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A Theoretical Background for Educational Video Games: Games, Signs, Knowledge

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ABSTRACT
The potential of video games for learning is now widely accepted among the community of Educational Technology. However, there is a critical lack of guidance for the design of educational games. In order to provide such guidance, there is a need for a solid theoretical basis regarding the nature of learning in games. This paper redefines what a game is, in semiotic terms, enabling four groups of strategies to be formally identified, depending on how the knowledge to be acquired is inserted into the game. These four groups are: systemic learning, when knowledge is embedded in the game mechanics; winner strategies, when the game provides an environment in which knowledge is required to reach the game's goal; loose coupling, when knowledge is arbitrary required to unblock the progression towards the game's goal; and contextual coupling, in which the game serves as a context for the exposition of static learning material. This theory is then put into practice by analyzing three commercial educational games. It constitutes a first step towards Instructional Game Design.

INTRODUCTION
The potential of video games for learning is now widely accepted among the community of Educational Technology (Quinn, 1997; Jones, 1998, Amory, 2001; Rieber, 1996; Prensky, 2001; Gee, 2003). Contrary to common belief, play and games are not specific to children, but constitute an essential activity for adults too (Huizinga, 1938; Rieber, 1996). Play is not frivolous but can be quite serious (Rieber, 1996). The recent explosion of computer and video games in modern culture makes it even more obvious that games are to be considered as a new medium, with unique properties.

Among the most cited advantages of video games over other instructional technologies are their motivational appeal and their compatibility with modern pedagogy (Kirriemuir & McFarlane, 2004, p. 19).

In terms of motivation, it is argued that games are intrinsically motivating; players are motivated to play regardless of the consequences of the learning activity (Malone & Lepper, 1987; Jones, 1998). This is related to one fundamental characteristic of a game: the fact that it has no perceived utility for the player (Huizinga, 1938). Games are played because they provide a multitude of emotions, such as fear, surprise, pride, relief, etc. and have other motivational aspects such as challenge and fantasy. Given this intrinsic motivation to play, several educational games have been developed, including all the games considered as “edutainment”. While it has been shown that games in certain contexts provide higher levels of motivation of engagement than traditional education (Wishart, 1990 in Hays, 2005), the level of engagement or “gameplay” of these titles seems lower than in pure entertainment games (Hagbood, 2005), as if adding pedagogical constraints to a game diminished the motivation. In other terms, “making learning fun”, as stated by Malone & Lepper (1987) remains a difficult task (Hays, 2005).

In terms of pedagogy, the active nature of games encourages learner-centered pedagogy. As described by Rieber (1996), play is a natural learning strategy for children according to the Piagetian theory; this makes video games suitable for computer-based learning. Game-based learning is usually associated to the situated learning theory (Brown, Collins & Duguid, 1989), because in many games, especially 3D games, any action has a meaning within a situation in the game (Gee, 2003, p. 84). However, in many educational games, the player's actions are not used to promote situated learning. Indeed, among players' actions, some are dedicated to learning while others are purely for the game play, resulting in a dissociation between game and learning which is contrary to situated learning. This insufficient integration between game and learning is also reported by several research studies (Malone & Lepper, 1987; Kirriemuir & McFarlane, 2004; Habgood, et al., 2005; Szilas & Sutter-Widmer, 2009).

Besides, using existing games for educational purposes is very difficult, since the games were not designed for that purpose. For example, several practical difficulties are reported when using commercial history strategy games to learn history in a classroom environment (Egenfeldt-Nielsen, 2004; Connoly & Stansfield, 2006).

This short overview leads to the conclusion that there is a need to design educational games that better exploit the pedagogical potential of computer games, but also that we lack guidance for such design. As far as learning is concerned, the field of Instructional Design (in the broad sense of the term) is dedicated to providing guidelines on tools/methods for organizing learning content and activity, should the tools/methods use computer or not (Reigeluth, 1999). On the game side, the field of Game Design provides more and more established methods to design games with a good gameplay, in terms of balancing for example (Salen & Zimermann, 2003). Each of these two design-oriented fields fails however in providing relevant methodology for educational games. Instructional Game Design (IGD) should emerge to improve the quality of current educational games. More specifically, the goal of IGD is to find a methodology making it possible to produce an efficient learning game from any given knowledge domain, if such a game is possible. Very few attempts towards IGD can be found so far, and they remain preliminary (Dickey, 2005; Kiili, 2005; Amory, 2007). These attempts tend to share elements between methodologies; this leads to a relatively shallow integration of Game Design and Instructional Design, without sufficiently taking into account the specificity and the difficulty of using games for learning. Questions related to this definition of IGD are:

- How to assess the quality of an educational game, in terms of learning?
- What can be learned with games, and what cannot?
- How to adapt existing instructional design methods to educational game design?

We consider that in order to provide further guidance in the design of educational games, there is a need for a solid theoretical basis regarding the nature of learning in games. To date, the connection between learning and game playing is not clearly established. More precisely, it is admitted that game playing promotes learning, but the exact nature of the articulation between these two activities remains unknown. Our position is that this articulation must be better understood before proposing more efficient guidance for educational game design.

This paper aims to contribute to such a theoretical base. We raise the fundamental issue: what are the relations between games and knowledge and how can this relation inform the design of educational games that promote efficient learning?

The chapter is structured as follows. First we propose a definition of games that is relevant within the domain of learning. Then, from this definition, some fundamental principles regarding games and knowledge are listed. In particular, four educational game types are distinguished, depending how the relation between game and learning is underlined. Then, three video games are analyzed according to the theoretical principles of games and knowledge. Finally, recommendations and future research direction are proposed.

REDEFINING GAMES

Why a new definition?

The difficulty in providing necessary guidance for the design of educational games is due to a very vague and extensive concept of games that is usually adopted. If one needs to understand, from a theoretical point of view, how learning and gaming can work together, it is necessary to rigorously define what a game is. Then, learning being the acquisition of knowledge, it will be possible to precisely identify how knowledge and games are potentially related, opening the way to a better understanding of the various possibilities of learning by game playing.

In order to limit the scope of this study, which still remains wide, only games with game-defined goals and rules will be studied here. Games where the player defines his/her own goals or rules, such as when children engage in free play or pure simulation games (i.e. Sim City), despite their potential benefit for learning, are outside the scope of this paper. Only single player games are discussed here, but to some extent, results of this paper can be extended to the multi-player case.

There have been several definitions of games, starting with the pioneer work of Johann Huizinga (Huizinga, 1938). More recently, academic interest for video games has raised updated definitions based on an overview of existing definitions (Salen & Zimmerman, 2003, p. 71; Juul, 2003). Despite these efforts, all proposed definitions lack precision or miss important features of games, as will be demonstrated below.

Games as signs

Some of the main features of games are the fact that the activity occurs outside ordinary life, in a separate time and space, and the activity is unproductive (Huizinga, 1938, p. 35). This notion of separation is difficult to defend since some current games, in particular pervasive games, are deeply interlaced with everyday life (Juul, 2003). Juul proposed to replace the notions of separation and non-productivity by the notion of "negotiable consequence": the fact that a game "can be played with or without real-life consequences". However, this latter notion, not only remains imprecise itself (who is negotiating with whom?), but is also based on the assumption that because one can earn money in a game, then the goal of the game is to earn money. However, the goal of the game is still to win the game, which by itself is not productive, even if the game is sometimes embedded in a larger context where there are consequences. The difficulties in understanding/addressing the notion of what Salen & Zimermann (2003) call "artificiality" can be solved if the focus is shifted from the objects themselves to their interpretation. The "arena" where the game takes place (Huizinga, 1938) is not necessarily a delimited physical space, but becomes separated from the real world through players' interpretations. For example, even if someone plays chess by e-mail (Juul, 2003), the game occurs in a separate world, not a world of physical objects but a world of interpretations. This brings us to the notion that games are made of signs (Salen & Zimmerman, 2003, p. 42). In the field of semiotics, which is concerned with the study of signs, a sign is considered a link between a physical configuration of the world and an interpretation (or representation) in the mind of the interpreter, the player in our case (Klinkenberg, 2000, p. 42). For example, the bottom left square in a chess board is a sign with a certain meaning in the context of the game. No matter the size of this square its precise color or material, the meaning of this square in chess comes from the rules of the game which provide specific relations between this sign and other signs in the game.

Games as dynamical systems

This example illustrates an important feature of signs: a sign in isolation does not mean anything because signs are organized into systems of signs. Salen & Zimmerman (2003) acknowledge the systemic nature of games, without explicitly stating that games are systems of signs. Furthermore, we want to be more specific in asserting that games are dynamical systems, by analogy with the dynamical systems formalization in mathematics. In other words, games are defined by an initial state and a function that describes its evolution, according to its inputs, including the players' action. This dynamical nature of games differentiates them from other semiotic systems such as languages: languages are static, and their rules (the grammar) define the set of correct sentences of the system. Games are temporal, and their

grammar not only defines the correct states in the game but also correct temporal evolution of those states.
The resulting definition that we propose is the following:
A game is a dynamical system of signs in which the player acts, independently of any consequence outside the system, in order to reach a goal assigned by the game.
This definition does not use the term “rules”, as in almost all other definitions, because it is included into the notion of dynamical system. Let us enter into the details of game dynamics.
A game contains two components: the game mechanics and the playing rules (see Figure 1). The game mechanics – equivalent to the constitutive rules discussed by Salen & Zimmerman (2003) – describe how the game evolves, according to the player's inputs. The mechanics itself is composed of a *specific component* designed for the game and of an *environmental component*, which is ruled by the physical environment. For example, in the board game “Connect Four”, the fact that the discs fall into the grid because of gravity, is a law of the environment, not of the game, but it has consequences for the game: one cannot put the discs in any position (as it is possible when playing with a grid on paper). Within the specific component of the game mechanics, the dynamics (the rules) can be automatically executed by the game itself or manually executed by the player (or another person). A particularity of video games is that their mechanics only have a specific component and are automated.
The playing rules – equivalent to the operational rules discussed by Salen & Zimmerman (2003) – define what the players are allowed to do in the game. That is, which inputs they are allowed to provide to the game mechanics. The playing rules act as a filter between all the possible actions of the player and the allowed actions provided to the game mechanics. In classical games, this filter is usually controlled by the player himself and by the other players when possible. Voluntarily not applying this filter is called cheating (which is not part of the game). A specificity of video games is that the player cannot easily provide an input that is not allowed, because the game can control the validity of the input. This makes it possible to avoid mentioning the playing rules.
Note that this definition is centered on one given player because the multiplicity of players is not a mandatory feature of games. In other words, a game only requires the point of view of one player to be considered a game. To include multi players’ case into this definition, other players are part of the dynamical system, more precisely in the environmental component in the figure 1 below.
There exists a classic distinction between games and toys, between *Ludus* and *Paidia* (Caillois, 1958). *Ludus* relates to rule based playing, where the player is constrained to follow rules. *Paidia* denotes free play, without precise goals and rules, as when playing with toys. The above definition clearly enters into the *Ludus* category, following the scope of the paper defined above. We are aware of this limitation, since *Paidia* games should be included in the scope of learning games in general, but this restriction allows us to draw stronger theoretical conclusion.

[[INSERT FIGURE 1 HERE: Formal architecture of a game.]]

Figure 1: Formal architecture of a game.

Note that the concept of fiction or diegesis (de Freitas & Oliver, 2006), although not necessary, is often associated to games, especially educational games. The system of signs related to the fictional game world should however be distinguished from the system of signs mentioned above. Fictional games add a level of complexity because the entities of the game not only constitute the game system mentioned in the definition above but also refer to our own world, as does any representational media (feature film, novel, etc.). Thus, in fictional games, two semiotic systems are superimposed.

THE PARADOX OF EDUCATIONAL GAMES

In this section and the following, we discuss the use of games for pedagogical purposes using the above definition of games.
First of all, one can observe a fundamental paradox when games are used for learning.

On the one hand, games are artificial: one plays for the sake of playing, regardless of the consequence of the playing activity outside the game (see previous section). On the other hand, learning is useful and must be perceived as such in order to be efficient: “there is now a wide consensus that effective, meaningful learning is facilitated by explicit awareness of and orientation towards a goal” (De Corte, 1995). It is considered important that the student understands the structure of what is to be learned (Merrill, 2002). In particular, it helps students reflect of their own learning activity. This paradox is also observed by Becker (2006): "If education is deliberate, and being *made* to play a game causes that object to cease being a game, then the whole notion of educational games would constitute a paradox." To solve the paradox, either the first or the second assertion has to be disproven.

Let us first disprove the first assertion and consider educational games as special types of games which are not artificial because they have a goal within ordinary life. In this case, the activity of playing an educational game would satisfy both the artificial goal of the game and the utilitarian learning goal.

The double goal hypothesis: The learner-player could maintain during his/her playing activity the two goals in mind, with two types of motivation. The learner-player would be motivated both by the game's goals (game-intrinsic motivation) and by the learning outcome. According to this hypothesis, the attention of the player would shift between the two goals. Designing a good game is already a tricky task, so designing a good game that manages to add learning goals and motivations to learn in the mind of the player without diminishing the interest of the game appears to be quite a challenging task, if not impossible. A more reasonable hypothesis consists in assuming that while both goals are present, one is more conscious than the other, at a given moment of the user experience. More precisely, the main goal is the game's goal, but the player is aware that s/he is learning something while playing, and pretends s/he is only playing. This attitude would be analogous to what is called the “suspension of disbelief” in film: the viewers know perfectly well that what happens on the screen is not true, but they suspend this belief in order to get immersed and feel various emotions (Tan, 1996, p. 228). In this case, the player would alternate between periods where s/he would suspend their disbelief that the game has only a gaming goal with periods in which s/he would take the opportunity to think of the learning goal and reflect on it (e.g. debriefing periods).

Let us now disprove the assertion that educational games are played with the intention to learn. Two cases can be distinguished.

Implicit learning: In this case the learners do not know they have learned, since educational games can be based on implicit learning. Ciavarro, Dobson and Goodman (2008) used a hockey game to train hockey players to behave properly during a match. A hidden rule gave advantage to players who did not use violent actions. As a result players did improve their in game behavior, without even noticing they had learned. They only played the game as a usual game, for the sake of winning the match. With implicit learning, a game can be used without interference between learning and playing.

Unsaid goal: In some situations, with children in particular, it is possible to omit mentioning the learning goal. Still, contrary to implicit learning, by the nature of the game or its context, players might guess that the game is dedicated to learning. In this case, the player experience switches to the “double goal” case. It remains possible for the learner to feel fooled because s/he was proposed a game that ends up being a pretext for learning. Note that there is also an interesting case where the learner is aware that learning content is targeted by the game, but does not know what exactly.

Among these solutions to the paradox of educational games, none constitutes a unique general solution to be applied in any situation. It appears that for the educational game to be a game, learning has to be considered a “side effect”. By this, we mean that, to benefit from the advantage of games, the learners should have the artificial goal of the game as a primary goal, and that his/her primary activity should be oriented towards that goal.

EPISTEMIC COMPONENTS OF GAMES

In this section, our goal is to identify where learning could take place in a game. More precisely, our goal is to identify various strategies for embedding an educational goal into a learning game, that is various articulations between the educational goal and the game’s components. The result we are after is a classification of strategies of using games for learning and not a classification of educational games. Many educational games would use several methods, as will be shown in the next section. Furthermore, our intention is not to pick up common game characteristics that are relevant for learning (Garris, Ahlers & Driskell, 2002; Wilson et al., 2009) but to deduce from a formal definition of games how the fundamental (or necessary) characteristics of games can combine with knowledge and its acquisition. For example, many authors, following Malone and Lepper (1981) mention fantasy as a game characteristic relevant for educational games. While we are not denying this assumption, we simply note that fantasy (or fiction) is not a necessary feature of games (see above) and that fantasy is also used in books, movies and simulations. Thus to understand why and how games should be used for learning, one needs to understand and focus on what games fundamentally are.

To establish a basis for IGD, a theoretical categorization of the strategies for mixing learning and games is essential. Starting with an educational goal, the learning game designer has to be aware of the various existing methods for inserting educational goals into the game. The game designer also has to understand the relative advantages and drawbacks of each method, in order to be able to choose the most appropriate ones to focus on.

As stated above, our approach consists in starting from the necessary and essential features of a game, described in the definition above and refined in Figure 1. First, from the game's general architecture depicted in Figure 1, one can straightforwardly locate two places where knowledge could be embedded: playing rules and game mechanics. We could not find any examples of a learning game whose learning content is located within the playing rules (operational rules) themselves. In a first person shooter for example, knowledge to be acquired would be that once there are no munitions with a weapon, one cannot shoot with this weapon; in order to go from one place to another, one needs to walk or run, etc. Learning at this level is equivalent to learning "prescriptive" knowledge, in a context where only correct knowledge effects the system. It seems more interesting to focus on the game mechanics (constitutive rules), a case that is studied below, as the learner has more freedom to explore the domain and observe the consequences of not following the rules to be learned. Therefore, we will not further elaborate the option of learning at the level of the playing rules in the rest of the article.

From the definition of a game, we can distinguish two types of learning in games: goal driven learning and mechanics driven learning. In goal driven learning, learning occurs because knowledge is required to reach the goal of the game. By arranging goals of various types and difficulty, games can be seen as a series of problems or exercises related to various knowledge to be used and acquired. This type of learning is then divided into two subtypes: *winner strategies* and *loose coupling*, depending on the level of integration between learning and gaming.

In mechanics driven learning, what is learned comes from the mechanics itself, the game's goal being an external factor in the learning. This type is further divided into two subtypes: In *systemic learning*, what is learned is the mechanics itself, that is the relation between the input and the output (see Figure 1), while in *contextual coupling* , what is learned is only an output of the mechanics (see Figure 1), regardless of the input.

In the following sections, these four types are presented in decreasing order of value from most valuable to less valuable types of articulations in terms of exploiting fundamental characteristics of games.

Articulation around the game mechanics – systemic learning

When players interact with the game, they learn its game mechanics. After having played, they acquire a certain knowledge of the system's behavior. To a variable extent, they can, for example, anticipate the system's behavior and adapt their actions accordingly. Such learning happens in most games, and at various levels. In a first person shooter for example, the players could learn how to handle the mouse, how to move the character in a corridor, how to orient in space, how to anticipate non playing characters' actions, etc. The player progressively acquires the part of the rules that constitute the game mechanics. This acquisition is neither automatic nor guaranteed, and it depends on the design of the game. If the educational goal is directly related with learning the game mechanics, we can use the game to obtain this goal.

From a pedagogical point of view, learning a system makes sense if the system shares similarities with an existing system of reference, so that the competencies acquired during play can be transferred to the system of reference. This learning strategy is applied instructional design when using simulations (Gokhale, 1996) and microworlds (Rieber, 2004) - a microworld is an engaging learning environment that students explore in a playful way, such as *LOGO*.

Games, in the sense of the goal-oriented games covered by this paper add a new dimension to simulations and microworlds by adding a goal structure to the simulation system itself. The benefits of this goal structure are twofold:

Firstly, the goal structure increases motivation for interacting with the simulated system. Even if microworlds are designed as toys to play with (Rieber, 1996), difficulties are reported getting learners engaged in the system (Gokhale, 1996; Rieber, 2002; Rieber, 2004, p. 599). The explicit goals attached to the game provide a solution to this issue.

Secondly, the goal structure allows a progressive exposure to the complexity of the game. The goal structure, of both goals and subgoals, initially exposes players with easy problems exposing them to only a subset of the game mechanics. Instead of letting the user interact with a complex system without guidance, the goal structure allows for the problem complexity to be smoothly increased, using a scaffolding strategy.

While the distinction between games and simulation is recognized (Prensky, 2001, p. 210; Gredler, 2003), the terms are often used almost interchangeably (see for example (de Freitas & Oliver, 2006)), as also observed in (Hays, 2005, p. 9) and the benefits of the former are often assimilated with the benefits of the latter. In fact, for the type of articulation we are discussing in this section, simulations and their benefits constitute a subpart of the game. Such “in-game” simulations can take various forms, from realistic simulations to simplified simulations (Horwitz, 2000) to imaginary worlds like microworlds (see for example *Cabri-Géomètre* (Laborde & Capponi, 1994), an abstract mathematical world).

The notion of fiction that was introduced above is particularly relevant in systemic learning. When creating an artificial world of places and characters that evoke real places and real characters, games provide the ability for a learner to rehearse a behavior that is relevant in real life, in the game world.

Articulation around winner strategies

The mechanics of games can also be used to produce learning, if it supports certain strategies and dismisses others in the pursuit of the game's goal. In which case, what is learned is not the dynamical system itself, but the winner strategies, which are reinforced by playing the game. Therefore, the goal of the game must be carefully designed in order to promote these winner strategies.

Such a game was used and analyzed by Brousseau to study the learning and teaching of mathematics, and resulted in the “Theory of Situations” (Brousseau, 1998). The theory was inspired by Piaget’s “learning by adaptation”, according to which, individuals learn by interacting with the world and adapting their actions in order to reach a goal (Piaget, 1959). The term “game” in the Theory of Situation is used by reference of the game theory, rather than video or child games; nevertheless, this theory is relevant for our purpose. For Brousseau, a game proposes a goal to be reached, defines the means that may be used, and (implicitly or explicitly) the actions that may be performed in order to reach the goal. If the goal is clearly understood and accepted, the subject will use a trial and error process, mobilizing his/her mental schemas, and will receive feedback that enables him either to confirm the validity of these schemas, or to adapt them in order to reach the goal.

Brousseau describes three types of situations in which mathematics learning is promoted at three different levels: action, formulation and validation. For our purpose, the action situation is relevant for the design of educational games. It defines a practical goal to be achieved within a given ‘milieu’. At this level, the knowledge is embedded in the actions that pupils do in order to reach the goal. The game is played with the world as an opponent. The game is organized so that the subjects do something to win. The rules and the ‘milieu’ (the game mechanics) grant that all actions produce a consequence that can be interpreted by subjects in terms of success or failure.

In this situation individuals learn by experimentation: they are confronted with a problem to be solved or goal to be reached, are provided with opportunities to perform certain actions (material, verbal or symbolic), and receive feedback from the 'milieu'. The feedback is as natural as possible (avoiding an authority evaluation: false/correct), and enables the subjects to evaluate their strategies by themselves, in order to correct themselves and reach the goal.

The most important factor in these games is what Brousseau calls the 'milieu', which we could assimilate to the game mechanics. According to the Theory of Situations, the most relevant feature of the 'milieu' is that "it has no pedagogical intention"; this means that the learner can assimilate its reactions to the natural reactions of the material world, in contrast with the reactions of a teacher, which could (voluntarily or not) give hints towards the correct actions to perform. In terms of the game mechanics, feedback in the form of judgments (true/false, correct/incorrect) should be avoided, and replaced by natural consequences of actions.

What subjects learn from this type of activity is the strategy that enables them to reach the goal. Therefore, an important aspect is to control all the possible strategies subjects could use spontaneously, and to ensure that the goal cannot be reached using a 'wrong' strategy (or a strategy that is not important to be learned). For example, if the objective is to learn to use a compass and ruler to draw a reflection about a line, it is important not to use a grid, which would enable reaching the goal without using a compass and ruler.

Applying these ideas to our definition of games, we could say that we can articulate the educational goal around the winner strategies if the game mechanics enforces three conditions:

- the player can enact different spontaneous strategies,
- only strategies that support the targeted knowledge objectives are successful,
- the feedback to the player's actions should avoid judgment and be presented as a natural consequence of the actions.

Therefore, this type of strategy only applies to domains where there exists some didactic knowledge regarding good or bad strategies and solutions, such as mathematics for example, in contrast with domains where there might be no right or wrong answer.

Articulation around the obstacles – loose coupling

In both categories above, the educational goal is embedded in the game mechanics. In many educational games however, certainly most of them, the game mechanics is composed of two almost dissociated parts, one dedicated to the learning goal and the other dedicated to gaming itself. The only link is the following: succeeding or failing to solve a task related to the educational goal changes a parameter in the gaming part of the mechanics. Typically, succeeding a task opens a new possibility in the game. This is a loose coupling because even if there is an interaction between the educational goal and the game, the structure of the learning task does not have any impact on the design of the rest of the game mechanics. As in winner strategies, knowledge is required to reach the goal of the game, but this is achieved at the price of a clear separation between learning and gaming components.

The articulation between learning and playing occurs via a component that is central to both activities: obstacles. On the learning side, several instructional strategies use problems or tasks that learners have to solve (Merriënboer, Clark, de Croock, 2002; Merril, 2008). These problems or tasks constitute obstacles, because they are not immediately solvable by the learner, otherwise there would be no learning. On the gaming side, the notion of conflict is considered as a core component of games (Crawford, 1982; Salen & Zimmerman, 2003). The conflict can occur between the player and the game rules, between players or within a player. It is related to the notion of competition which is one of the four categories of play identified by R. Caillois (1958). Thus the wide use of obstacle-based coupling between learning and playing can be explained because obstacles constitute the most obvious way to connect the two apparently separate fields.

Furthermore, it should be noted that obstacles are also basic components of narrative and drama. This notion is widely used in the domain of screen writing (McKee, 1998; Vale, 1972), where it is often termed "external conflict". It is also discussed in narratology. According to U. Eco for example, a narrative sequence needs actions which are difficult to perform (Eco, 1985, §6.4). In the theories of Greimas and Souriau, one of the actants is the opponent, which acts against the protagonist (Greimas & Courtes, 1979; Souriau, 1950). With many modern games being based on stories, obstacles are naturally used as the locus of integration between games, narrative and learning.

Loose coupling however meets several limitations. First, contrary to previous approaches, the systemic nature of games is not exploited. The game is used as a "motivational recipient" of activities that would be considered less motivating otherwise. The problem with such games is twofold. On one hand we wonder whether the recipient effectively motivates the learner or not and on the other hand if it does not just distract the learner and impede learning.

Second, the pedagogy behind the use of obstacles is often very limited. The obstacles are often questions asked to the learner (quiz) which departs from the active and constructive nature of learning that should be supported in game-based environments. An extreme example, outside of the computer realm, is the game *TRIVIAL PURSUIT®*. It is definitely a good game, in terms of entertainment, but the player does not learn much with it despite its heavy relying on players' knowledge. The part of the game related to an educational goal consists of a series of unrelated anecdotal questions in various domains, an approach that cannot be supported by any learning theory. In other words, some educational games are a "sugar coating of 'fun'" (Kirriemur & McFarlane, 2004) on top of an irrelevant pedagogy.

However, the obstacle-based coupling approach should not be rejected. It is the lack of pedagogical thinking in the design of the obstacles that provides a poor learning product in the end. Obstacle-based coupling is still a valid approach in various contexts, in particular, in the context of low level learning of recurrent tasks (Merriënboer, Clark, de Croock, 2002). Games can provide a relevant environment by exposing the learner to repetitive tasks, a strategy which is suitable for this kind of learning. For example, the game *TYPERSHARK* uses a fictional setting in which sharks are dangerously moving towards the player character. In order to remove these obstacles (the sharks), the player has to type the word that is written on the shark. The learner automatizes his/her typing skills by repeatedly typing words to remove sharks.

To sum-up, obstacle-based coupling between games and learning is a straightforward approach for learning with games which does not exploit all potentialities of games but which can be appropriate if the obstacles are designed in a pedagogically meaningful way.

Articulation around the context – contextual coupling

In this last category, the educational goal does not interfere with the game mechanics. The educational goal is fulfilled by delivering information during the game, and the way the user processes this information has no effect on the game. We call this type of articulation contextual coupling, because while the educational information does not advance the game, it can be considered as context for the core game.

Several edutainment games are based on this principle. For example, in French historical games such as *VERSAILLES* or *CHINE*, the plot happens within a historical context. The visual environment teaches about the culture and society related to the game. Encyclopedic information is also provided within the game, by clicking on the game's elements (a character, a building, etc.). At last the player is sometimes faced with documents which also contain information to learn. All this content is usually not relevant for solving the game, but it is provided in a narrative context that could help memorization. Note that all these instructional strategies are not equivalent. When information is provided via a separate encyclopedic hypertext or within a separate document, the relation to the context is weaker than when information is transmitted in dialogs, which are a more integral part in the fiction of the game.

Fiction again is quite useful in this type of articulation. If an educational goal is related to a specific place or time, setting a game within a fiction in that place provides the player with plenty of information that is relevant to the educational goal.

This example illustrates that there exists a variety of configurations where learning-related information can accompany a game mechanics, while not being part of it. These various configurations are not all

equivalent. The most valuable are the ones which manage to integrate smoothly into the games, so that learning is not completely separated from the playing activity.
Contextual learning however does not fully exploit the characteristics of games. In particular, the user's action has no role in learning. Typically, contextual learning could be used similarly within non interactive media, such as movies or comics.
Contextual learning in games is often used in combination with more integrated learning strategies. While other strategies above such as *systemic learning* or *winner strategies* typically promote meaningful and situated learning, it should be accepted that such learning has to be reinforced by declarative knowledge. It has been shown that when learning occurs only by interacting with an environment, following a situated approach, learners tend not to be able to use their knowledge in other contexts (Rieber, 2002). Thus contextual coupling can be used to support situated learning with classical content.

ANALYSES OF GAMES

In order to illustrate our formal classification of game-based learning strategies, this section analyses in more detail three educational games. For each game, the goal is to identify which components make it belong to one or the other category.
Such analysis is difficult since all games are themselves complex and composite interactive products. The choice of the granularity level at which our analysis should be performed is not obvious. It is to some extent arbitrary.
The selection criteria for the three games were:

- being purely educational games rather than typical games adapted to learning, such as *CIVILIZATION* for History, *SEGA RALLY* for driving, *SIMCITY* for city management, etc.
- being different from eachother, possibly covering different types of games according to our classification,
- having good gaming qualities (this criteria is subjective, but the idea was to avoid game with obvious flaws),
- available for free via Internet.

Dimenxian

Description

DIMENXIAN is a commercial game published by Tabula Digita, designed to teach algebra at high school. It proposes four different missions. Only the first activity of the first mission is analyzed here, available as a demo on the publisher’s web site (Dimenxian, 2010). It concerns the use of coordinates in Mathematics.
The fiction: The game uses a science fiction scenario, in which the player takes the role of a commando member in charge of detecting and neutralizing a virus introduced by enemies on an island. The player has to obtain data in different locations and introduce them on computers to analyze them. In the first mission, Kep (the hero) is teleported on the island to collect data from five meteorological stations located at different points. A voiceover is used for communication between “the base” and the player’s character.
The mechanics: The player is presented with two representation systems of the island (see Figure 2):
- A tridimensional (realistic) system, with all characteristics of the landscape where the character must evolve (objects, plants, water, etc.). The character is represented at the center, as a body seen from behind (third person perspective).
- A bidimensional (formal) system, in the form of a 10x10 grid, with coordinates of rows and columns at left and bottom. The character is at the center and is represented as an arrow.
The player can move the character around using the keyboard. Also, the mouse controls the direction of the eyes (look to the floor, to the sky or in front, to the left or to the right).
The tridimensional representation system also has lines that represent the grid of the bidimensional system, and coordinates of some points.

In some cases, it is sufficient to look at the bidimensional system, but in others cases there are physical obstacles to avoid that are only represented on the tridimensional system. This forces the player to quit his/her trajectory temporarily to avoid the obstacle.
In some other cases, enemies come to kill the hero, and s/he must shoot them. This forces the player to quit his/her trajectory temporarily and concentrate on enemies.
Finally, when the player moves too far away from the target, two types of guidance aids are proposed:
- The environment itself is bound, so the player cannot move further away from the target.
- A head-up display is proposed to guide the movements of the player until s/he begins to follow the right direction for a certain duration.

[[INSERT FIGURE 2 HERE : Screenshot of the game *DIMENXIAN]]*

Figure 2: Screenshot of the game DIMENXIAN (© Tabula Digita. Used with permission).

The goal: Station locations are given as coordinates. The player must determine his/her own location in the coordinate system and move in the appropriate direction to reach the various stations.
Educational objectives: Learning to use coordinates to locate a point on a grid (pointing to the place on a grid represented by a pair of numbers), and determining the relative location of one point with respect to another given two sets of coordinates – left or right, up or down).

Articulation between the educational goal and the game

The game is a good illustration of the winner strategy articulation. To succeed the missions, the strategy is:
- If my abscissa is greater than the abscissa of the station, then I must move to the left of the grid, otherwise to the right.
- If my ordinate is greater than the ordinate of the station, then I must move to the bottom of the grid, otherwise up.

The game mechanics ensures that only this strategy will enable the player to find the stations. Wrong strategies, for example going to the right if the own ordinate is greater than the ordinate of the station, will not produce a judgment feedback, but simply not reach the station. And other possible strategies, for example 'visually' guiding the movement, are unusable because the target objects do not appear on the representation systems until they are very close.
The goal of the game (finding a station) and the educational goal (using coordinates to guide movement) are embedded in the game mechanics in such a way that the goal of the game can only be reached if one reaches the educational goal. Using the coordinate system is not only a condition for the educational goal, but also for the goal of the game. The player can use different strategies, but only one of them will succeed, and strategies that get around the educational goal are unusable.
In the general case, in DIMENXIAN, the feedback of the system is not given in the form of judgments, but as natural consequences of the actions: getting lost, or reaching the stations. Exceptionally, when the player gets lost for too long, the heads-up display provides a more explicit and less natural feedback. This feedback attempts to reestablish a proper gaming situation in which the player makes effective use of the natural feedback from the environment, that is the 10x10 bi-dimensional grid.

Trivia Machine

Description

TRIVIA MACHINE is a trivia game published by *HIPsoft*, available through various game websites (Trivia Machine, 2010). The version evaluated here is the free demo download. The game consists of asking players questions in several domains.

[[INSERT Figure 3 HERE: Screenshot of *TRIVIA MACHINE]]*

Figure 3: Screenshot of the game TRIVIA MACHINE (© HipSoft. Used with permission).

The fiction: contrary to DIMENXIAN, the fictional elements are limited in TRIVIA MACHINE; no characters or tridimensional worlds. The game contains however an imaginary machine, represented in 2D (see Figure 3), which asks questions to the player.
The mechanics: At each turn, the game generates a new set of three questions. Each question is associated to a domain and a level: easy, medium and hard (having more than three domains, these change at each turn). Each level is associated with points; the more difficult the question, the more points to be won. The player chooses a question according to its domain and level, receives the question, and then has one minute to pick the right answer from a possible four. If the answer is correct, the player wins the points. If it is wrong (or not given in one minute), the correct answer is given and some points are lost. A threshold mechanism in the scoring is implemented: when one threshold is reached, the player's score can never go below this threshold. Thus, at maximum the player looses the amount of the question, but often s/he is just set back to the previous threshold. The player can also simplify the task by limiting the number of choices to two, in which case it halves the score. When the player reaches a certain score, s/he moves to the next level.
The goal: gathering points and reaching the last level.
Educational objectives: Learning facts.

Articulation between the educational goal and the game

As all trivia games, *TRIVIA MACHINE* is a typical case of an articulation between the educational goal and the game based on obstacles. The players get points depending on their ability to answer questions. From a game perspective, *TRIVIA MACHINE* is a good game. It provides the player with a choice for the level and domain of questions, with an engaging dilemma between a difficult but rewarding question versus an easy but less rewarding one. Furthermore, this dynamic is combined with the choice of the domain, which depends on the player's self perception of expertise in the domain. Finally, suspense is created as the player approaches a threshold.
From a pedagogical perspective however, the product consists of a series of questions for the player, with a feedback limited to "right" or "wrong". No strategy is proposed to either understanding his/her mistakes or improving his/her skills. In terms of learner control, the mechanics of the game doesn't allow for players to deepen their study of a subject.
The metaphor of the machine, which increases the playfulness of the experience, does not however support the learning. The educational goal is not related to the machine in any manner.
In short, *TRIVIA MACHINE* manages to make learning fun, but fails to make learning efficient. It would be interesting to explore whether this game could be improved from a pedagogical point of view, without altering its gameplay. Would the addition of feedback be of any interest from a ludic point of view? Could the game memorize successes and failures in order to guide the player towards certain questions?

Energyville

Description

ENERGYVILLE is a *SIMCITY*-like game, edited by *Chevron*, a large American petroleum company. It is freely available on the Internet (Energyville, 2010). It aims to demonstrate that the choice of a global energy strategy has various impacts on economy, environment and security, and that this choice is not trivial.

[[INSERT FIGURE 4 HERE: Screenshot of *ENERGYVILLE]]*

Figure 4: Screenshot of the game ENERGYVILLE (© 2010 Chevron. Used with permission).

The Fiction: ENERGYVILLE is based on a simulation of an imaginary city, inspired from the classical game *SIMCITY* (see Figure 4). The player plays the role of the “owner” of the city and in this role s/he has to make various choices regarding the energy supply of the city. Choices regarding energy sources visibly modify the fictional environment.
The mechanics: Two types of choices are performed by the user: choices of energy sources and global strategic decisions (favoring economy over environment for example).
According to the choices, the system determines events that occur until 2030 (a terrorist attack on a gas pipe, an innovation on wind production technology, etc.). The impact of the user’s choices and the events on economy, environment and security is then calculated and displayed.
Contrary to a usual simulation, the player does not intervene when time goes on but only at two distinct instants: in 2007 and in 2015. The player is given two sets of feedbacks after these two interventions.
During the game, the player is given plenty of information on various energy sources such as solar, nuclear, gas, petroleum or biomass. S/he is also given the impact of these energy sources on economy, environment and security.
Goal of the game: At the end of the game, three curves are displayed, showing the evolution of impact on economy, environment and security over the whole period (2007-2030). A final score is also given, and compared with scores from other players. Although no explicit goal is given, this score appears to be the implicit goal: maximizing the global score and appearing in the top ten scores.
Educational objectives: Raising awareness on energy strategic management.

Articulation between the educational goal and the game

As a simulation, *ENERGYVILLE* is primarily based on the first type of articulation: around the game mechanics. Indeed, the educational goal of the game is to teach the users the impacts of various choices on the evolution of a city. The knowledge is located in the mechanics itself, for example: adding more nuclear power is dangerous for security; dependence on oil and gas presents risks in case of terrorist attacks; wind and solar energy are better for the environment, etc.
In *ENERGYVILLE*, the articulation between the educational goal and the game also occurs around the context. A significant amount of information is given via text bubbles and information screens, which are accessible only in the context of the game. For example, when the user is about to choose between wind and oil, s/he can access factual data related to these types of energy. Providing such information in the context of the game, when it is needed by the player or at least when it is related to what the player has in mind, increases the chance of memorization. This is similar to the concept of “just in time information”, promoted by some pedagogical strategies in Instructional Design (Merriënboer, Clark, de Croock, 2002).

TOWARDS INSTRUCTIONAL GAME DESIGN

Given the four types of game-knowledge articulations discussed and illustrated above, that stem from our definition of a game, the next step consists in deriving useful guidelines for designing educational games.
As a preliminary remark, the theoretical discussion above illustrates the fact that an educational game is a very complex learning object. As a game, it contains at least one specific system of signs that is dynamic (the game mechanics) and often several systems of signs superimposed to it (e.g. the fictional word, the iconic language, the language included in the texts, etc.). The adding of pedagogical goals to a game adds another layer of complexity. This complexity of educational games tends to be overlooked, but if the goal is to be able to optimally convert a learning objective into a game, this complexity must be understood.
It is certainly too preliminary to derive a whole Instructional Game Design model, from our theoretical approach. However, some recommendations can already been proposed, which are direct outcomes of the theoretical discussion above.

Recommendation 1: First choose an articulation between the game and the knowledge

The way the knowledge is embedded within the game should constitute the initial design step. One type of articulation must be chosen by the designer as the main design principle. This choice depends of course of the type of knowledge included in the instructional goal, but also on the time and effort available for the project. Starting from an existing game is, most of the time, suboptimal, because, as we discussed above, if the knowledge is specific, the game must be specific as well. But designing a totally new game requires much more time and effort, which is not always available. Although we recommend integrated types of articulations (see next recommendation), other articulations might be an alternative for some projects.

Recommendation 2: Try to invent relevant game mechanics

Any process of Instructional Design relies on an analysis of the learning goals and the set of knowledge targeted by these goals. This being accomplished, if one wants to use a game for an educational goal, one should first try to fit into one of the first two categories above (systemic learning, winner strategies). Indeed, only these two categories really exploit the systemic nature of games, and their ability to really situate learning in a relevant activity in context.

Such a game mechanics is thus quite specific to the educational goal. Even if a lot of games have been invented so far, it is probable that existing game mechanics do not really fit the educational goal, hence the necessity to invent a specific game's mechanics, whenever it is possible.

In some cases, this game mechanics can be naturally derived from the idea of simulating the domain itself. For example, learning Newtonian laws would involve objects (e.g. spaceships) moving in a space according to these laws. In others cases, it might seem difficult to find a system of rules that is relevant to the domain. Note however that the rules of the game do not need to be the strict model of the domain itself. For example, suppose you want to teach the duration of various notes in music, that a time span of the quarter-note is half of the time span of the half-note. Starting from the shooting gameplay, so popular in videogames, one can imagine a game where a player should shoot on a half note in order to decompose it into two quarter-notes in order to produce the desired rhythm. The game mechanics would implement the fact that "two quarter notes make a half note" as a dynamical system which is not musical but still relevant.

Applying the "winner strategy" approach is different. We are not directly looking for a game mechanics but we are searching for a problem that can be solved (the game's goal) within an environment governed by a mechanics where:

- A large choice of actions and strategies is available;
- Finding the set of actions that reach the goal requires having the knowledge specified by the educational goal;
- It is not possible to reach the game's goal without this knowledge;
- Whenever possible the feedback for wrong actions should appear as natural consequences of the actions, rather than judgments; and
- Learning can be scaffolded from easy goals to more complex ones otherwise learning could be too difficult.

It is not an easy task to design such an environment. A key stage is to identify the wrong knowledge and strategies used by learners and design the environment such that these wrong strategies are inefficient (Margolinas, 1993). This requires certain knowledge of both the field and the didactics of the field.

Recommendation 3: Analyze the learning tasks independently from the game mechanics (in some types of educational games)

In the case of an educational game where the educational goal and the game mechanics are articulated around obstacles or around the context (categories 3 and 4 above), how can the validity of different propositions formulated during the design phase be assessed? According to the theoretical analysis above, if knowledge is not embedded into the game mechanics, the game component of the software can be considered as an additional layer on top of a learning strategy existing by itself. This additional layer is meant to improve the receptivity of the learner, in terms of motivation and context. However, the designer has to be aware that this additional layer does not substitute a learning strategy. In other words, one has to analyze a design by considering only the learning events, and determining whether they constitute a valuable learning organization or not. The Trivia Machine above is a trivial (!) negative example: once the game mechanics is withdrawn, only a very poor learning organization and strategy remains. The game TyperShark, also discussed above is a more positive example, since repeatedly training a learner to type words is not a bad strategy, given the motor nature of the task. However, it does not reach the pedagogical quality of a real typing instructional design, which includes teaching proper hand and finger positions on the keyboard.

Furthermore this additional layer can be resource consuming, resources being time or effort. Regarding time, games are often acclaimed for their potential for learning, but efficiency is rarely questioned. A game that teaches equally well than another multimedia product but that takes two or three times more time is not necessarily interesting from an instructional point of view. This aspect is rarely discussed in the literature on game and learning. Regarding effort, the game mechanics itself can require considerable attention and effort to the learner, at the expense of the learning itself. In that case, the game is a distraction from the main educational goal. The designer must be sure that the ratio between the player's attention/effort to play and the player's attention/effort to learn is not too high.

Recommendation 4: define the status of the player regarding learning.

Given the paradox discussed above, the status of the learner must be decided beforehand. We believe that in general, the "willing suspension of learning goals" hypothesis is the most valuable strategy because it enables the learner to keep his/her general motivation to learn (if any…) while concentrating his/her effort on the game itself, and being engaged in it. In terms of design, it means that the educational goal has to be announced before the active gaming session itself. During the learner's/player's activity, the educational goal does not need to be regularly restated.

In term of motivation, we are not making the claim that "learning is boring" to justify that learners should forget about learning during play. Rather, we are claiming that the motivation to learn is not necessarily correlated to the motivation to play and that for the game to be efficient, both in terms of learning and pleasure, it has to be intrinsically motivating. Thus, when assessing the quality of an educational game, the only motivation that must be measured is the motivation to play. In other words, a question such as "did you like learning mathematics with this game" is biased, because only learners who like mathematics will tend to answer positively. A better question is "did you have fun with this game?" The assessment regarding learning can then be based on acquired knowledge.

Recommendation 5: do not use games in isolation.

We have stressed that what makes games particularly relevant for learning is their systemic nature and the fact that the user can act on the dynamical system underlying the game. Therefore, as for simulations (Fanning and Gaba, 2007), debriefing is needed as games are not good for reflexive learning and conceptualization. A single active learning session requires an additional stage, where learners are encouraged to verbalize and assess their contextual skills in order to build stable and transmittable knowledge. As reported by Rieber (2002), "the use of games generally interferes with explicit learning (ability to answer test questions), but improves participants' tacit learning (ability to perform other tasks embedded in the simulation)".

In Didactics, as explained above, the active learning phase is followed by two additional phases: formulation – verbalization of learner's strategy – and validation – assessment of the validity of the strategy – (Brousseau, 1998). The importance of debriefing in instructional games is also reported by Hays (2005): "Debriefing gives the learners the opportunity to reflect on their experience with the game and understand how this experience supported the instructional objectives of the course or program of instruction."

The necessity of a classical debriefing is problematic as it often required a specific expertise from the teacher. Therefore, designing a larger software that includes game sessions and debriefing sessions is a promising direction to explore. How to alternate these two kinds of sessions is an important issue, that has been experimented recently (Sutter-Widmer, 2010).

FUTURE RESEARCH DIRECTIONS

This research is still preliminary. We intend to extend it in at least three directions.

First, the above discussion remained at a general level. In order to provide more specific guidelines to the design of educational games, one needs to take into account the type of skill that is targeted by the learning objective. Starting from an existing classification of knowledge types (Carson, 2004; Paquette, 2005, p. 196), we expect to be able to precisely inform design choices according to each knowledge type concerned by the game. Such a classification will resemble existing attempts to match knowledge types to learning games types (Garris, Ahlers & Driskell, 2002; Wilson et al., 2009; Wouters, van der Spek & Van Oostendorp, 2009), but with stronger theoretical foundations.

Second, in order to empirically verify the principles that have been enunciated, we need to design a cognitive model of educational game playing. According to this model, predictions related to the relative efficiency of one design choice versus another could be made and empirically tested. Currently, experimental research has found little evidence regarding the benefits of games for learning (Hays, 2005; Egenfeldt-Nielsen, 2006). We expect that such a model could greatly help guide experimental investigation towards more precise comparisons between conditions.

Third, a better knowledge of the fundamentals of educational games should form the basis of new authoring tools for educational game making. Existing tools for making educational games are oriented either towards games but do not include any pedagogical principles (e.g. *Game Factory*, *Game Maker*, *Neverwinter Night* toolset, etc.) or towards multimedia tools (*Authorware*, *Adobe Captivate*, etc.). With a specialized authoring tool, we both expect to decrease development time, and improve the quality of the final result, because the tool will naturally foster proper use of games for learning. The ability to design such an authoring tool will be an indicator of the feasibility of Instructional Game Design, as a general strategy for improving current university and professional curricula.

CONCLUSION

Despite the large amount of research and development that use, promote and analyze games for learning, there exists limited experimental or theoretical work that supports the hypothesis that games are beneficial for learning, beyond general considerations. This lack is also correlated to a lack of understanding of what a game is. Therefore, this paper attempted to establish some fundamental principles of the utilization of games in instruction.

From a formal redefinition of games and a careful examination of pedagogical principles currently in use in instructional theory and practice, we found some answers to our initial question (the relation between game, knowledge and learning):

- Game playing always involves learning, but this statement does not inform us how to design a game for a given learning objective.
- At the level of user intention, gaming and learning are fundamentally incompatible, a phenomenon that we term the paradox of educational games.
- Within an educational game, we distinguished four types of articulation between the educational goal (target knowledge) and the game itself. These articulations are around: the game mechanics, the winner strategy, obstacles, and context.
- Even if some of these articulations exploit games more efficiently than others, they may be combined to improve learning.

These considerations have been put in practice into the analysis of existing games and have been used to enunciate some recommendations.

Our findings constitute premises of a yet to be invented methodology, that we have termed “Instructional Game Design”. While (good) games are easy to play, they are very hard to design. Instruction as well is quite difficult to design. Combining the two still adds other constraints which make IGD a very challenging task. This challenge is usually underestimated, leading to a weak integration between learning and playing.

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KEY TERMS & DEFINITIONS

Game: A game is a dynamical system of signs in which the player acts, independently of any consequence outside the system, in order to reach a goal assigned by the game.
Instructional Game Design (IGD): the goal of IGD is to find a methodology making it possible to produce an efficient learning game from any given knowledge domain, if such a game is possible.
Paradox of educational games: games are played for the sake of playing, regardless of the consequences of the playing activity outside of the game while learning is useful and must be perceived as such in order to be efficient.
Systemic learning: articulation between game and knowledge in which knowledge lies in the rules of the game mechanics.
Winner strategies: articulation between game and knowledge in which learning occurs when the game proposes a non didactical system in which knowledge is required reach the game's goal, and in which this goal cannot be reached without the knowledge.
Loose coupling: articulation between game and knowledge in which rules that involve the knowledge to be learned are loosely connected to the main rules of the game mechanics.
Contextual coupling: articulation between game and knowledge in which knowledge to be learned lies outside the game mechanics.