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Educational game models: conceptualization and evaluation

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ABSTRACT

The relationship between educational theories, game design and game development are used to develop models for the creation of complex learning environments. The Game Object Model (GOM), that marries educational theory and game design, forms the basis for the development of the Persona Outlining Model (POM) and the Game Achievement Model (GAM). POM provides researchers with a means to more easily match software development with the intended audience and expected outcomes. The concrete GOM interfaces are realized in GAM which provides a convenient way to develop and document educational games. These models were developed to better understand the relationships between story, play and learning. Both qualitative data collected from group workshops and qualitative data obtained from interviews with people closely associated with the game design process were used to evaluate GAM. Results indicate that GAM is an efficient, well conceptualised and supportive model that can easily contribute to successful development and writing of stories for complex learning environments.

INTRODUCTION

Costikyan (2000) wrote ''there's a direct, immediate conflict between the demands of story and the demands of a game'' and ''to the degree that you make a game more like a story ... you make it a less effective game''. However, Phillips Mahoney (2001) argued, ''3D graphics adventures are sustained not by their visuals, but by the stories the visuals help to tell''. In his editorial DeLoura (2001) posed the question: ''Given that games can teach people, why aren't there more fun educational games available? ... As an industry, we could be making games which take the boredom out of school for the next generation of students''. Computer games may or may not be about story telling or teaching tools. However, gaming ''is the most vital art form of the age'' and a ''field that may become the predominant art form of the 21st century'' (Costikyan 2000).

The first part of this article will concentrate on the relationship between educational theory and game conceptualisation in order to better understand the role/s that games could play in educational environments, present a model that integrates educational theory and game design and outline a systematic approach needed to develop sound educational games. In the second part the use of the model is evaluated during the development of a specific story in order to test the validity and use of the model.

EDUCATIONAL THEORY

Constructivist educational theory focuses on concept development and deep understanding, rather than behaviours or skills, as the goals of instruction (Fosnot 1996). Furthermore, this development and deep understanding are constructions of active learner reorganisation. The fundamental principle of constructivism is that knowledge is not transmitted directly from one known to another, but is actively built up by the learner (Driver, Asoko, Leach, Mortimer & Scot 1994) – learning involves individual constructions of knowledge that come about through interactions with one's environment or culture (Rieber 1996). Therefore learners are viewed as constructing their own knowledge of the world.

For effective learning, knowledge should be uniquely constructed by people through play, exploration and social discourse with others. Learning objectives

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presented in constructivist learning environments should be firmly embedded in context, and should, at least in some way, represent every day life situations. Learners should also accept responsibility for their own learning and be self-motivated to explore different knowledge domains.

Formal education contexts are comparatively unfamiliar when compared to real-life experiences as they often emphasise abstract, decontextualised knowledge which is difficult to transfer to real-life situations (Choi & Hannafin 1995). This knowledge is then inert and can be recalled in tests but not readily applied in problem-solving situations encountered in everyday life (Cognition and Technology Group at Venderbilt 1990). In contrast, in informal learning contexts, individuals apply the knowledge practically and routinely to solve everyday problems (Brown, Collins & Duguid 1989). Knowledge and tools can only be fully understood through their regular use and using them requires the user to change their view of the world (Brown, Collins & Duguid 1989).

Traditional instructional design usually involves strategies that promote deductive learning (Gagne 1985). For example, a concept or a rule is usually presented to students followed by examples and non-examples of practice (Gagne, Briggs & Wager 1988). In contrast, inductive learning based on discovery (Bruner 1966) or ''learning by inventing'' (Bruner 1986:127) is perhaps a method of learning that is more effective. Through engaged experience in a domain learners induce, or construct, their own concepts and rules based on their interpretation of the instances encountered.

Play, and play associated with games, is an important aspect of learning (Quinn 1994; Rieber 1996). Play performs important roles in psychological, social and intellectual development, especially during early childhood, and could be defined as a voluntary activity that is intrinsically motivating, involves some level of activity (often physical) and may possess make-believe qualities.

Games can affect cognitive functions and motivation (Rieber 1996); inherently stimulate curiosity (Thomas & Macredie 1994) by including challenges and elements of fantasy (Malone 1980, 1981a,b) and novelty and complexity (Carroll 1982; Malone 1984; Malone & Lepper 1987; Rivers 1990); and can promote goal formation and competition (Neal 1990). Skills required to play games include motor skills, logic, memory, visualisation and problem solving (Quinn 1994; Quinn 1997; Amory, Naicker, Vincent & Adams 1999) that are fundamental to learning (Schank & Cleary 1995). Learners appear to be intrinsically motivated (Malone & Lepper 1987), metacognitively active, behaviourally active and self-evaluating (Rieber 1996) while playing games.

Simulation and adventure games have been proposed as appropriate viable educational tools (Quinn 1994, 1997; Roberts 1976; Ju & Wagner 1997; Amory, Naicker, Vincent & Adams 1999). Simulation games are often used in educational environments as students are focussed on single goals, there is decreased competition between students, and such games allow students to explore or experiment at their own pace (Roberts 1976). However, such simulation games are based on the concept that students need to engage in real-world activities and fail to acknowledge that play is part of our everyday lives (Blanchard & Cheska 1985). Also, the concepts used in the simulations are often hidden from the player and therefore players can only develop a surface understanding of the concepts.

Educational researchers, who support constructivism, developed the term microworld to describe a situation where learners do not study a particular domain but become part of the scenario, thus stimulating interest and motivation, and are able to interact with and explore complex ideas within such spaces (Rieber 1996). Rieber believes games, rather than simulations, may provide a meaningful way to present microworlds to learners.

Therefore, educational games that are built on sound educational theories could be seen as instruments that promote the use of modern educational theories in the classroom. In the next section I will present a model that integrates education theory and game design.

GAME OBJECT MODEL (GOM)

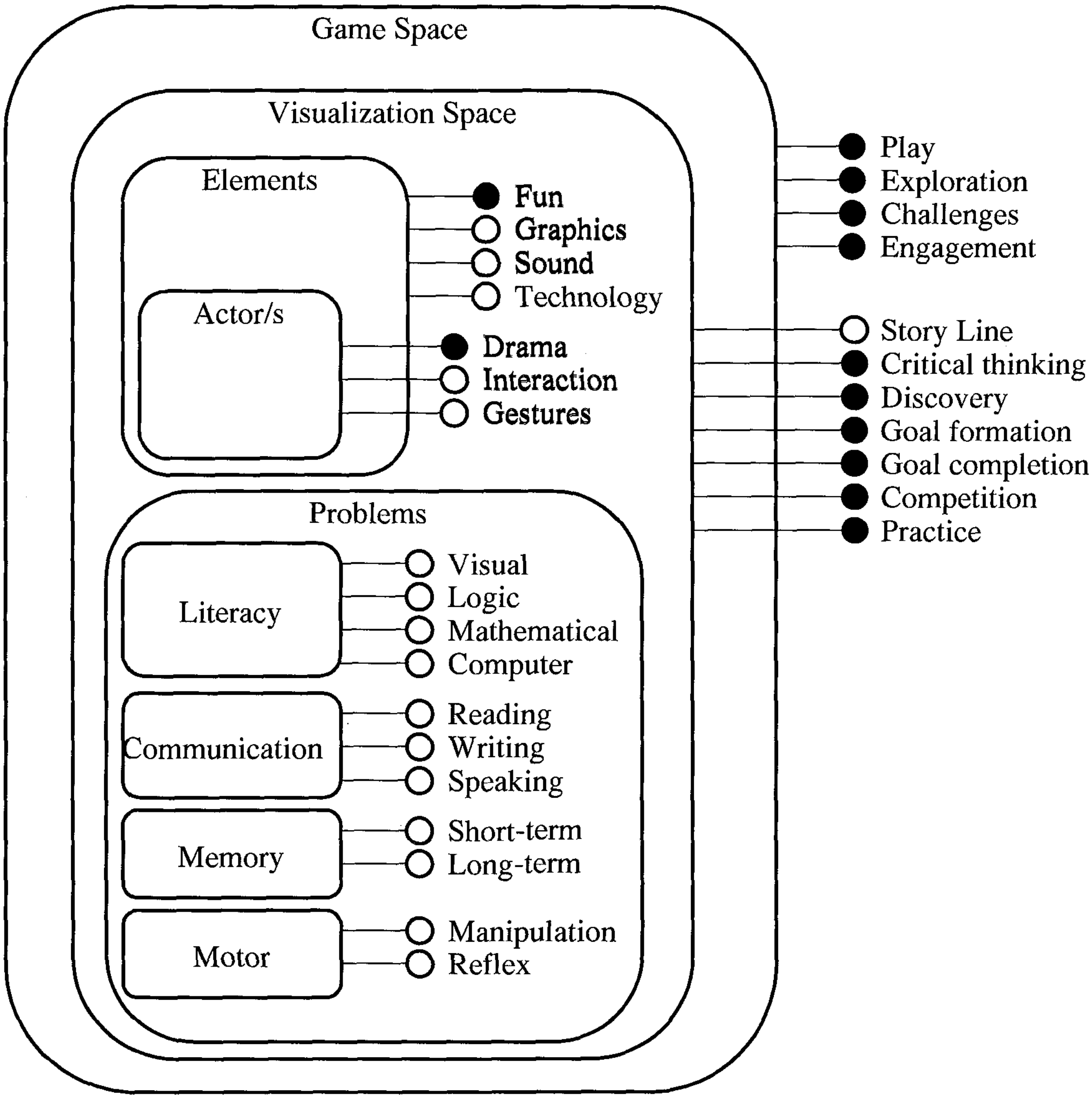
Model Description

GOM (Figure 1) (see Amory 2001), based on Object Orientated Programming concepts, attempts to create dialectic between pedagogical dimensions and game elements and includes *components* (represented by rounded squares) that promote educational objectives *(abstract interfaces)* and those that allow for the realization of such objectives *(concrete interfaces)* contained within different spaces. Components accommodate either abstract or concrete *interfaces* (represented by circles: abstract, black; concrete, white). *Components* may either be freestanding or part of other *components*, in which case they inherit all the parent *interfaces*. Inner *components* contain concrete *interfaces* while the outer ones are more abstract. *Interfaces* are also listed from the most to least important.

Therefore the *game space component* consists of four motivational interfaces (play, exploration, challenges and engagement) and contains the inner *visualisation space component*. This *visualization space component* includes two domain spaces (game elements

Figure 1

Visualization of the Game Object Model
(● — abstract interfaces, ○ — concrete interfaces; from Amory, 2001)



and problem components). The *visualization space component* contains the story line, critical thinking, discovery, goal formation, goal completion, competition and practice *interfaces*. The *elements component* contains components and *interfaces* (fun, graphics, sound, and technology) that make up the story line, appearance and playability of the game and are related to the discovery and goal formation *interfaces* of the *visualisation space component* and *engagement interface* of the *game space component*. The *elements component* includes the *actor component* that is specifically related to the *engagement* and *story line interfaces* and contains one abstract *interface* (Drama) and two concrete (Interaction and Gestures) *interfaces*. The *actor component* therefore also inherits all the interfaces from its parent, the *elements component*.

The other *interfaces* of the *visualization space components* (critical thinking, discovery, goal formation, goal completion, competition and practice) are expressed via the *literacy*, *communication*, *memory* and *motor components* of the *problems component*. Pedagogical elements are therefore represented by abstract *interfaces* and game elements by concrete *interfaces*.

This model is used to develop a qualitative approach to persona development (Persona Outlining Model) and the Game achievement Model used to realize all the concrete interfaces of GOM.

Persona Outlining Model (POM)

The construction of complex software is often supported by Software Engineering methodologies that attempt to resolve the conflict between failure of a product to emerge when no process is used to drive product production, to the wrong product being produced when a very rigid phased approach is used.

Newman and Lamming (1995) proposed the use of a feedback system to manage software development where the first step in the process is to articulate the "Situation of Concern", that describes the current unsatisfactory state of the world that the software will attempt to solve [*Why*]. Thereafter the problem statement is defined to address the *Situation of Concern*.

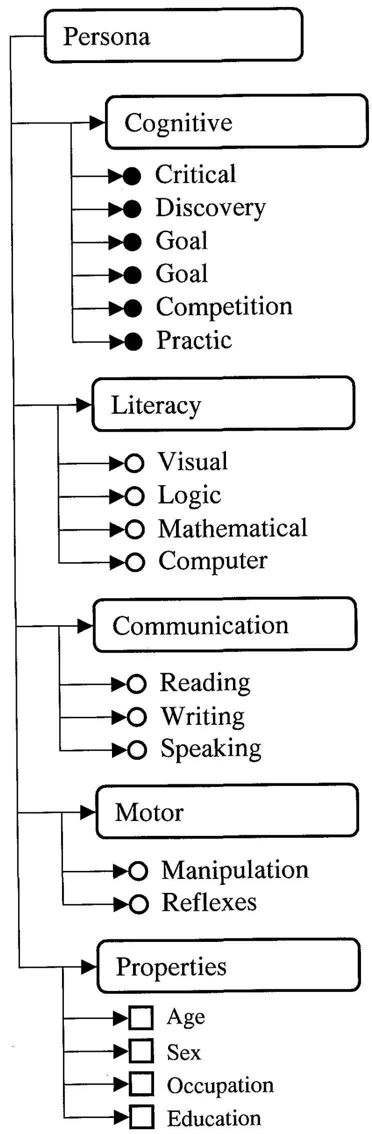
The problem statement in interactive computer systems consists of four elements that describe the:

1. Users who will exploit the system [*Who*]
2. Human activity that the system will support to satisfy the situation of concern [*What*]
3. Support provided by the system [*How*], and
4. Techology used to develop the system [*With*].

From a Human Computer Interaction perspective the *Who* and *What* could be defined in terms of a "persona" (characteristics of a fictitious user of the system). However, persona descriptions are often not built from real data and do not allow the use of vigorous statistical tools during the user evaluation phases of software development..

Figure 2

(● — abstract interfaces, ○ — concrete interfaces; □ — properties)



In order to solve these problems a persona could be described in term of educational learning theories and GOM. This Persona Outlining Model (POM) (Figure 2) includes all the abstract interfaces of the GOM *visualization space*; the concrete interfaces of the *problem space*; and a number of properties (age, sex, education and occupation).

At the start of a project development cycle a value (for example, in the range from 1 to 4) could be assigned to each interface of the POM and thereby create the *Who* definition of the *problem statement*. By changing the values associated with each interface according to the *Why (Situation of Concern)* the *What problem statement* can be defined. User studies conducted prior to development and during software testing can then be used to accurately access the scores and to determine statistically if the software actually solves the intended problem.

Game Achievement Model (GAM)

While the Game Object Model provides a framework that links learning theory to game design, it does not clearly articulate how to design and build educational games. The outermost GOM interface is that of the story line and this interface should therefore form the basis of the development. However, if educational software is to be successful, the learning objectives need to be clearly defined. Such objectives relate back to the *Situation of Concern*. Therefore, the first priority in describing an educational game is to define the learning objectives and to outline the basic story (Figure 3a). These activities, or actions, are the starting point of the Game Achievement Model (GAM).

Computer games, just as a play, or film, should be made up of a number of acts. Traditional plays often consist of three acts while the demarcations of acts within a film are more difficult to discern. Games can therefore consist of any number of acts. Each act needs to achieve specific objectives, tell a part of the story and can consist of one or more scenes (Figure 3b). Acts therefore implement the story-line interface of the *visualization space* and define specific objects that need to be realized in the scenes.

Figure 3a & b

Components of a Game Description
(a. Basic definitions: objectives and story; b. Act definition: act objectives and story line interace)

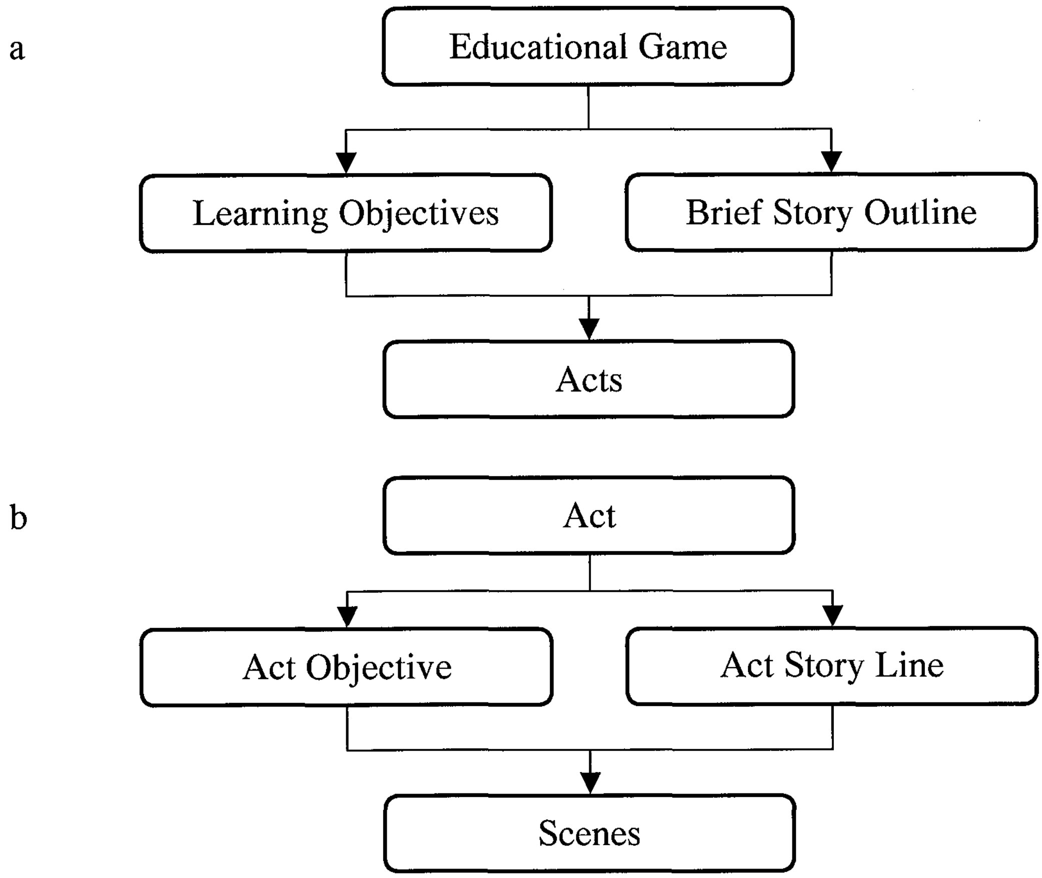
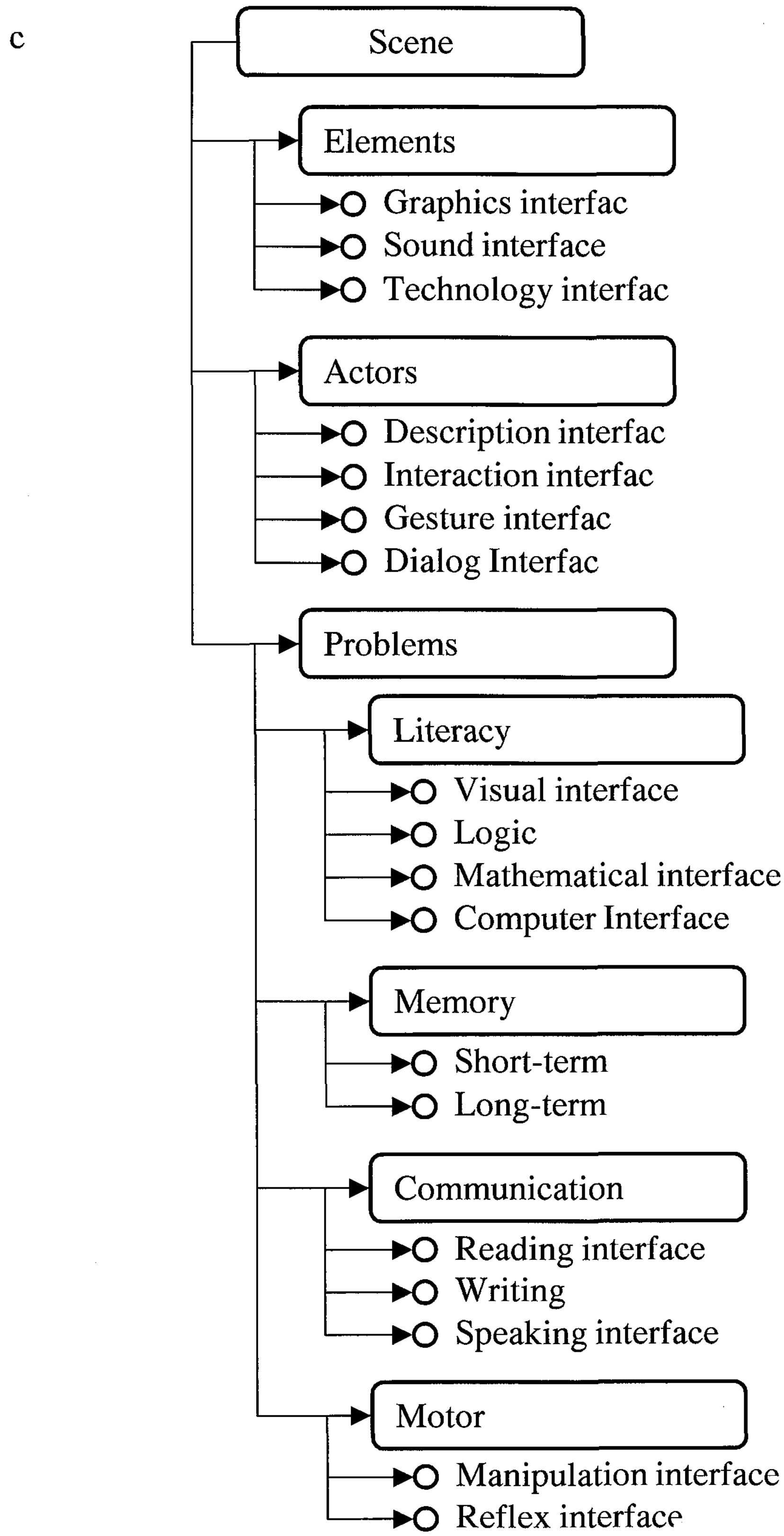


Figure 3c

Components of a Game Description
(c. Scene definitions: elements, actors and puzzles)



A scene includes a number of spaces: Elements, Actors and Problems (Figure 3c) that map directly to GOM. The *Elements Space* includes the Graphics, Sound and Technology *interfaces*; the *actors space* consists of the *description*, *interaction*, *gesture* and *dialog interfaces*; and the *problem space* contains a number of spaces (literacy, communication, memory and motor) and their associated *interfaces*. Therefore, a scene implements all the inner *interfaces* of the *visualization space* of GOM. The learning objectives, as defined by the *Who* and *How* and described by POM, are realized by, or implemented through, a scene.

USE OF THE GAM

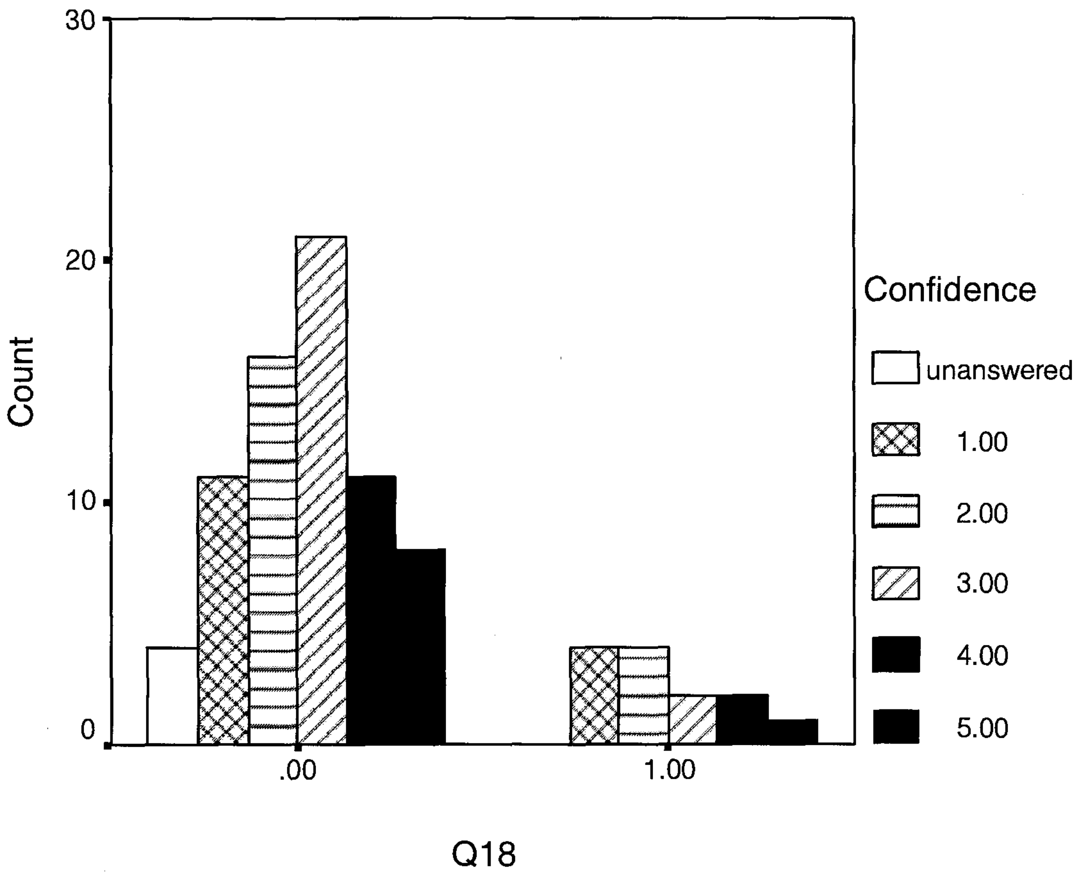
The first priority of the GAM is to define the learning objectives for the game and to decide on a story-line that will encompass these objectives and be exciting enough to provide intrinsic motivation for the players to play the game. The learning objectives for the game were identified through the use of questionnaires that probed the knowledge of students at the University of Natal, Durban about aspects of certain diseases, namely HIV/AIDS, tuberculosis, malaria and cancer. Students (n = 200) from across the University were polled and asked to answer questions regarding these diseases before then ranking their confidence in their answers. The results of the questionnaires were coded (as either a correct or an incorrect answer) and entered into a statistical program (SPSS, SPSS Inc USA) before being cross-tabulated and eventually graphed to produce a visual representation of the results (See Figure 4 for an example graph produced for each question).

Analyses of the results indicated that there were persistent and common gaps in knowledge regarding these diseases and lead to the identification of problems in the following knowledge domains:

1. The transmission, biology, symptomatic expression and prevention of HIV, malaria and tuberculosis;
2. The biology and mechanism of cancer; and
3. The differences between viruses and bacteria.

Figure 4

Example of student responses cross-tabulation and corresponding confidence levels (0 = incorrect answer; 1.00 = correct answer)



After defining the learning objectives, a story workshop was held where all people with a stake in the game agreed on a story-line that encompassed the learning objectives and would provide intrinsic motivation for gameplay.

Thereafter, a smaller team consisting of a researcher, a graphic designer and a script-writer met on regular occasions to refine the details of the story-line and to define individual acts, the act learning objectives and individual scenes within each act. The definition of these acts, scenes and specific act learning objectives was done according to the GAM.

EVALUATION OF THE GAM

The evaluation of the GAM was performed using qualitative data collected from people involved with the game design at different stages of the process, namely the story workshop session and from the focus group closely associated with furthering the story-line and writing the complete script.

Story workshop

The workshop lasted approximately 90 minutes and was attended by 16 members. The entire story workshop was recorded onto an audio tape and later transcribed. NVivo (a qualitative data analysis package, QSR, Australia) was then used to organise the data and query it for any trends. In this way, the data was used to analyse how people responded to the GAM, or the concept of using the GAM in designing the game story-line (Figure 5).

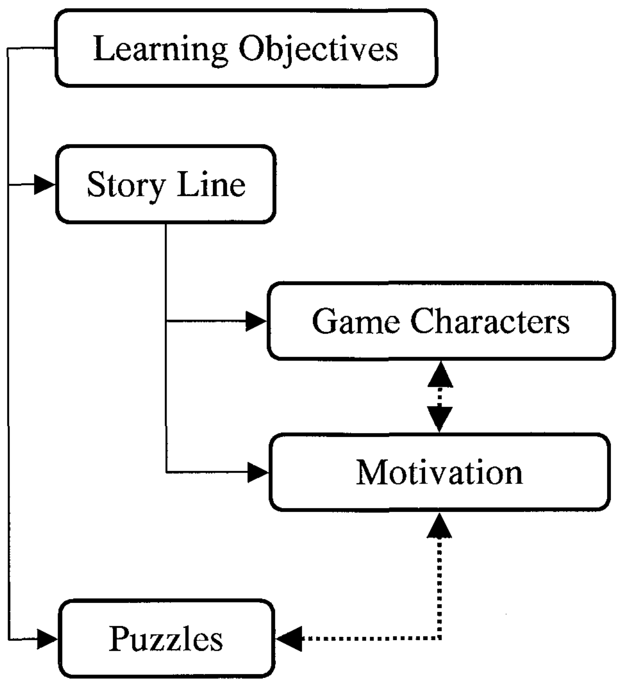
The story workshop began with the presentation of the learning objectives for the game. The participants were then informed that whatever storyline emerged from the workshop would have to encompass the learning objectives and ultimately facilitate the realisation of these learning objectives. The development of the story-line, however, was completely up to those present at the workshop to negotiate.

The discussion started at a very broad level with individual members submitting various different ideas for discussion, followed by a fair amount of conjecture between members. However, once the members had agreed on a location for the game setting, the exchange became a lot more refined and that is when headway was really made.

The strength of this stage of the GAM was provided largely by pre-stating that the story would have to enable the realisation of the learning objectives. Because of this, the initial scope of the story-line was confined to manageable levels. By constantly comparing the emerging story to the learning objectives throughout the process, the final story was both

Figure 5

An NVivo derived model showing the importance of the learning Objectives in defining the story and the influence of the puzzles, storyline and game characters on motivation



feasible and practical. Another real strength of this step of the process was the diversity of the members that attended the workshop. A rounded view was instrumental in the planning of this game as it will be marketed to a large multicultural audience.

FOCUS GROUP

The focus group was where most of the hard conceptualisation and planning work took place. The process this group followed was of defining different acts that would occur within the game, and then defining the learning objectives that should be realised in each act. In addition to that, individual scenes were then defined, with each scene in the act contributing to the realisation of the learning objectives for that act. Scenes were defined as individual geographic locations within the game and were scripted with appropriate puzzles and objects to realise the learning objectives.

The scripting process was iterative with constant review and revision with each meeting of the focus group. In this way, the three members negotiated a more specific story-line amongst themselves with, once again, these different members bringing something unique to the process.

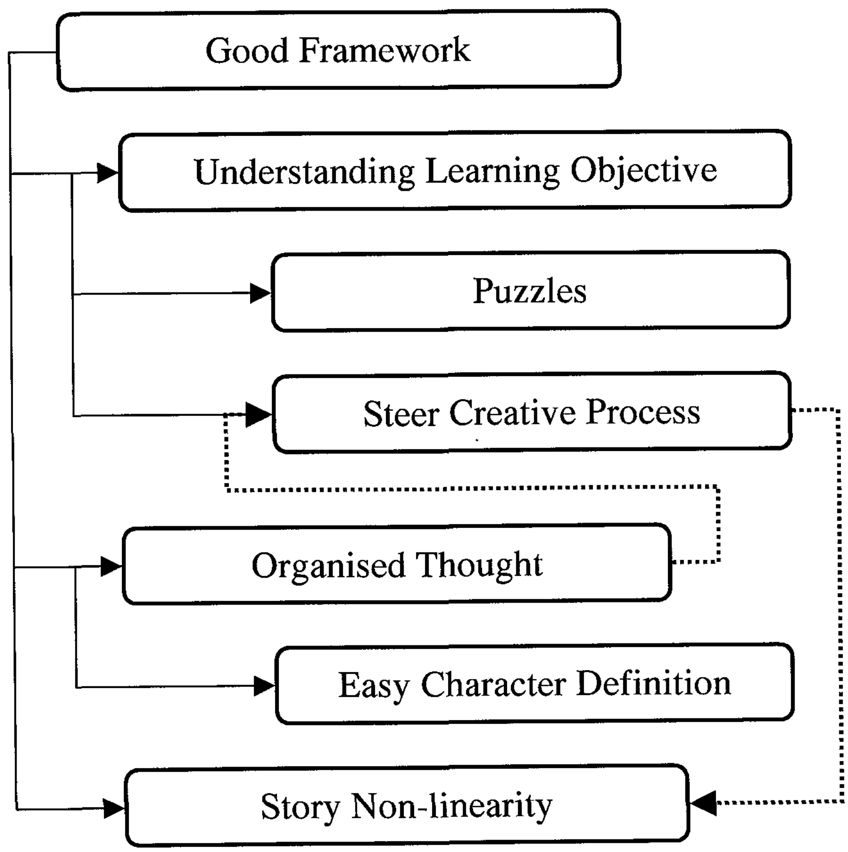
As a result of approximately five separate meetings, the game was fully documented with three acts, seven scenes and a number of educational puzzles to enable realisation of the learning objectives. Throughout these meetings, the GAM was used as a guideline, and made conceptualisation of the overall level much easier.

The people involved in this process were interviewed on aspects of the process. Their answers and opinions were recorded and organised using the qualitative data analysis package, NVivo (Figure 6).

The members found the GAM to be a useful tool in that it provided a good framework structure around

Figure 6

An NVivo derived model showing the thoughts of the designers on the Game Achievement Model and te relationships to other factors such as organising thoughts, character definitions and the understanding of learning objectives



which the groups' thoughts could be organised. The structure provided the team with a good starting point and steered the creative process in the right direction. This would not have been possible if the scripting had been attempted with no structuring.

DISCUSSION

While the models presented here provide a framework for the conceptualisation, design and development of educational games, two aspects, story development and graphic design, are not clearly described as both require specific creative abilities not easily captured through reductionism.

GAM suggests that the foundations of any game are the objectives and the story line. However, most of the GOM concrete interfaces are realized through the Problem space supported by the Elements and Actor spaces of GAM. Also, the learning objectives are realized through the Problem space. Games therefore consist of three interlinked gears: the story, the problems and the graphical realization of the story and problems.

So are games a new form of story telling?

Before attempting to answer this question it would be interesting to look at a few of the most successful games and identify the role of the story in these games. The most successful game of all time, Rand and Robyn Miller's Myst, is an adventure game with a very strong story-line that has been embellished to create two sequels, Riven and Myst III: Exile and has also resulted in the publication of traditional books based on these games. Grim Fandango by LucasArts, voted best adventure game by GameSpot in 1998, entertained players with both engaging storytelling and appropriate puzzle solving (Costikyan 2000). In his post-mortem of the most anticipated strategy game of 2001 Black&White, game designer Molyneux (2001) wrote: ''We thought it would take no more than two months [to write the story], but after a while we realized the we didn't have the skill set needed to take care of this vital aspect of the game'' and therefore hired a scriptwriter who ''turned our ideas into a fully plotted story line, wrote hundreds of challenges and quests, and wrote all the dialogue in the game''. Therefore successful adventure and strategy games appear to be based on strong story lines. This may also be true for role-playing games but not so for action, driving, simulation and sport games. Therefore, some forms of games require well-crafted stories to support game play.

It is central to the Game Achievement Model that all members of the story-writing team fully understand the learning objectives behind the story before attempting to refine the story. The GAM is very good at making explicit these learning objectives before the creative process begins and, therefore, demonstrates to everyone what should be achieved in the course of the game. This allowed all the team members to start from the same common place. The fact that the learning objectives are defined at the act level, and not at the individual scene level, gave the story-writers a lot of freedom in that each individual scene could have one or more learning objectives addressed in it. This allowed the design of a more flowing and contextualised environment.

Essentially in an exploration game of this nature, it is not practical to have a linear story that goes from beginning to end, but rather to have a story where exploration is the key and the player can determine for themselves which route they want to take to reach the end point. Therefore, the use of a linear story is not feasible in such a game. However, writing a non-linear story is quite complex and difficult. The GAM, with its' support structure, allowed the team to work from a linear story in the beginning, and then design a non-linear adventure around the original script. The model was instrumental in enabling us to do this.

The open nature of the GAM allowed us to easily identify different characters within the story and define how the inclusion of these characters would enhance the game and further the learning objectives of the game. The model allowed for descriptions of the actors, their interactions, gestures and dialogue, and helped the team place in perspective what functions they performed within any particular scene or act.

Finally, the inclusion of appropriate puzzles in a game is often difficult. Puzzles can be complex to design and they can often be misplaced in the context of the game. The GAM, because of its good support structure and transparency, allowed the team to match the puzzles to the learning objectives and ensure the puzzles were appropriately placed within the game.

The realization of the story line and problems depends on the skills of graphic designers, sound artists and programmers *(Elements Space interfaces)*. However, many of the new games released, or those in production, place greater emphasis on the technology than on any other aspect of game design. While game development often pushes the boundaries of both hardware and software development, these are but part of complex interlocking game parts.

Educational adventure games, or edventure games (Amory 2001), designed to solve specific learning misconceptions have been well received by learners and appear to support the argument that play is an integral part of the learning process (Amory *et al* 1999; Amory 2001).

Therefore games are much more than a new way to tell stories.

Games should therefore rather be viewed as a new entertainment medium that builds on the traditions of plays, movies and television where the story forms the foundation. In addition games could play an interesting and constructive role in the classroom when developed on sound learning theories.

CONCLUSIONS

The development of a number of models to explore the relationships between educational theory and game design provides developers with a conceptual and practical framework that can support the development process. Also, well-crafted games appear to require appropriate puzzles integrated into strong story-lines where graphics, sounds and technology are used to create an entertainment medium that could also champion learning objectives. The GAM proved to be an efficient, well conceptualised and supportive model that enabled our design team to work together, despite differing areas of expertise and culture, to construct a coherent, exciting and appropriate story-line for an educational adventure computer game.

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