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Linking Pedagogical Theory of Computer Games to Their Usability

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This article reviews a range of literature of computer games and learning theories and attempts to establish a link between them by proposing a typology of games which we use as a new usability measure for the development of guidelines for game-based learning. First, we examine game literature in order to understand the key elements that constitute games. This is then followed by the theoretical discussion of the relationship between the game components and the learning theories, namely behaviourism, cognitive constructivism, and social constructivism. Ten games are analysed using the learning theories and a typology of game is proposed that classifies games into four major categories. Then based on these findings we developed a set of guidelines for game-based learning using Human Computer Interaction (HCI) methods.

Despite the increasing popularity of computer game based learning (Malone, 1980; Prensky, 2001; Egenfeldt, 2005; Squire, 2003), not much has been done to research the Human Computer Interaction (HCI) elements and the learning process that occurs within the game.

Although some work has been carried out to study the potential of computer games in real classroom settings and it is often associated with a learning theory such as constructionism and social cultural theories, it is noted that this work focuses on the "learning through games," rather than "learning to play games." We believe that a better understanding of learning process within games helps design better and thus more usable educational games. This article looks into the learning that takes place within computer games and tries to cast some light on it through the study of well established learning theories.

In this article, two studies are presented. First, the typology of learning in computer games is developed based on an analysis of 10 games. Then based on this typology, the second study is conducted to produce a set of design and evaluation guidelines for game-based learning.

COMPUTER GAMES

There are many definitions that try to describe the different aspects of a game. While some focus on the game itself, some concentrate on the activity of playing the game. In this article, we use Juul's (2003) definition:

> A game is a rule-based formal system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels attached to the outcome, and the consequences of the activity are optional and negotiable. (Juul, 2003)

A classification of computer games is proposed by Aarseth (2003) when he is studying how computer games should be analysed methodologically and formally. Although his initial intention is to categorise game research and analysis, this typology is very useful for studying games (Figure 1).

Gameplay deals with strategies and motives of the player, game rules deal with the rules and structure of the games while game world deals with the fictional contents of the games.

It is not difficult to see that a modern computer game has both simulative and narrative qualities in it. It usually contains rules that simulate a game space which projects a narrative world, in which players plot strategies to

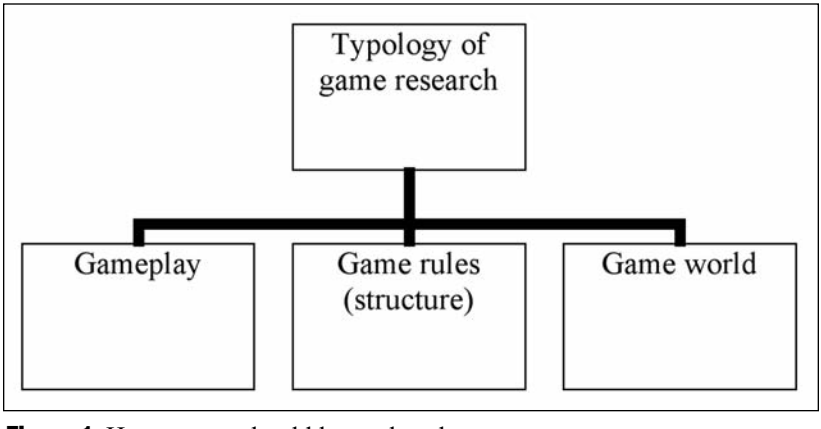

Figure 1. How games should be analysed

attain the game goal. In the following section, we examine three components that make up modern computer games: rules, play and narratives.

Game Rules

Rules are one of the most important components of computer games as they define not only how the virtual world operates, but also how to win the game. Juul (2001) defined computer games as an activity based on formally defined rules and containing an evaluation of the efforts of the players. He also explained at length how the game rules contribute to complex and interesting gameplay (Juul, 2002).

Frasca (1999) identified two kinds of games: ludus refers to the games whose result defines a winner and a loser, while paidea refers to the games whose result does not. Based on this, he introduces two types of game rules: paidea rules and ludus rules. Paidea rules are established to play the game as paidea, while ludus rules are established to win or lose the game. In SimCity 4 (2003), a game in which no explicit ludus rules are defined, the players are involved in paidea by playing with the buildings. Once they establish a goal: say to build a city with a population of 10,000, they immediately switch to a ludus activity.

Game Play

Though they constitute a very important part of computer games, rules are not the only thing one needs to know in order to play (Juul, 2002). Game playing is more than simply memorising the game rules. Having learned the rules merely establishes the ability to play, and successful play does not necessarily require learning all the rules (Lindley, 2002). We need to understand something more complex that can arise from the rules: the gameplay. Game play is activities conducted within a framework of agreed rules that directly or indirectly contribute to achieving goals.

Usually, paidea rules are fixed and defined by the game designer. The player cannot breach paidea rules and their planning of strategies should conform to these rules. If the game defines that the game character can only move forward and backward, the player can never move it upward or downward. Ludus rules are more flexible compared to paidea rules. The player may change the ludus rules and be involved in a different gameplay the game designer has intended. Gameplay emerges from paidea rules, but without ludus rules there is hardly any gameplay. Paidea rules can be simple, but ludus rules can lead to complex gameplay. For example, if the players do not set the ludus rules while playing SimCity 4 (2003), the gameplay does not exist in the play session, because the players' actions are not oriented toward achieving a goal.

Game Narratives

In most modern computer games, the players can naturalise their actions as the solving of a familiar type of problems (Ryan, 1994/1999; Murray,

1997; Jenkins, 2002). In Myst (1993), the player needs to track down the villain; and in Super Mario Brothers 3 (1988), the player is trying to save Princess Toadstool.

Ryan (2001) tried to understand narratives in computer games and she proposed a definition of narrative based on mental images. According to her, a narrative is defined as a mental image, or cognitive construct, which can be activated by various types of signs. This image consists of a world (setting) populated by intelligent agents (characters). These agents participate in actions and happenings (events, plot), which cause global changes in the narrative world.

Several useful terms are recognised in this definition: world or setting, character and action. First, a game has a spatial representation of a world whether it is real or abstract. Second, most computer games feature explicit characters, which would interact with the world or the player. Third, games are usually discerned from linear narratives by the existence of interaction: the reciprocal actions between players and games. These actions include not only the action of the player, but also the autonomous actions of the characters in the game world.

LEARNING THEORIES AND COMPUTER GAMES

In this section, we investigate how three different aspects of computer games – game rules, game play, and game narratives – are learned by drawing some three learning theories: behaviourism, cognitive constructivism, as well as social constructivism. It is found that learning could occur at two levels of interaction, player-game and player-player. In player-game interactions, the player interacts with the game and learns to be a better player through behaviourist and cognitive constructivist learning while social constructivist learning clarifies the understanding of the game through player-player interactions.

Player-Game Interactions

Player-game interaction is the most common interaction that occurs in every computer game. It refers to the information exchange between the player and the game usually by the means of input and output devices. Player-game interaction could be physical and virtual; physical in that players refer loosely to the game manuals or guide books, which are also a part of the game; virtual in that the interaction of players and the virtual world of a game is of course virtual in any sense. In this player-game system, it is assumed that players learn a game through communicating with the game environment, they will either infer meaning from the interaction, or the meaning is transmitted to them during game play.

Behaviourism and games learning. The theory of behaviourism concentrates on the study of overt behaviour that can be observed and measured. One of its major focuses is conditioning learning by associating stimuli and responses. Behaviourism stresses a new behavioural pattern being repeated until it becomes automatic. It views the mind as a "black box" in the sense that response to stimulus can be observed quantitatively, ignoring the possibility of thought processes occurring in the mind. Learners are regarded as a biological machine, which could be shaped to respond to conditioning by controlling reinforcements and punishments.

In term of learning strategy, it is based on observable changes in behaviour (e.g., basic paired associations, discriminations, rote memorisation). One of the key players in the development of the behaviourist theory is Skinner (Hergenhahn & Olson, 2001). His operant conditioning has a significant impact on education in which unpleasant and pleasant consequences (known as reinforcements) are used as a means to mould the learner's behaviour. In addition, Skinner's work advocates that learners should be taught difficult concepts after they have been first exposed to the simple ones.

Behaviourism in learning game rules. Probably the first things to learn when playing a computer game are rules. Without understanding the game rules, it is almost impossible to continue playing the game in a meaningful way. It involves the learning of both kinds of rules; paidea and ludus. First, the player needs to learn the paidea rules that deal with the mechanism of the game: what can be done and what cannot be done, as well as the causality of the action taken. Having learned the paidea rules, the players need to know their goals, the ludus rules, so that they can win the game. Behavioural learning plays a very important role in almost all games, as they involve the learning of the physical-virtual action association. Pressing the "B button" which is associated with jumping in the game for example, is learned through operant conditioning, especially when the jumping is reinforced by positive reinforcement (getting more lives) or negative reinforcement (avoiding monsters). Another example of conditioning is the learning of avoiding or approaching certain kinds of objects. In Super Mario Brothers 3 (1988), when Mario touches a monster object, an unpleasant sound is played, and Mario shrinks or loses a life. Because of these, players would learn the consequence of touching monsters (the causality of touching monster and losing lives is established) thus avoid them.

Behaviourism in learning game play. Successful playing of a game needs more than just the learning of game rules. Play arises from the rules and players should learn the play pattern and strategies to achieve the goal. Behavioural learning is especially useful to explain autonomous responses elicited when facing certain situations. This is particular true for games with a faster pace like most real time action games such as Tetris (1985), Pac-Man (1980),

and so forth. The players are conditioned to play in a certain pattern, for example, in Super Mario Brothers 3 (1988), taking mushrooms, avoiding monsters, etc. It should be noted that learning the rules about Mario-monsters interaction is different from learning to avoid monsters by jumping over them. The learning of rules gives knowledge about the mechanism of the game, while the learning of play gives information on playing and possibly winning the game.

Behaviourism in learning game narratives. Since behaviourists treat players as a machine to be filled with information, they are expected to absorb narratives represented passively in the game world. This is usually done with presenting cut-scenes or textual information from the nonplayer character (NPC) as the game's subgoal. The player learns the stories by accomplishing the game task and generally gets a reward. More often than not, the game world appears to be only one dimensional and flat. Most early attempts to tell stories in games are done in such a way that stories are told to the players in a direct method. Games like Super Mario Brosthers 3 (1988) are a good example of telling stories with texts.

Cognitive constructivism and games learning. Cognitive constructivism, as derived from the work of Piaget defines learning as a process of accommodation, assimilation, and equilibration (Boden, 1979). It is based on the premise that we all construct our own perspective of the world, through individual experiences and schema. Constructivism focuses on preparing the learner to problem solve in ambiguous situations. (e.g., heuristic problem solving, personal selection and monitoring of cognitive strategies). To teach well, we must understand the mental models that students use to perceive the world and the assumptions they make to support those models.

Cognitive constructivism in learning game rules. Behaviourism is unable to explain all rule learning in some games, especially games with a more complex virtual world, which is usually composed of several micro-worlds. Super Mario Brothers 3 (1988) is a game which consists of many different micro-worlds: the under water world, the desert, the cloud kingdom and so on. Each of this word has quite different sets of rules. The player needs to process this information and structure it in their mental schema instead of being conditioned to learn in different situations. The players are also able to learn the rules they have not experienced by deriving the information based on previous experiences and test it on the new situation. Cognitive constructivist learning is also important to explain mental processing in some games where players need to guess the rules with logic thinking like some puzzles in adventure games.

For some games where rules are highly sophisticated and somewhat unstructured, each player will need to construct their own understanding of the rules based on hypothesis building and testing. By interacting with the

game, the player will observe, reflect, and infer the rules underneath it. The Sims (2000), a game with simulated rules of human life, requires that players construct their own understanding of the rules by testing different strategies. This game also requires that players construct their own ludus rules in order to play the game.

To sum up, in behaviourist learning, rules are learned through trial-and-error and association; in cognitive constructivism, rules are learned by hypothesis testing, mental reflection, and construction. In behaviourism, the rules are understood by everyone as the same set of rules, while in cognitive constructivism, each player might construct their own understanding of the rules.

Cognitive constructivism in learning game play. When the game is getting deeper (compare the depth of Tetris [1985] and Pong [1972]), and the solution is not as explicit as it seems, the player needs more than behavioural learning to master the game. They will start to engage in some forms of cognitive thinking to learn the gameplay. Puzzle games are a good example of this kind of learning. Instead of associating stimuli with desired responses, the game demands logic thinking to find out the solution. The player might pause for a while, reflect on the problem and plan for a strategy or solution.

In behavioural learning, the problem and the solution are explicit; it is just the matter of being skilful enough to solve it. In cognitive constructivist learning, the problem might be explicit, but the solution is implicit. Therefore, it depends on how well they could come up with a solution to the problem. In some games however, both problems and solutions are not explicit. The players need to be strategic in identifying the problems and solve them. In SimCity 4 (2003) for example, the player might notice the drop in population in the city, but he needs to figure out the problem, and thus plan for strategy to solve it. If behavioural learning makes players more skilful in playing a game, cognitive constructivist learning makes them more logical and strategic.

Cognitive constructivism in learning game narratives. Understanding the world and the story of the game is hard to explain with behaviourism theories when the game world becomes sophisticated, involving emotional conflicts of the game characters. The players need to learn the meaning of the space, events, and characters, instead of just learning to behave in a certain way. Players might involve in the thinking of the motive of a certain action taken by a character. The player observes and experiences the world and updates their understanding of this world.

If the world is not static, and under constant changes, which are dependent on the player actions, cognitive constructivist learning is required to understand the world. In such a world, many different possible views of the world, characters, and stories might exist as players proceed in the game, thus the players are constructing their understanding of the world instead of trying to know the prewritten story. In Grand Theft Auto: San Andreas

(2004), the presentation of the world depends largely on the player, for example the player could view the world as a city with a lawful traffic system by driving carefully on the road, or a city with unruly traffic by crashing every lamppost or other cars. The representation of the world thus relies very much on how the player chooses to play the game.

Player-Player Interaction

Player-player interaction occurs only when more than one person is playing the game at the same time. This interaction is usually mediated through computer games. Player-player interaction could also be physical as players meet face-to-face to play a particular session of game; it can also be virtual, as it occurs in multiplayer online games. The learning that occurs in a player-player system postulates that meaning is not in any player's mind, but embedded in the social practices of the group (Gee, 1999). Players not only have to play to learn, but they have to play with others if they hope to develop genuine gaming skills. During collaboration, the focus is on the activity, with game instructions and guidebooks playing only an ancillary and supporting role.

Social constructivism and game learning. Social constructivism focus on the importance of social cultural context in understanding what occurs in the world through social interaction and constructing knowledge collectively.

Social constructivists view learning as a social process. It does not take place only within an individual (McMahon, 1997). Meaningful learning occurs when individuals are engaged in social activities. Vygotsky (1930) emphasised the importance of social cultural aspects of learning, advocating that learning is mediated by cultural tools in which knowledge amasses. Learners do not interact with the environment directly; instead the interaction is socially mediated through artifacts, be it signs or tools, especially language. Language and communication become the principle focus of learning, as throughout most of their lives people learn and work collaboratively, rather than individually.

Social constructivism in learning rules, play, and narratives. Social constructivism infers that the game rules for interacting among players and games are constructed and understood socially. A lot of games, especially noncomputerised games could not be played by only one person. Players are actively interacting either with other players or the game environment, and individually construct their understanding of the game interaction rules. In the case when they are teaming, the more advance players would help naïve players learn the rules by collaborating toward a shared goal. Furthermore, collaborative play has the potentiality to create a new rule, which is agreed by all players. When competing against a goal, they might impose restrictive rules on more fluent players to have a more challenging game.

In a multiplayer game, each player plans strategies to help or impede each other. In these games, a new strategy is socially constructed by interacting with players. The player is not only solving a problem in the game world, but also a problem which might be imposed by other players. Besides, the players might also try to solve a problem in the game together, which could not be solved otherwise.

In some computer games, the players determine how the world looks. The individual perception of the game world/stories is constructed by players interacting among each other and the world. The game world is populated not only by nonplayer characters, but also by other real players. In this case, the understanding on the world is highly dependent on the other players' actions and behaviours in the game. The story is then formed through the comprehension of the entire social interaction of the world instead of the world alone.

STUDY 1: TYPOLOGY OF GAMES

It is almost undoubted that people have to learn to play a game, and the learning could be divided into three dimensions: (a) game rules, (b) game play, and (c) game narrative. In certain games, more effort is put on learning the game rules, while story-based games require more understanding on the game world. Having reviewed how learning might occur in computer games, it is of our interest to look at the learning process in games which might guide us in creating a classification of computer games. In this study, we analyse 10 computer games against learning theories to create a typology that will become the matrix for usability measure for guideline development.

Methods

To construct the typology, we first identified different kinds of learning in the three learning dimensions of games. We then constructed a matrix of game-learning and looked into the way people learn in each category. For this purpose, we analysed through expert evaluation ten commercial games (spanning across all genres of games).

For each game, we examined the following:

- Is the learning of world, rules, or play significant in the game in order for the player to experience the game or to advance and win it?
- For each category, we investigated how learning occurs, based on the major learning theories.

The game was played for at least an hour before it was reflected and analysed through identifying the aspect of learning that relates to each game component. During the analysis, it was necessary to refer back to the game to confirm certain aspects of the analysis. Materials external to the games such as game manuals, game magazines, and so forth, were also examined.

Findings

Some game characteristics (Table 1) were extracted from the 10 games and were categorised to match the theoretical discussion on learning theories and game elements.

Table 2 shows the results of the analysis of the 10 games. One, "1" denotes the significant present of that particular type of learning in the game.

By putting the 10 games in the matrix table, we have identified at least four major classes of contemporary computer games: ludic games, narrative games, simulation games, and multiplayer games. Ludic games are games which are about pure and abstract play in which the fundamental enjoyment

Table 1
Learning Theories and Computer Games (New Matrix)

Game element	Learning theory	Game characteristics
Narrative	Behaviourism	It projects linear story progression (one dimension of the world), where the player conceive the same reality (virtual world) intended by the designer
	Cognitive constructivism	It projects multiple path story progression (thus multiple dimensions of the world), where every player constructs their own story in their mental schema (understanding the story is important to progress)
	Social constructivism	A world with many possible stories, depending on the social interactions of two or more players
Rules	Behaviourism	It requires only the understanding of simple physical-virtual mapping rules (symbolic paidea rules), for example, press A to fire, and so forth, and simple semantic paidea rules (how things work and are related)
	Cognitive constructivism	It requires the understanding on complex rules such as a simulation system, where players need to construct their own goal (ludus rules), thus strategy to achieve the goal.
	Social constructivism	It requires that people interact and actively create the understanding of the interaction rules or even negotiable rules.
Play	Behaviourism	It involves (real-time) action where response pattern is important. Logical thinking is less important, usually autonomous actions matter.
	Cognitive constructivism	Logical thinking is needed. It provides multiple-way solution where play could plan for alternative strategies. Players might solve a problem not even thought about by the designers
	Social Constructivism	Socially construct a new strategy to solve a problem by interacting with people and the game world

Table 2
A Matrix of Learning in Computer Games

	Narrative			Rules			Play		
	Behaviourism	Cognitive constructivism	Social constructivism	Behaviourism	Cognitive constructivism	Social constructivism	Behaviourism	Cognitive constructivism	Social constructivism
Ludic game									
Spacewar! (1962)				1			1		
Tetris (1985)									
(single player)				1			1	1	
Super Mario Brothers 3 (1988)(single player)	1			1			1	1	
Narrative game									
Myst (1993)	1	1		1			1	1	
Grand Theft Auto: San Andreas (2004)	1	1		1			1	1	
Final Fantasy VII (1997)	1	1		1			1	1	
Simulation game									
The Sims (2000)		1		1	1		1	1	
World of Warcraft (2004)	1	1		1	1		1	1	
Multiplayer game									
Counter Strike (1999) (multi player)		1	1	1		1	1	1	1
EverQuest (1999)	1	1	1	1		1	1	1	1

of this type of game is to play and win the game. Although some ludic games might contain narrative elements, they are far less dominant than play itself. Super Mario Brothers for example, contains a fair amount of narrative elements. However the narrative element is not significant in the way that removing it from the game would not affect the ability of the player to play the game.

In addition, it is important to point out that all games are ludic to a certain extent, but not all games are narrative or simulative. If we look at Table

2, it can be concluded that all four categories require the learning of play in a constructive manner.

It can be seen that narrative games have more complicated world and thus stories, while simulation games tend to have complex rules. However, we should notice that a narrative game, which features highly rich narrative like an adventure game would not have been called a game if not for the puzzle incorporated into the game. It can be said that narrative games are abstract ludic games clad with rich story environments, so that as players solve the puzzle of the game they also enjoy revealing the story in the game.

Similarly, simulation games would have been called a simulation, if there was no play element in them. Even in games without a goal, the players would construct their own goals and engaged in a ludic activity. This type of game does not attempt to tell a story; instead they could be used to construct a story. Story telling is usually not intrinsic in the game itself, but arises from the game playing.

EDUCATIONAL GAMES AND USABILITY

In his recent work, Gee (2003) described gaming as a complex social practice where computer game players engage in high order thinking that requires complex cognitive effort. The overarching idea is that players learn to participate in new domains by playing computer games. They learn to make sense of new areas, not only on their own, but also by engaging with their peers, discussing, and sharing information. Thus games could be a tool for educational purposes (Rieber 1996, 2000).

One of the most quoted research papers, when it comes to game-based learning, is probably that of Malone (1980) where he emphasised the three essential characteristics of good computer games, which he identified as: challenge, fantasy, and curiosity. Furthermore, Prensky (2001), the pioneer in educational games, identified six additional principles for good game design. We will look at usability issues in the next section.

Usability and Computer Games

One of the most famous usability methods is heuristic evaluation proposed by Nielsen (1994). He proposed a list of 10 heuristics originally developed by Molich and Nielsen (1990), which aimed to ensure that usability is taken into account in general interfaces. However, Nielsen's 10 revised heuristics, as popular and general as they are, do not stretch far enough to cover educational systems fully (Kaur & Yusof, 2002).

Following him, a lot of effort has been done in expanding/developing heuristic evaluation so that it is applicable to other areas, including e-learning. In their study, Kaur and Yusof (2002) claimed that educational systems, in order to be successful, must have all their usability problems addressed before the students have access to them. This ensures the students can fully

concentrate on the learning tasks, without their attention being diverted to usability problems of the system. Ardito et al. (2004) produced a set of specific guidelines for the evaluation of e-learning systems. They support that the educational system must not overwhelm the student. So students can be fully engaged in the learning content, the interfaces must be well designed.

In fact, the study of computer games has been approached by usability experts. Various design methods such as player-centred design, player testing, usability and playability are being explored. For example, there is a call for early involvement of players in scenario studies for game design. Microsoft Game Studios study play-testing during game development by treating game design as an exploration of a design space, as research, by way early prototyping, playing, play-testing (Davis, Steury, Pagulayan, 2005).

Some are using HCI methods to help game design and evaluation that could hopefully benefit the game industry. Federoff (2002) for example attempted to generate heuristics and usability guidelines for the creation and evaluation of fun in video games. According to his initial findings, the three focal aspects of video game playability are (a) interfaces (controls and display), (b) mechanics (game interaction), and (c) gameplay (problems and challenges).

Desurvire, Caplan, and Toth (2004) developed a method, known as Heuristic Evaluation for Playability (HEP) as a comprehensive set of heuristics for playability. The HEP heuristics were based on the current literature and reviewed by several playability experts and game designers.

Heuristics and Guidelines

Drexler (1986) defined "Heuristics" as "Rules of thumb used to guide one in the direction of probable solutions to a problem." Heuristics and guidelines are used in all walks of life, helping to focus the inexperienced user on the tasks in hand. In the case of game-based learning, the heuristics will ensure that game designers (or other stakeholders) are able to rely on previously conducted research to produce better games in terms of usability and learning. Using heuristics can prove to be cost effective, as it reduces the need to carry out several rounds of evaluation and usability testing. Guidelines help the designer focus on the end user and not let personal pride get in the way of designing a useable end product.

STUDY 2: USABILITY GUIDELINE DEVELOPMENT

In this study, we used the typology developed earlier as a guide to construct a set of design/evaluation guidelines for game-based learning. The understanding of the fundamental attributes of games and the learning theories associated with them is significant so that during the development of the guidelines, we place equal importance in the game as well as its learning. We believe that the typology provides a direction to the construction

of guidelines because:

- games have their own design issues and problems, which are quite different from conventional work-based software;
- game studies reveal certain aspects (such as social and narrative) of games which must be taken into account when designing games; current studies on game usability tend to overlook these; and
- it's important to understand learning theories underlying each game aspect for our focus is educational games rather than exclusively entertainment games.

The approach followed in this study included an extensive literature review in the area of computer games, HCI, learning, and usability. The development of an initial set of guidelines was based on the reviewed literature where each initial guideline was extracted from at least one academic paper read. The development of the guidelines also included a card sorting exercise for their classifications, an affinity diagramming exercise for the reduction and further refinement, heuristic evaluation for their validation and test of robustness, and finally a rephrasing activity to fine tune the wording of the final set of the guidelines.

Methods

1. *Initial guidelines development*: The study began with an extensive literature review of numerous academic papers on the areas of games, learning, usability, and general HCI topics. From the review of the literature, an initial set of 60 guidelines was established.
2. *Card sorting*: Once the initial set of guidelines was in place, a card sorting (Shneiderman 1992) activity was performed to better categorise them. Twenty two participants (consisting of 11 males and 11 females, all between the ages of 20 and 36) took part in the card sorting activity. All had taken a course in HCI, and some had specific interest in computer games and/or e-learning. They also had an average of three hours/week experience in game playing.

Each of the participants was provided with a pack of 60 cards. Each card carried one of the guidelines. The participants were then asked to put the cards into groups that made sense to them, and to give a heading to each group, as they saw appropriate. The results from the card sorting activity were then fed into EZSort, a freely downloadable cluster analysis software application from IBM.

3. *Focus group*: Once the card sorting activity was analysed, a focus group activity was scheduled to help revise the 60 guidelines and their groupings. This enabled us to further refine the categorisations we obtained through the card sorting exercise.

In this experiment, the 60 guidelines from the card sorting session were printed out and stuck onto the wall into the 15 categories produced by the EZSort cluster analysis.

In the focus group, the objectives of the activity were explained to the six participants: go through all the guidelines in their current location, suggest headings, relocate guidelines to categories that they felt would more appropriately incorporate the specific guideline, review guideline content in order to remove duplicate, merge similar guidelines and finally suggest rewording to guidelines they felt were worded misleadingly or ambiguously. This exercise resulted in a second revised version of our guidelines.

4. *Heuristic evaluation*: Fourteen participants were recruited for this exercise: seven males and seven females, of ages ranging from 19 to over 36. Most had very good knowledge of HCI, although two were recruited on basis of their keen interest in games. The game chosen to be used for the evaluation of the guidelines was "The Lost Army of Fu-Shi" (business studies) (2005).

This experiment was conducted in the following way: first, before they were shown the guidelines, each participant was allowed five minutes of initial browsing of the game interface. Then, each participant was asked to play/browse the game as much time as needed for them to decide whether each one of our guidelines was met, not met or "not applicable" in the game interface. They were then asked to rate, from 1 to 5, the ease of interpreting each of the guidelines and asked to suggest rephrasing of any of the guidelines they felt were not clear or might be ambiguous. At the end of the evaluation the experts were asked if they believed any of the guidelines were not relevant for the evaluation of game-based learning. The postquestionnaire concluded the evaluation session, with participants sharing their views on the activities just performed, as well as their feelings on the game's usability metrics.

5. *Guideline rephrasing*: Five participants took part in the activity which, building on the results of the heuristic evaluation, was designed to finalise and where necessary rephrase the guidelines to improve their clarity. This exercise resulted in a third and final version of our guidelines.

Findings

The complete guideline (see Appendix 1) is broken down into six categories, four of which are based on the typology developed earlier. The play category deals with the play element of games, which includes user experiences and user skills as well as game challenges. The rules category deals with the game rules, that is, the structure and control of the game. It ensures that the game structure is designed properly to provide enough controls to the players. The narrative category is mostly about audio and visual infor-

mation as well as the players' immersion into the storyline while the social category enables the way two or more players interact if social interaction is an important feature of the game.

Two extra categories, interface and learnability, are necessary due to the focus of the guidelines on educational games. The learnability category of guidelines also ensures that two types of learning – learning the game itself and learning the subject matter – are designed properly to ultimately improve the learning of the specific subject matter.

Discussions and Conclusions

This article employed a systematic approach for the development of guidelines for the evaluation of game-based learning. This was done by unifying existing guidelines in the areas of games, learning, usability, and human-computer interaction to ensure a better learning experience for the game-based learner. The development of the guidelines was achieved by an extensive literature review that spanned the areas mentioned previously and ensured that the final set of guidelines is backed up by at least one piece of published or acknowledged study or research.

Furthermore, a new matrix of usability was created due to the unique nature of computer games. In fact, many see computer games as a special type of software whose design is often treated differently from conventional software or groupware (Dyck, Pinelle, Brown, & Gutwin, 2003). Thus it is rational to assume that computer games have their own usability issues, which need to be handled separately. Although some work has been done in this area, these HCI approaches tend to overlook the work from classic computer game studies, namely ludology and narratology. Most notably most of this work tends to focus on gameplay and mechanics, giving lack or no emphasis on the narrative and social aspect of games.

By reviewing the vast amount of literature on ludology and narratology, as well as several learning theories, we create a new usability measure for game-based learning, which served as a foundation for our guideline development.

Apart from the contribution through the new guideline for game-based learning, this article highlights an important issue that deals with computer game studies. Learning that happens in computer games is described through three components – play, rules, and narrative – with behaviourist and constructivist learning theories. Based on the learning theory and game component matrix, 10 games are analysed to identify the learning process and thus categorise them through the learning process within the games.

There are a number of possible ways in which this work can be extended:

- By including more games in the analysis to identify more categories or subcategories in the typology. As pointed out earlier the creation of our typology was driven by an expert evaluation we conducted on 10

games, an empirical study on player behaviours in learning computer games can also be carried out to further refine our typology.

- The validity of our guidelines can be further enhanced by comparing the findings from our heuristic evaluation with user observations.
- Currently there are 60 guidelines, as this might be too many to make the heuristic practical in the industry, additional classification techniques could be used to reduce this number further and prioritise their importance.

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Appendix 1

Continued on following pages.

H1. Play

Guideline		Evidence	Description
H1.1	The game should make explicit the ability of the avatar. The players always have control over the avatar and know the tactics and strategies they have.	(Desurvire et al, 2004) (Accessibility guidelines RCN)	The players must always have a sense of control over the game through manipulation of the characters and by using tactics and strategy...
H1.2	The game should provide a positive experience for the user.	(Desurvire et al, 2004)	The game should react in a challenging and exciting way to the players' actions and provide a positive game experience rather than a negative experience, resulting players wanting to play more rather than quitting.
H1.3	The game environment should not frustrate the player or prove too complicated while remaining challenging.	(Malone and Levin, 1984) (Desurvire et al, 2004)	Computer games can evoke a learner's curiosity by providing environments that have an optimal level of informational complexity. Or in other words, the environments should be neither too complicated not too simple with respect to the learner's existing knowledge. They should be novel and surprising, but not completely incomprehensible.
H1.4	The game should reward the players by increasing their capabilities and customisation abilities.	(Ardito et al, 2004) (Desurvire et al, 2004)	The game should represent a motivational experience for the players through rewards that immerse them in the game, increasing their capabilities, unlocking more contents and expanding their ability to customise the game.
H1.5	The game should be enjoyable to play over and ove again, be engaging and fun.	(Desurvire et al, 2004)	The gaming experience is an enjoyable one that can be replayed. Repetition should be designed so that it is enjoyable when replayed for the players to practice the learning content over and over again, as they may engage with the learning content when practicing.
H1.6	Practice tasks should be appropriate to the player's level of progress and appropriate feedback should be provided (e.g. understandable, productive, immediate and motivating).	(Lesgold, A. M., cited in Malone and Levin, 1984) (Desurvire et al, 2004)	Tasks should be learnable through a natural and conceptual model using reasoning and logic appropriate to the learner's level of progress. Understandable, productive, and immediate feedback should be given to help the player complete tasks and progress in the game. The player should also experience fairness of outcome that is appropriate to the tasks.
H1.7	Players should not be penalised repetitively for the same failure.	(Desurvire et al, 2004)	If the players are weak at certain aspects of the game, they should not be penalised repetitively for the same failure.

H2. Interface

Guideline		Evidence	Description
H2.1	Everything the player needs should be accessible through the Graphical User Interface (GUI) – not through a command based interface.	(Apple Computer Macintosh Human Interface Guidelines)	Everything the user needs should be accessible through the GUI. Command based interfaces should be minimised and hidden features should only be used if they can be easily made visible. Concepts like WYSIWYG (what you see is what you get) should be taken on board.
H2.2	The game interface should look pleasing, graphic design should be simple, easy to navigate, consistent in look and varied in gameplay	(Apple Computer Macintosh Human Interface Guidelines) (Paddison and Englefield, 2003) (Desurvire et al, 2004)	The user interface should be consistent (in control, colour, typography, and dialog design) but the game play should continue to develop and vary with each action. Game interface elements should look good, graphic design should be simple, and follow the graphic language of the interface without introducing arbitrary images to represent concepts so that the player can experience the menu as part of the game.
H2.3	The most important information should be located in the most noticeable location in the screen, while allowing players to see and point rather then remember and type unless it is done on purpose to increase the game challenge.	(Benson et al, 2001) (Apple Computer Macintosh Human Interface Guidelines) (Nielsen, 1993 and Nielsen and Molich, March and April 1990)	The game learning program presents information in accord with sound principles of information-processing theory: i.e. is the most important information on the screen placed in the areas most likely to attract the learner's attention. The repertoire of available actions should be made salient while see-and-point concept should be used instead of remember-and-type in order to minimise the players memory load on interface so that they can focus on learning.' (I.e. facilitate recognition than recall).
H2.4	It should be possible to personalise the interface both in terms of graphics/interface and content.	(Ardito et al, 2004)	It should be possible to personalise interface graphics and learning content. The adaptation of the graphical aspects to the context of use should be provided.
H2.5	The game interface should provide feedback that is ontextual and relevant to the problem or task in which the player is engaged.	(Benson et al, 2001) (Hostetter & Clements, 2002)	The game should provide feedback that is contextual and relevant to the problem or task in which the learner is engaged. E.g.: Interaction and tasks should be related to the interface in order to support meaningful learning.

H3. Rules

Guideline		Evidence	Description
H3.1	If a game object is a real world representation, its behaviour /control should match as much as possible its counterpart in real world.	(Apple Computer Macintosh Human Interface Guidelines) (Ardito et al , 2004)	If appropriate, screen representation of objects should match their non-computer representation so that they can be directly manipulated. Using metaphors from the real world will take advantage of people's knowledge of the world, thus making control more intuitive and that it is mapped in a natural way.
H3.2	Goals and purposes should be clearly presented throughout the game.	(Desurvire et al, 2004) (Malone, 1980)	The overriding goal should be presented as early as possible as wel l as short-term goals throughout play. Goals should be obvious and compelling.
H3.3	The game should have different difficulty levels and each should have multiple levels of goals.	(Malone, 1980)	Computer games should be playable at different difficulty levels. These can be determined automatically by the program, by the player, by the opponent's skills, or by a combination of the first two. This will ensure that even if a player is certain to win in one level, the following one will present new goals and new challenges.
H3.4	A player should always be able to identify their score, status and progress through a clearly visualised score keeping device.	(Benson et al, 2001) (Malone, 1980) (Desurvire et al, 2004) (Ardito et al, 2004)	The game should enable learners to monitor their progress through the material; i.e. course structure and progress tracking are clearly visualised, user profiles are managed. The players must be able to tell whether they are getting closer to the goal, identify their score/status and goal in the game.
H3.5	The game should allow users control of potential distractions, provide a means to easily turn the game off and on, and be able to save games in different states.	(Paddison and Englefield, 2003) (Desurvire et al, 2004) (Apple Computer Macintosh Human Interface Guidelines)	Players should be allowed to turn the game features/preferences on and off, save the game in different states realising potentia l distractions without penalty.
H3.6	The game should provide feedback that is constructive and minimises the possibility of self-esteem damage.	(Malone, 1980) (Ardito et al, 2004)	Performance feedback should be presented in a way that minimises the possibility of self-esteem damage. In order for the game to be educational, feedback should be constructive and help learners see how to improve their tactics to become more complete, consistent, or parsimonious. It should also encourage them to continue to play.

H3. Rules - *Continued*

Guideline		Evidence	Description
H3.7	Where the player can leave an unwanted state, re-order or cancel tasks, then it should avoid extensive dialogue.	(Nielsen, 1993 and Nielsen and Molich, March and April 1990)	Player may easily leave an unwanted state, re-order or cancel tasks. A task should be divided into smaller sub-tasks so that the player doesn't have to restart from the beginning. Rather the player should always be able to repeat the sub-task that he failed.
H3.8	Error messages and warnings should always be in a plain language (no codes), indicating the problem and suggesting a solution.	(Nielsen, 1993 and Nielsen and Molich, March and April 1990)	Good error messages should be expressed in plain language (no codes), precisely indicating the problem, and constructively suggest a solution. Adequate warning should be given, and a situation such as getting killed without warning should be avoided.
H3.9	Explicit commentary should be given when the player makes an error so that they know what they did wrong, even if their error was just a careless one.	(Burton and Brown, 1979)	If the player makes a potentially careless error the game should allow for such actions with the option to cancel them when questioned. Nevertheless, it should still provide explicit commentary as it may not necessarily be a careless mistake but an error they should learn from.
H3.10	Feedback should keep the players informed about what is going on and notify them within a reasonable time of problems and errors.	(Apple Computer Macintosh Human Interface Guidelines) (Desurvire et al, 2004)	Problem and error notification should be immediate to show that user's input has been received and is being processed on. Inform users of expected delays.

H4. Narratives

Guideline		Evidence	Description
H4.1	Game dialogue should be supportive of the player's task; simple, intuitive, non-intrusive and accurate.	(Nielsen, 1993 and Nielsen and Molich, March and April 1990) (Desurvire et al, 2004)	Dialogues should contain important information which is relevant so that players do not need to use a manual to play the game. All information should appear in a natural and logical order. The dialogue should be expressed clearly in words, phrases and concepts familiar to the user, rather than in system-oriented terms.
H4.2	The game should transport the players into a level of personal involvement which makes them interested in the story line and let them think about possible story outcomes.	(Desurvire et al, 2004)	The game should provide stories to suspend disbelief so that players discover the story as part of game play. If the story experience can be related to their real life it will maintain their interest.
H4.3	Fantasy in a game should be intimately related to the materials being learnt and should be dependent on skills.	(Malone, 1980)	Intrinsic fantasy depends on the use of the skill, but not vice versa'. An advantage of this is that this can indicate how the skill could be used to accomplish some real world goal', (i.e. simulation games). 'More importantly, when the fantasy in a game is intimately related to the material being learnt, the player is able to exploit analogies between their existing knowledge about the fantasy world and the unfamiliar things they are learning'. E.g.: advancement in a game should depend on how well the player had answered a question.
H4.3	Audio / visual effects should be used for of the following five purposes: as feedback, decoration, to enhance fantasy, as a reward, or as a presentation system.	(Desurvire et al, 2004) (Malone, 1980)	Audio and visual themes should be recognisable to the player, as unique features of the game, whilst also serving necessary functions. Computer games should appeal to sensory curiosity through the use of audio and visual effects. There are important motivations behind these features, such as decoration (unaffected by players actions), to enhance fantasy, as a reward or as a representation system (to convey information more effectively through icons and symbols).

H5. Social aspects

Guideline		Evidence	Description
H5.1	Interactive and / or social support that is relevant to the content and objectives should be provided.	(Levin, J. and Cole, M. Cited in Malone and Levin, 1984)	Educational systems should enable and encourage interaction such as knowledge sharing among peers and ideally between novices and experts.
H5.2	Synchronous (e.g. chat) or asynchronous (e.g. email) communication tools should be provided for games where social interaction is important.	(Ardito et al, 2004)	Even if the platform of the game itself is intended to be used offline, either synchronous or asynchronous communications tools should be provided in order to allow social dynamics among learners.
H5.3	Where necessary, communication among players should be possible through different media channels and is used in an optimal way.	(Ardito et al, 2004)	Communication should be possible through different media channels which are used in an optimal way for the individual preferences of the player. Specific communication media should be used for appropriate subjects and learning goals. It should be possible to limit or choose the media channels.

H6. Learnability

Guideline		Evidence	Description
H6.1	An interesting and absorbing tutorial that mimics game play should be provided.	(Desurvire et al, 2004) (Burton and Brown, 1979)	There should be an interesting and absorbing tutorial that mimics game play but should not tutor before the student has a chance to discover the game for himself.
H6.2	Learning tasks should engage the players but not make them feel overwhelmed.	(Ardito et al, 2004) (Benson et al, 2001)	The user should be involved in the learning process without being overwhelmed. The tasks should be designed to be closely aligned with the learning goals and objectives necessary at their stages of play.
H6.3	Any online help and documentation should be focused on the player's task, be contextual and easy to use.	(Desurvire et al, 2004) (Nielsen, 1993 and Nielsen and Molich, March and April 1990)	Players should be given context sensitive help while playing so that they do not get stuck or have to rely on a manual. If needed, provide help information that is easy to search, focused on the players' task, and concise.
H6.4	The system should proactively offer advice / help but only on sections in which the player is weak.	(Burton and Brown, 1979)	Before giving advice, be sure the issue used is one in which the student is weak. Offer advice once, giving the player the option of turning help function off.
H6.5	In order to check the player's progress at any time, assessment tests that are aligned with the program objectives and content should be provided.	(Ardito et al, 2004) (Benson et al, 2001)	Assessment opportunities that are aligned with the objectives and content should be provided to check one's progress at any time.