions: what is not allowed and the consequences of choosing one action or another

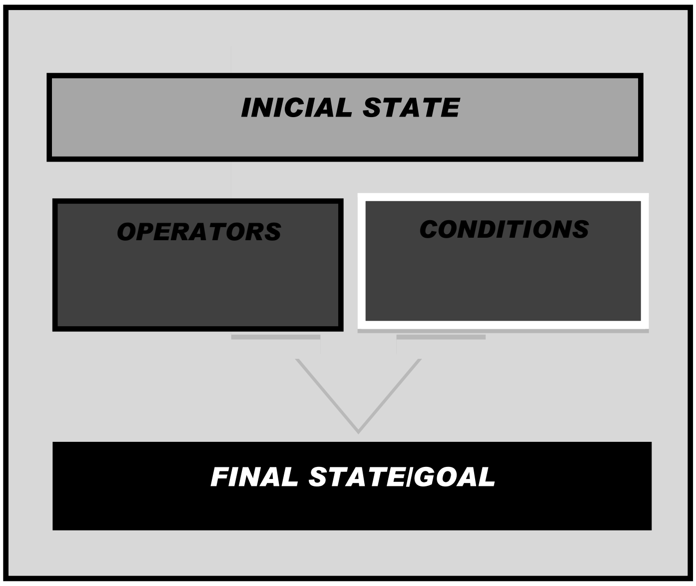

Figure 1. **Problem space elements**

Moreover, It should be noted that the representation the person constructs of the problem may be *internal* or *external* (Hayes, 1989, Novick & Bassok, 2005). The former involves mental objects and relationships that correspond to the objects and relationships of the problem presented externally. Sometimes, an *internal representation* is sufficient to solve a problem, but in other cases an *external representation* is needed. Drawing, writing, using symbols or other aids may serve to establish connections between parts of the internal representation.

According to Hayes (1989) to form an appropriate internal representation of a problem, it is necessary "to represent the goal and, for those problems that require it, the initial state, operators and operator constraints" (p.7). Thus, the representation includes the components of the problem space proposed by Newell and Simon (1972). Generating an internal representation implies selecting information and determining which aspects of the problem are relevant. Consequently, representations are not a copy, because an active process is involved in which the person adds, removes and interprets information from the original situation (Hayes, 1989).

From this follows the importance of offering students problems that will enable them to gain expertise in different areas. Solving problems presented in a game can be a mean to acquire knowledge and enhance previous experience, which may be useful when dealing with other problems.

Problem Solving Strategies: sub-goals and schemas

Once we have acknowledged the existence of a problem and created its representation, it must be solved. To this end, different strategies can be employed, strategies here being understood as the different methods that can be adopted to reach the solution (Lacasa, 2011). Some are simpler, like *trial and error*, where people do not have or do not use information indicating the easiest way to attain the goal. It can be an effective method when the problem space is small (Hayes, 1989), but in other cases other strategies are needed such as *proximity methods*, which use different heuristics (Novick and Bassok, 2005). One is *hill climbing*, where at each step, an operator is applied which leads to a new state that appears to be closer to the goal state. According to Novick and Bassok (2005) another widely used strategy is *mean-ends analysis*, which is more sophisticated than the former since it does not depend on similarity to the goal. The difference between these two heuristics is that the latter generates *sub-goals*, which provide direction and reduce the gap between the initial and goal state (Hayes, 1989). Sub-goals have been identified as components of task structure that can be taught to learners (Catrambone, 1996). Another strategy worth emphasising is the *fractionation methods*, which also consists of breaking the problem down into sub-problems. Thus, this method also involves identifying and working towards sub-goals (Hayes, 1989).

Moreover, in some problematic situations, people turn to *schemas* that have used previously. A schema is a packet of information about the properties of a particular type of problem in which its elements (initial state, goal, operators and conditions) are presented in a certain way (Hayes, 1989). Schemas allow people to recognise similar experiences, remember the framework created previously and use it to tackle the new problem (Marshall, 1995). These can thus be called *knowledge-based methods* (Hayes, 1989), because all the knowledge acquired through solving previous problems is applied to resolving the new problem (Novick & Bassok, 2005). Also, it has been reported that video images help establish relationships and make it easier to retrieve these schemas (Goh, Tan & Choy, 2012); consequently, video games could be used to encourage this type of transfer. Furthermore, by using these previous representations, it is possible to say that the problem is being solved by *analogy*. Concerning this, Gick and Holyoak (1980) noted that: " In essence, both an analogy and a schema consist of an organized system of relations" (p.309). Moreover, Holyoak (2005, 2012) mentioned that two situations are analogous if their constituent elements share a common pattern of relationships, even though they may differ between both situations. This type of reasoning is common in everyday life and is useful for solving real-life situations.

Learning to solve problems is not easy, and either knowing how to choose the right strategy. However, given that problems occur every day in people's lives, it is essential to find ways to teach young people how to develop problem solving strategies. Johnson-Laird (2008) stated that individuals are not born equipped with such strategies, but rather they develop them through tackling similar situations several times. Thus, offering experiences to the students, which bring these skills into play, could facilitate that acquisition. In this regard, video games are valuable tools in educational scenarios aimed at developing problem solving processes since they offer constant challenges to solve.

Video games and problem solving: an integrated approach

Several authors have reported that video games provide the opportunity to teach problem-solving processes (Egenfeldt Nielsen, Smith & Tosca, 2008; Juul, 2005; Gee, 2007, 2008, Squire, 2003). However, as mentioned earlier, few studies have addressed practical implementation. Nevertheless, these authors clearly believe that this resource aids problem solving and presents certain specific characteristics that enhance its potential (Lacasa, 2011). It is therefore appropriate at this point to describe the general characteristics of video games that allow us to build a representation that goes beyond common sense and the informality of daily life (Egenfeldt-Nielsen, Smith & Tosca, 2008). In this study, we considered video games to constitute *systems based on rules* (Juul, 2005) in which a result is pursued through the efforts of the player controlling the game. This definition highlights the fact that games are systems with specific results (Egenfeldt-Nielsen, Smith & Tosca, 2008), and thus there is a difference between games and non-games (Juul, 2005), although borderline cases do exist, such as Sim City, the game used in our study. This is due to the open-ended nature of this game, where there is no clear goal to indicate that a player has "won", but it is nevertheless possible to establish different goals and sub-goals that serve the purpose of the game: to create, build and manage a virtual city (Monjelat, 2009).

Furthermore, it is important to note that video games enable "learning by doing" (Shaffer, 2004). Thus, learning becomes a process of constant practice and interaction in increasingly challenging tasks, where players gradually discover the underlying system of rules (Sandford & Williamson, 2005), which is important for solving the problems presented in the game. The design of a game may include certain rules that function as constraints, establishing what is and is not allowed during the game. Another point to consider is the possibility video games offer to enter virtual worlds (Shaffer, 2006), where complex concepts can be understood without losing the connection between abstract ideas and real problems. Due to the characteristics mentioned above, simulation games motivate learners to explore and play (Baek, 2010) whilst incorporating educational principles (Gee, 2007), which renders them a powerful educational resource.

Here, we will analyse how the Sim City Creator video game was used to solve problems in a workshop conducted with 3rd year of secondary education students, which will be described in detail in subsequent sections. On the basis of the characteristics of video games described above and the problem solving processes discussed previously, we have developed a diagram that outlines the relationship between the theoretical model, the characteristics of video games and the context in which one was used.

The diagram shown below in figure 2 represents both the starting point of our study and a summary of these questions.

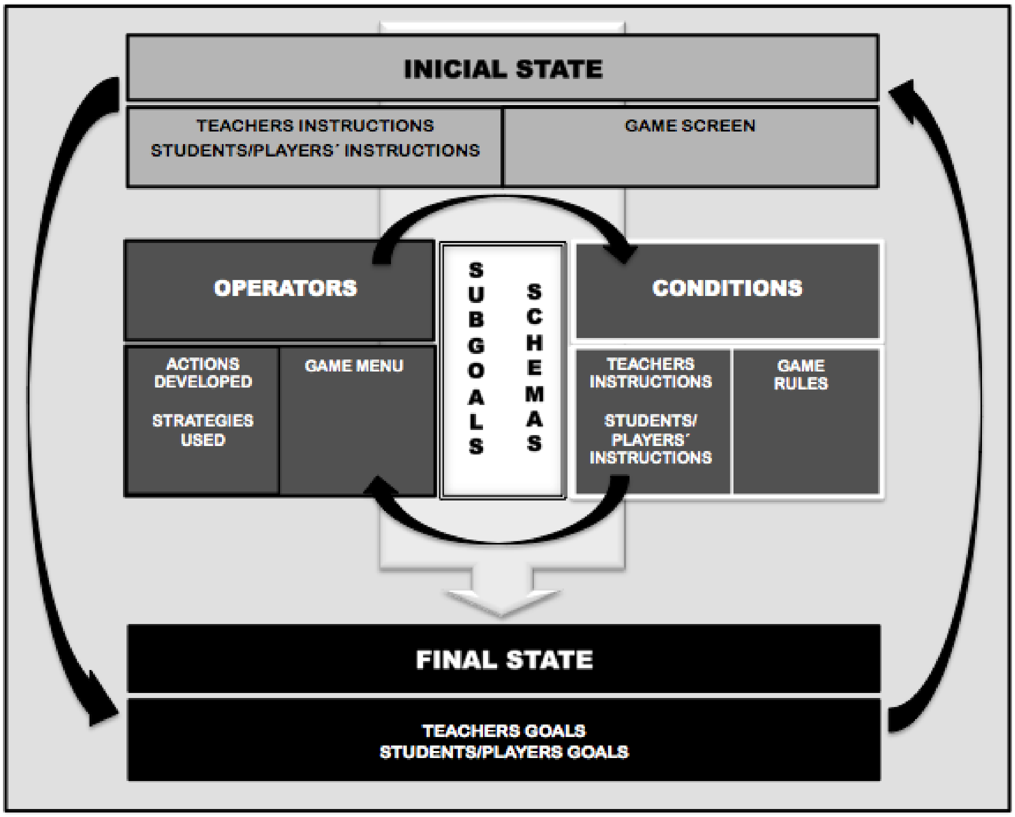

***Figure 2*. Problem representation based on workshop characteristics**

The diagram depicts a representation of the problem space which includes the different elements, and these are presented in terms of the context of our research, the main components of which are: the participants, the game and problem solving processes. Analysing the diagram, it can be seen that the *initial state* corresponds to the instructions given by the teacher or by the students themselves, but that while playing, it is also necessary take into account the information displayed on the game screen. The *final state,* the goal of the game, can be also determined by the teacher or the students themselves because, as we pointed out earlier, the game is open-ended and does not impose specific goals.

To bridge the gap between the initial and goal state, we need to find *operators*. In the case of this game, these are the menu icons used to implement the actions and strategies necessary to advance. To choose appropriate operators, it is necessary to consider the *conditions* stating what can and cannot be done. In this case, the conditions are usually set by the teacher or the students, but they could also be related to the game's own rules or its design. We have also added the concepts of *sub-goal* and *schema*, referring to intermediate stages in the process arising from the interaction between the conditions and operators, being employed as problem solving strategies. In the specific case of this study, these concepts were crucial since most of the problems presented in the game were resolved by the use of these strategies to reach the goal state. Thus, this diagram depicts the implementation of a classic problem-solving model in a specific context, in this case, when using video games in a school scenario.

Studying problem solving processes: methodological framework

The present research was conducted using an ethnographic approach (Anderson-Levitt, 2006; Lacasa & Reina, 2004) and performing a qualitative analysis (Denzin & Lincoln, 2011) of a case study (Stake, 2006; Yin, 2011). Discourse analysis was also employed (Gee, 2011; Gee & Green, 1998). The uses of this methodology have received many critics concerning its validity, especially when this type of studies are compared with quantitative ones that employ statistical methods or look for generalizations (Anfara, Broen & Mangione, 2002; Flyvbjerg, 2006; Hoepfl, 1997; LeCompte & Goetz, 1982). However, what could be a limitation for others authors justify the use of this approach in this study. In that regard ethnography, by emphasize the interplay between variables in a natural context, allows a deeper analysis of the situations, which could not be the case in other methodological perspectives (LeCompte & Goetz, 1982). In our study this is relevant since its validity is not based in the frequency of the appearance of a phenomenon, but in the detailed explanation of cases (Ragin & Becker, 1992; Stake, 1995) where it is possible to explain how people give meaning to their activity in a defined sociocultural context (Lacasa, 2011; Lacasa, Méndez & Martínez, 2008; Spindler & Hammond, 2000).

In this respect, we aim to analyse the shared representations of the problems generated in a school situation. In this context, our goal is to analyse the processes involved in the solving problem situations within the classroom context, where commercial game Sim City Creator for Wii was used. We will present different sequences that emerged over the course of our research which illustrate the thinking process that led participants to bridge the gap between the initial and goal state when navigating in the problem space (Hayes, 1989; Simon & Newell, 1972). While playing, the students encountered different problems when they had to build the infrastructures and services needed in the city. Regarding this, we will also show the representations of these problems, analysing how the constituent elements were presented and how participants solved them, on the basis of the theoretical framework presented above.

Context and participants

Our study was conducted within two projects coordinated by the Research Group "Culture, Technology and New Literacies" at the University of Alcalá. One in collaboration with Electronics Arts, as part of its social responsibility program and the other, funded by the Spanish Ministry of Education and Science within the national plan of I+D+I[1]. The study was conducted during the academic year 2008-2009 (Lacasa et al., 2009) at a secondary educational institution in the south of the Autonomous Community of Madrid (Spain).

The data presented was collected during a workshop developed within the sociolinguistic subject of Curriculum Diversification[2], involving 10 students in their third year of compulsory education and their teacher, working with the commercial video game, Sim City Creator. This simulation game allows players to build and manage a city, assuming the role of mayor. In the workshops, small groups of 2 or 3 students shared a Nintendo Wii console to play. In the analysis, we will focus on one group formed by Mary and Peter[3].

Design and development of the workshop

Before implementing the workshops and proceeding to data collection, various meetings were held at the school to facilitate access to the research setting (Lacasa et al., 2009; Lacasa, 2011). As shown below in figure 3, different activities were conducted in order to inform the participants about the basic aspects of the project and to answer possible questions about it, which allowed them to approach to the context of the study.

***Figure 3.* Access to the research setting**

[1] Project "Aprendiendo con los Videojuegos" funded by Electronics Arts, project "Nuevas Alfabetizaciones" funded by the National Plan of Social, economics and legal Sciences. "Programa SEJ (Educación). Ministerio de Educación y Ciencia. Plan Nacional de I+D+i EDU2009-07075 (subprograma EDUC) (2008-2011)". Natalia Monjelat is funded by the Spanish Ministry od Education, Culture and Sports, holding a scholarship from the "programa de Formación del Profesorado Universitario".

[2] Literal translation from "diversificación" which refers to a course where students presents some learning difficulties.

[3] Students' names were changed to preserve their identities.

On the basis of this exchange between teachers and researchers, an initial programme was established of 7 weekly sessions of 1 hour each, in which students would work in pairs or groups of three with the Sim City Creator video game, using a Wii console, a screen and 2 remote controls. Figure 5 shows the time sequence of the workshop on two levels: first, all the sessions, and second, what usually happened during a typical session. Here, the different stages of the workshop are depicted: the first part (4 sessions), which mainly focused on the game, and the second, which was devoted to audio-visual production (3 sessions).

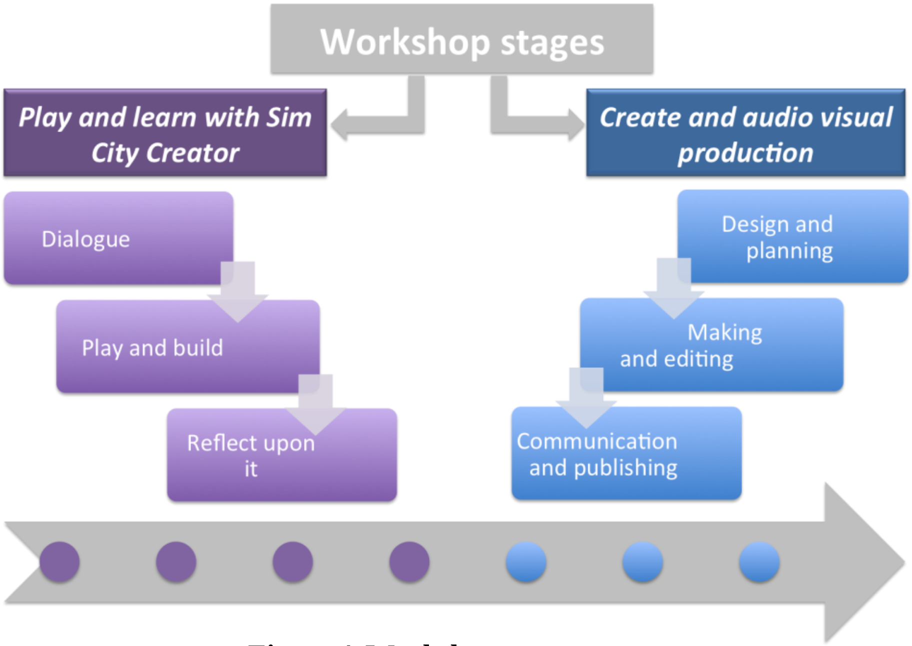

Figure 4. **Workshop structure**

In this article, we will focus on the first stage, analysing fragments of dialogue from the second session, presenting the interactions that occurred between participants whilst playing the game, as well as the reflections and discussions that emerged before and after each session.

Data collection and analysis

Throughout the project, the researchers acted as observers, collecting different materials that were useful for further analysis of the workshop. As shown in Figure 5, we collected different types of data, most of it in audio-visual format (Pink, 2007):

Course	Sessions	Pictures	Audio recordings	Video recordings (Fixed and mobile cameras)
3º Secondary School Diversification Sociolinguistic subject	7	208	2:05:43 hs.	7:24:11 hs

***Figure 5*. Data collected**

Once collected, the data were analysed using the Transana software package, which enables an initial consideration and easy manipulation of the digital audio and video recordings, selecting the most revealing fragments depending on our focus of interest. After the data had been organised and displayed, transcripts were made, providing a written version of the dialogues that took place during the workshop. Based on these transcripts, levels of analysis were established to reflect the problem solving processes that we wished to address.

Results and discussion

We will focus our analysis on two specific issues that are crucial to solving a problem. On the one hand, we will discuss the importance of operators and conditions for building an appropriate representation, highlighting how they are presented in the game problems. In addition, we will also focus on the role of sub-goals and schemas in order to highlight different approaches to solving problems that require a more complex strategy.

Approaching the problem: operators and conditions

When faced with a problem, we need to build an *internal representation* of it to guide our steps and attain the goal (Bassok & Novick, 2012; Hayes, 1989). In this section we analyse how the participants built these early representations and what aspects of the workshop itself and the video game influenced the process.

Locating the operators in the game menu: conditions of the game and of the participants

The game menu is extensive and players should choose the icons that will function as operators, allow them to solve the game problems. The figure 6 shows the three main levels in the menu. The levels are grouped by category; thus "Construction" includes "Transportation" or "Public Services", and within this level, possible building options (e.g. transport: straight road, curve, motorway, etc.).

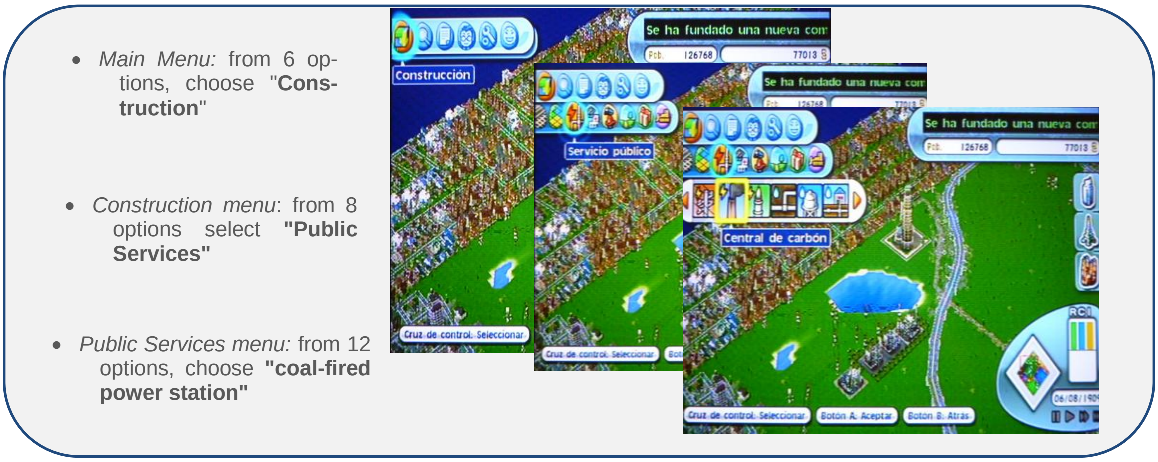

***Figure 6*. Levels inside the game menu. An example.**

Due to the complexity of the menu, finding the operators is not straightforward, as discussed in the following turns, when students and teacher were trying to work out how to install electricity in the city

Excerpt 1: Locating the operators in the game
2009 02 23. Session 2. Fixed Camera

1. Peter[6]: Where is the...
2. Teacher: The power lines, you must create the power station first.
3. P: But where is it?
4. T: The two you have, you have both there ((looking at the screen)). You have one on the right ((shows the icon for the coal-fired power station))
5. P: That's it, isn´t it?
6. P: ((he selects it) Where do we put it?
7. Mary: Not in the middle, because there will be... ((inaudible))

In this dialogue, Peter appeared unsure of what to do. Therefore, he asked the teacher about the location of the icons in the game menu, as can be seen in turns 3 and 5 (*But where is it ?; That's it, isn´t it ?).* Although the goal was clear, he was still unable to identify the operators. Therefore, the teacher outlined the problem space, indicating the *conditions* (Newell & Novick & Bassok, 2012; Simon, 1972) that would allow the students to locate the icons and make progress in solving the problem. First, as is seen in turn 2 (*The power lines, you must*

[6] In transcriptions (P) corresponds to Peter, (T) to teacher, and (M) to Mary.

create the power station first), the teacher determined a sequence of steps (Novick & Bassok, 2005), indicating *conditions* at the time of building elements. The *rules of the game* (Juul, 2005) state that in order to provide an electricity supply, it is necessary to first build the power lines and the power station: unless the city has both, the service is not considered installed. Although the game design does not establish an order for this and it does not matter what is built first, the teacher determined that the construction of the power station must come first, which makes sense if we think that in real life, lines come from there.

Moreover, in turn 4 (*the two you have, you have both there*) the teacher once again helped students find *operators* in the menu by indicating where they were located. After identifying the operator, the coal-fired power station icon, the students wondered where to place it in the town. Certain *conditions* emerged again, but in this case imposed by Mary, who in turn 7 (*Not in the middle...*) said where she thought it should not go. Although the game allows players to locate it where they want, this student was conscious of certain conditions, but unfortunately the audio quality makes it impossible to understand the entirety of her sentence. In this excerpt, we see how the *game rules* only state that it cannot be placed on top of another object or on water, but the players' criteria also came into play, and they took advantage of the flexible parameters to place it where they thought was best.

Although progress had been made toward the goal state, the players still needed to decide on the location of the other part required to achieve full installation of the service: the power lines. Having placed the power station, the students were engaged in the construction of these.

8. P: Oh, I've lost the arrow ((stops and then sits down)). What do we do?
9. P: ((Selects from the menu and places the power line pylon))
10. M: ... <u>But we need more of those, don´t we?</u>
11. P: Well look, you know what we're going to do?
12. M: A s ***** ((laughs))
13. P: Erm, <u>there</u> ((he has placed one pylon at the far end of the city)), and we'll fill it like that, <u>like a square</u>.

In this dialogue, it can be seen that because Peter had previously addressed *the problem space* (Newell & Simon, 1972, Simon, 1978), he no longer had any difficulty finding the pylon icon that acted as *an operator*. Once located, the students had to think again about the best location for these elements, and also consider the strategy for doing so. In this case, Mary suggested a possible *condition* in turn 10 (*But we need more of those, don´t we?)* while in turn

13, Peter suggested using a square to cover a larger area. In this example, we can see that the players needed to know about the menu icons in order to make progress in the game. In this regard, the *conditions* open the possibility of locating the *operator*, identifying the sequence of steps and deciding on the location of the element to build.

Given the above, it is interesting to note that although the game's design and goals are open-ended (Juul, 2005), this does not prevent the participants from having their own goals and implementing their own conditions. When these latter are added to those given in the rules of the game, it becomes possible to locate the operators and to construct a representation of the problem which attempts to provide a solution and reach the goal state.

Game elements and problem representation

Sometimes, to build an *internal* representation (Hayes, 1989) is not simple and extra aid is needed. The water supply problem allows us to analyse this.

Excerpt 2: Elements of the game that affect the representation of the problem
2009 02 23. Session 2. Fixed Camera

1. M: And now what?
2. P: So now we have to decide on a location for the water.
3. M: Where do I go? Here ((she wants to give the Wii remote control to Peter))
4. P: ((does not take it)) Press "B", the one below ((shows her where))
5. M: <u>Here?</u> ((Returns to the main menu of the game))
6. P: <u>Yes. And now you move with the arrow.</u>
7. M: <u>I lost the arrow...</u>
8. P: <u>With the remote control arrow</u>.
9. M: Ahh ↓ It's not working Peter...
10. P: <u>Press "A". Below. See? There it is....</u>
11. M: Ahh ↑ ↑
12. M: <u>Which one do I choose? Create zone?</u>
13. P: There, press "Public Service" and create the water.

We can see in this passage that although María knew where the set of operators were, she had difficulties with the console remote control that prevented her from locating them easily. If the remote control is not used properly, participants go backwards through the menu levels or lose sight of the arrow that allows them to move within the game screen. Thus, it is even more difficult to locate the correct operator, as seen in the sequence of turns 5-11. In this case, one of the game's elements impedes building the representation and finding the operator, and instead diverts the students' attention from the game to the remote control, as shown in one of the images presented in figure 7, where instead of looking at the screen, the student was focused on the remote control.

***Figure 7.* Students interacting with the remote control**

Moreover, as can be seen in turn 12 (*Which one do I choose? Create zone?*) the student did not understand how the menu icons worked, since to create the water supply, she tried to use the "create zone" icon. Each menu icon generates a different action that allows players to advance toward the goal or, on the contrary, choose a wrong path. Consequently, the game menu can represent an aid to finding the operators and therefore constitutes an *external representation* (Zhang, 1999). On the other hand, in the following turns another element is presented that also has that function.

14. M: ((select it)) Oh no! Where do I put it?
15. T: Near the population
16. M: We still haven't created the population...
17. T: Where is the population? Wasn't it in the east?
18. P: Yes, top right.
19. T: In the east, let's look at the map. The population was over there, wasn't it? That's the east; this is more like the northeast. Well, now build it here in the northeast, no, no, a little more...

In these dialogues, the *map*'s role in the problem solving process is evident, functioning as another element, in this case inherent in the game itself, which helps the students to build the *problem representation*. In the video game, the city is built on a virtual map that can be seen from different angles. Thus, the map serves as an aid provided by the game itself, which helps players to understand the problem, represent it and think of its solution. Based on the teacher's recommendations, his conditions and the elements of the game itself, the students positioned the water towers correctly and solved this part of the problem. The *representation* was extended (Hayes, 1989) to include this new information, enabling them to move towards the solution.

Sub-goals and schemas: two ways to address complex problems

We will analyse two different ways to addressing some of the game's problems, focusing on the role of schemas and sub-goals in the problem solving process, which suggest a different approach to some more complex problems.

Establishing sub-goals to reach the solution

In the previous section, we saw how the two identified problems (providing water and electricity) involved the construction of certain infrastructures to reach the goal state. Solving the problem entails solving both intermediate states, which in the case of Sim City Creator, involves the construction of certain elements to be selected from the game menu. This structure, organised around sub-goals, is also present throughout the game in other sequences, for example, in the one shown in fragment 3:

Fragment 3. Sub-goals for railway construction
2009 02 23. Session 2. Fixed Camera

1. M: What do I do? ... Oh no, it's moving all over the place. Transportation ((looks at menu options: transport, health, accident prevention...))
2. P: Select a train or something.
3. M: Well, this is going to have everything, and which one is it? ((looking at the menu)) train station right? Where do I put it? Right here?
4. P: Wherever you want.
5. M: ((selects the train station and places it on the map)) Oh! ((by mistake returns to previous menu and sees the options again)) metro line, ah, or metro station, Pedro, What do I do?
6. P: Create the railway, right? The train
7. M: ((selects "railway" and starts building the railway line in a sort of curve around the city)) Oh no, you'll see, I'm going to make a mess. I'll put it here...
8. P: Make a big curve, as long as it covers everything...

We can see in the above dialogue that in turn 2 the students were anticipating the goal state: the construction of a train (*Select a train or something*). To reach the goal state, they again had to build two elements, in this case, the train station and railway line. In turns 5-7 (-*selects the train station and places it in the map-; -chooses "railway" and starts building the* *railway line*-), we can see how the students selected the necessary icons from the menu and then placed them on the map. Figure 8 shows how the structure is the same as in the other problems, where it was necessary to resolve two *sub-goals*.

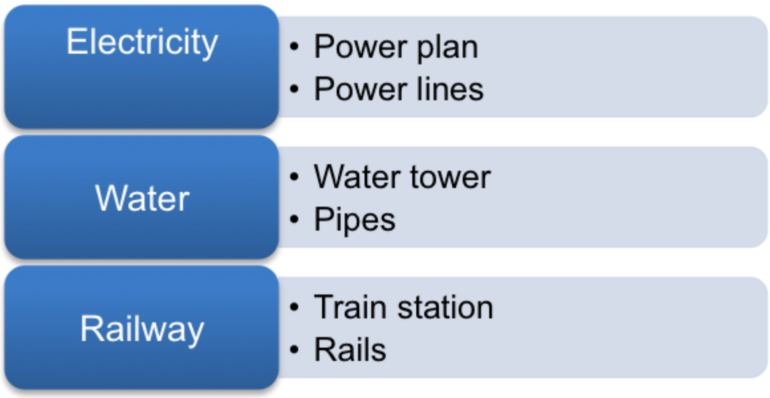

***Figure 8*. Sub-goals in each problem**

This approach to problem solving corresponds to the *fractionation method* (Hayes, 1989), where the aim is to divide the problem into sub-goals, reducing the size of the problem space. The game design is consistent in these cases and in order to consider the service as installed, not only must both elements exist but they must also be interconnected, which is logical, since this is how real cities work. Thus, the power lines must be connected to the power station, the pipes to the water tower and the railway lines to the train station.

Previous schemas for solving complex problems

During the session students tackled various problems while playing the game. They placed water and electricity in the city and built roads and trains. These experiences allowed them to acquire knowledge about the mechanics of the game and its rules that was useful in solving future problems (Novick & Bassok, 2005). Some of the fragments featured in the previous sections showed that while solving certain problems, the students used the same strategy: building was intended to cover a large area using the least possible time and effort. We would like to present another example of this approach that will enable us to analyse the use of *schemas* (Hayes, 1989) as a problem solving strategy.

Fragment 4: Using previous schemas

2009 02 23. Session 2. Fixed Camera

1. M: Which one do I press?
2. P: There, press that one
3. M: Transport?
4. P: Yes ((looks at the menu options)) should we create a motorway? Making a circle... ((both laugh) (...)
5. M: A slip road onto the motorway, right? There, now create a road, or something in there ((points to the edge of the map with the remote control))
6. P: Sure, some curves ... so that they go everywhere

In this example, the students were building a motorway. Turn 4 (*should we create a motorway? Making a circle...*) shows that they want it to be circular. The students also applied the same design to roads, as seen in turn 6 (*some curves ... so that they go everywhere*). For Peter, using curves, circles and squares allowed them to cover large spaces with ease and that is why they used this *strategy* to build the power lines, railway lines and, in this last example, motorways and roads.

These constructions are depicted in figure 9, showing screen captures from the moments in the game that we are referring to.

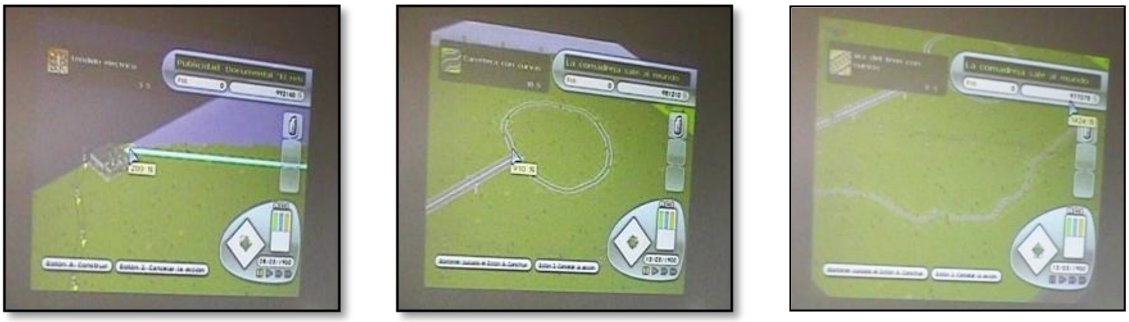

***Figure 9.* Schemas.**
Square for the railway lines, curves for motorways and circles for rails.

Since he had already employed this strategy, the student retrieved the previously generated *schema* to solve a similar problem and used it to carry out new constructions (Marshall, 1995). Although the service changes (electricity, roads, railway lines), the construction is analogous. The above also implies *analogical reasoning* (Gick & Holyoak, 1980), since similar schemas were retrieved and included in the representation of the problem. In this case, when constructing the water and train services, the students internalised the *rules of the game*

(Juul, 2005) related to this type of construction that facilitated solving new challenges. This strategy not only allows us to solve problems more easily, but also to tackle more complex problems when they arise for the first time, once we realise that what needs to be done coincides with a previously learnt *schema*. However, using a prior schema or reaching an intermediate state does not always lead to the solution, and it is necessary to go a step further to achieve the goal, by combining both strategies. The fragment corresponding to the construction of the train provides an illustration of this kind of situation.

Fragment 5: Schemas that become sub-goals
2009 02 23. Session 2. Fixed Camera
(Continued)

7. M: What a curve I've made, right? They'll go a little ... Where is it? Oh no,... What's that? ((There is a flashing zig-zag symbol)) (...)
8. P: I don't know, Teacher! When that appears.. That zigzag thing?

(...)

9. P: When the zigzag appears... on the train, what does it mean?
10. T: You don´t have electricity. You must also provide the train with electricity.
11. M: More! My goodness.....
12. P: Well, create some more of those power lines.

As shown in the dialogue, a zigzag symbol like a ray of light appeared, indicating the need to provide electricity for the new construction. Not knowing its meaning, the students sought help from the teacher who, in turn 10, indicated that the sign means that the train needs electricity. Thus, in addition to attaining the two sub-goals, in order to reach the goal state, a railway, it is also necessary to once again solve the problem of electricity. This schema for creating electricity has already been created, and now it constitutes a sub-goal of this problem. In this case, the students needed to extend the power lines and place a new power station, because the ones already in place were insufficient to supply the new network.

Moreover, the rules are clear about this and resemble a real city, where it is reasonable to assume that when expanding the infrastructures, services should also be expanded. The game indicates this with a flashing zigzag symbol, indicating that it is necessary to provide the new construction with electricity. Knowing the meaning of the symbols that appear on the screen is important in order to grasp the mechanics of the game, and in this case, understanding their meaning allowed the students to refer directly to their previously internalised schema of the electrical system.

Conclusions

As noted at the beginning of this article, we were interested in analysing the problem solving processes that emerged when a simulation game, Sim City Creator, was introduced into a classroom. The data presented here show that solving the problems presented in the game is not easy. Building a virtual city requires the implementation of processes that involve creating an adequate *representation* (Hayes, 1989) of the problems and carrying out a sequence of steps to solve them (Bassok & Novick, 2012). On the one hand, we have focused on an analysis of the role of *operators* and *conditions* (Newell & Simon, 1972), showing how these were presented in the game and in the context of our study. We have also studied different approaches to solving problems, either by using *fractionation methods* (Hayes, 1989) to establish *sub-goals*, or by using previously generated *schemas* (Marshall, 1995).

From the results, it can be seen that in the case of Sim City Creator, the *operators* (Bassok & Novick, 2012) are presented on the screen in the game menu, which is navigated using a remote control. The visual presentation (Goh, Than & Choy, 2012) of *operators* through pictures/icons on the menu provides students with a specific element to use to address the problem. Each icon generates a different action that can help students to progress towards the goal or, in contrast, to choose the wrong path. Hence it is important to identify the appropriate operators and understand the function that each performs in the game in order to choose the correct one. This task was not easy for the participants, who often found it difficult to navigate the different levels of the complex game menu. However, repeated navigation of the problem space together with help from the teacher enabled them to acquire the necessary skills to locate the correct operators.

Solving problems using media such as video games is different, for example, to a maths problem, which can be solved using a pencil and paper. In this case, the problem space presented the interactive characteristics inherent in the technology, but also required motor skills that, as we saw, were not easy to achieve. Sometimes, the game itself does not help players to find the operator but instead diverts their attention away from the game to focus on the remote control. However, the fragments analysed show that once they understood the purpose and function of the various operators and had succeeded in operating the remote control, students were able to access the operators, reach the goal and solve the problems posed by the game.

In this process, the role of *conditions* (Bassok & Novick, 2012) is particularly relevant. In our study we observed that these were raised both by the participants, teachers or students, and also by the game. Those proposed by the former were primarily based on prior experience and the relationship between the real and the virtual world, looking for similarities with real life (Shaffer, 2006). The teacher's role as a guide, defining the problem space with his suggestions, was crucial in helping students to construct correct representations and resolve the various problems posed by the game. On the other hand, the conditions imposed by the *game rules* (Juul, 2005) determined what was or was not possible within the virtual world. In this respect, the excerpts presented illustrated, for example, the need to build a power station and power lines to supply electricity, since without both items the game would not accept that the service was installed; another rule was that it was not possible to place one element on top of another, and the appearance of a zigzag symbol indicated that more electricity was needed in that area. It is also important to note that even though the game's design and goals are open-ended, this did not prevent the participants from having their own goals and implementing their own conditions which, when added to those inherent in the game, enabled them to represent and solve problems.

The importance of certain features that contributed to the construction of a *representation of the problems* (Novick & Bassok, 2005) should also be highlighted. In our study, these were present in both elements of the game: the map and the teacher's suggestions throughout the workshop. The map allowed students to navigate the virtual city and provided a constant point of reference when they had to build infrastructures and services. Furthermore, we observed that the teacher's *internal representation*, based on his own experience as a player, served both as an *external representation* for students, and as an inherent condition of the problem, since he defined the problem space and indicated a determined sequence of actions to follow (Hayes, 1989).

Thus, the *conditions* and *operators* acquired specificity within the scope of the game, and also, within the school context in which the activity took place. Building a virtual city also involved working with different *strategies* (Lacasa, 2011) to create the elements required. In this regard, we observed that the design of the game offers various options for building services and infrastructures, which involve the construction of several elements. Thus, the students moved through the problem space, identifying what these elements were, which operators to use and what conditions to follow for their correct installation. It was through this conjunction of *operators* and *conditions* that *sub-goals* emerged (Hayes, 1989). This approach allowed students to apply the *fractionation method* (Hayes, 1989), analysing the problem, identifying sub-goals and deciding how to solve them. In the case of this game, most services required this strategy, and thus it was employed on several occasions.

The importance of *schemas* (Marshall, 1995) in addressing new problems has also been discussed. In solving the problems posed by the game, players internalised their properties, and these then became available later in the form of schemas. In addition, by identifying points in common with other problems that had been resolved earlier in the game, students were able to retrieve previously created schemas and use them to solve the new ones (Novick & Bassok, 2005). This not only allowed them to solve problems more easily but also to tackle more complex problems when they appeared for the first time. This strategy involves *analogical reasoning* (Gick & Holyoak, 1980), and consists of retrieving similar schemas and including them in the representation of the problem. Thus, a successful strategy that has yielded positive results when solving a problem is internalised and remains available when tackling new challenges. In some cases, these two approaches were combined, where the *schema* itself represented a *sub-goal*.

As a final conclusion, the results presented here are an example of how playing a video game does not only involve leisure and fun. The data analysis results indicated that the construction of the various services and infrastructures required for the virtual city in the Sim City Creator video game involved constant problem solving processes. The incorporation of a commercial video game into the learning environment allowed students to tackle various problems they had to represent and solve properly. Given the importance of problem solving in everyday life, we believe that our study demonstrates the potential of video games to enhance these processes.

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