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A design process for balanced educational video games with collaborative activities

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Abstract
The efficiency of educational video games could be improved through the use of a specific development method that allows them to keep both their educational and recreational goals and maintains their playability. Accordingly, we present a process for the incremental design of educational video games with collaborative activities based on Software Engineering principles. This process intends to make the specification and design of educational and recreational contents easier, and also ensures a balance between educational and playful components. To support this methodology, we present a pilot authoring tool that implements our design process.

Keywords: Digital Game-Based Learning; Methodologies; Educational Video Games Design; Computer-Supported Collaborative Learning.

Proceso de diseño para videojuegos educativos con actividades colaborativas

Resumen
El uso de un método de desarrollo específico para videojuegos educativos que facilite la definición de objetivos pedagógicos y lúdicos podría mejorar la eficiencia instructiva de este tipo de aplicaciones, sin perder su jugabilidad. Con esta intención, en este trabajo se presenta un proceso de diseño incremental que aplica principios de Ingeniería del Software para generar videojuegos educativos con actividades colaborativas. Siguiendo dicho proceso, la especificación y diseño de contenidos educativos y de juego es más sencilla y permite garantizar el equilibrio entre los componentes educativos y de juego. Complementariamente, se presenta un prototipo de una herramienta de autor que implementa la metodología propuesta.

Palabras clave: Aprendizaje basado en juegos; Metodologías; Diseño de videojuegos educativos; Aprendizaje colaborativo soportado por computador.

1. Introduction

In a society in which Information and Communication Technologies (ICT) have been incorporated into every aspect of our daily life, it can be assumed that they can also be incorporated into educational environments. Actually, e-learning has now been incorporated into many disciplines, both for formal and informal learning processes (e.g., [1]). In addition, it is also well known that learning by playing has benefits for students, from kindergarten to postgraduate students, due to the motivation that this way of instruction provokes in learners [2]. For this reason, the studies about Game-Based Learning (GBL) [3] have been revised, in order to be applied together with ICT. This has brought binding results in the form of a powerful learning tool that emerged under the denomination of Digital Game-Based Learning

(DGBL) [4,5], which reinforces the benefits of the game with 3D graphics, high interactivity, monitoring and student adaptation, etc.

Moreover, collaborative learning and, in particular, computer-supported collaborative learning (CSCL) have been widely proven to improve learning processes due to, among other factors (e.g., [6]), the additional motivation experienced by students when they work together (e.g., [7,8]).

A specific application of DGBL is educational video games that intend to teach educational contents embedded in a recreational and interactive story [9]. The educative content of an Educational Video Game (EVG) can be implicit or explicit. Our research focuses on the first type, in which the educative activities are hidden, and are disguised as play activities. As such, we intend to fully take advantage of using ICT, DGBL and CSCL.

Furthermore, several experiences, such as [10,11], or a more in-depth example in [12], have revealed that balancing the educational and entertaining contents in this kind of video game is very important to obtain the expected results. Additionally, Egenfeldt-Nielsen [13] has stated that many educational games fail to integrate game and educational goals, which reduces the game's effectiveness in terms of fun or learning, depending on the aspect that is less developed.

In the review undertaken in [12] we found that when teachers use a commercial game to involve children in a new content or to practice some aspect of the curriculum, they have to work hard. As Felicia [14] explains in the *handbook for teachers*, they have to know, among other factors, what video games exist, what the game is about and how they can use it to teach in their classrooms. Consequently, the chances to include this kind of video game as educational tools is reduced, since many teachers have less knowledge or interest in making the required effort. On the other hand, video games especially designed to teach are usually too educative in nature, and the game is then little more than a *virtual textbook*. In these cases, children quickly detect that those games are different from the video games they have at home, and this makes motivation much lower.

In conclusion, we found that educational video games could be improved through the use of specific methods that allow the definition of educational goals maintaining playability [15]. Thus, we have defined a design process for educational and collaborative video games based on Software Engineering principles, such as incremental construct, the *divide and conquer* approach, graphic modeling, etc. In order to validate the proposed process, we have developed a pilot authoring tool that is focused on the components that support the design activities, both educational and entertaining.

In summary, this paper's main contribution is presenting a design process specifically for educational video games which:

- Involves the teacher in the video game design.
- Defines educational goals, tasks and curricula,
- Defines game stages, levels and activities,
- Interrelates educational tasks and play activities
- Models individual students: learning outcomes and game challenges, and
- Models student groups: collaboration, cooperation and communication.

We also propose a pilot authoring tool based on this design process, which is:

- Intuitive, by using graphical notations,
- Simple, by separating issues into the four phases proposed, and
- Evolutionary, by allowing backtracking at every phase.

The rest of paper is structured as follows: In section 2, we analyze related works on general recommendations and guidelines for the design of educational video games. Section 3 describes the proposed design process, dividing its development into four different phases. In section 4, we present the pilot authoring tool to design educational video games with collaborative activities. Finally, in section 5, main conclusions obtained from this study and further works are outlined.

2. Related works

It is well known that video games are widely present in the majority of households in developed countries, either PC games, console games or many other devices. Moreover, some years ago, there were different experiences with the introduction of using video games as educational tools, for example, the ones presented in [14] or [16].

In this paper, our focus is on the particular case of these educational video games, which are especially designed to teach some educational content by playing. Nevertheless, using video games as an educational tool, although they have not been especially designed with an educational intention, has several benefits for students [14, 17]: reducing boundaries from the real world and allowing *different worlds*

Table 1. Capabilities development from an educational standpoint

Personal Development	Increases self-esteem Increases motivation to learn Increases knowledge and control over self-learning process Increases curiosity and creativity Increases perseverance, understanding of rules and response to frustrations	[18, 19]
Social Development	Creates a sense of belonging to a group Improves attitudes towards teachers and classmates Fosters collaboration, cooperation and competition Fosters social learning Fosters situated learning: learning occurring not only in the individual mind, but embedded in the social and cultural world	[20, 21]
Cognitive Development	Fosters abstract thinking Fosters critical thinking and decision making Fosters incidental learning Allows exploratory and proactive learning: learning by doing Fosters learning self-regulating Fosters planning strategies to achieve goals Increases capability to understand cognitive maps, simulations, pictograms, and so on. Fosters learning retention in the long term	[16, 20, 21]

Source: [16,18-21]).

Table 2. Summary of proposals studied

Proposal	General or Educational Purpose	Aimed at teachers of developers	Explicit separation of educational and recreational aspects	Collaborative Aspects	Adaptive Aspects
‹e-Adventure› [23]	Educational	Developers	✗	✗	✓
WEEV [24]	Educational	Developers	✗	✗	✓
Guidelines [25]	Educational	Developers	✗	✓	✗
Layered framework [26]	Educational	Developers	✗	✓ (groups)	✗
Puzzle-it [27]	Educational	Developers	✗	✓	✓ (in progress)
General Structure [28]	Educational	Teachers	✓	✗	✗
TAT [29]	Educational	Teachers	✓	✗	✓

Source: [23-29]

to be accessed, which allows students to exercise their fantasy; fostering instant repetition and trying again in a safe environment; promoting the mastery of skills because players can repeat actions until they dominate them; facilitating relationships with other people in a non-hierarchical way; improving hand-eye coordination; reducing reacting times; improving spatial conception, memory, technological understanding; etc. In addition, from an educational standpoint, video games allow personal, social and cognitive capabilities to be developed. Table 1 classifies these benefits in the three aforementioned categories.The history of video games shows us that its evolution is marked by the constant search for more entertainment and ease of use. This search must be addressed both from a technological and methodological standpoint, otherwise the solution will be incomplete.

On the technological level, two fundamental aspects are considered [22]: 1) the search for immersion through increasingly realistic environments, as well as new, interactive and more natural elements; and 2) the creation of specific devices that facilitate interaction, simulating real elements and offering new gaming experiences.

On the methodological level, we think it is unavoidable to use a design process that ensures the quality of the video game. In our opinion, one only technological approach, will lead to video games that are empty of substance, both educational and fun.

While some guidelines for creating educational video games do exist, we believe there is a need for a more comprehensive proposal for the development process, including both entertainment and educational aspects. In this regard, we agree with the proposals stated in [23], where some of the limiting factors for educational video games and emerging trends are highlighted. Consequently, the work proposed in this paper is intended to address some of the issues that the previously mentioned work highlights, in particular the *list of addressed limits and trends*:

1. The teacher plays a very important role both in the design process and in the play time. Thus, the design process must be focused on teachers, rather than on game developers, in order to promote teachers' involvement in the design, development and use of educational video games.
2. Video games designed by using the proposed design method allow for elements to be reused and are flexible in order to provide each student with a more suitable experience.
3. Combining our user model and the video game's setup capabilities, in order to be able to adapt the learning experience both from educational and recreational standpoints is very important.
4. Video games designed by using the method proposed allow the teacher to obtain information about how well the student has learnt the educational contents.
5. Collaborative activities are included and information about relationships occurred during the play time is recorded.

In order to compare our approach with others existing in the literature, Table 2 summarizes some of the main features of the related works studied, paying attention to five main aspects: if the proposal is for general purpose or specific for education, if the proposal is aimed at teachers or developers, if it separates educational and recreational aspects explicitly, if it includes collaborative elements and if the resulting video game can be adapted to each student. We explain them in more detail after the table.

Undoubtedly, one of the most important proposals is the ‹e-Adventure› platform [23], which integrates methodology, architecture and author tool to support the design process [30]. This framework is mainly focused on the development of educational tools, although it can also be used for non-educational video games, but it does not incorporate collaborative aspects [31].

As an extension of this system, [24] we propose the WEEV methodology, which is especially designed for educational video games. This methodology uses three main elements to design a game: a) defining actors, b) defining the world in which the game takes place; and c) creating the story by a graphical representation to describe the flow of the game. We find that the focus should be moved to teachers, who still are unaware of using video games as educational tools and, as such, they are not involved in their design and development.

WEEV covers collaboration, showing that there is a gap in the market in the specific field of educational video games with collaborative activities. To fill this space, we present a set of guidelines from previous works [25]. These guidelines are based on the five pillars of cooperative learning [33]:

positive interdependence, individual accountability, face-to-face promotive interaction, social skills and group self-analysis . In this work, we present a set of recommendations to foster each of these elements in order to facilitate activity design in the game.

More focused on a technical level, but with a softer definition of a development process, another proposal to make the design of serious games easier can be found in [27]. This proposal consists of a framework with three layers that divide the problem of game design into several steps. The first step focuses on the conceptual level, where aspects related to the gameplay, student features, teacher requirements, and game management are solved. Each of these aspects is modeled using a subsystem on a conceptual level. The second part of the framework deals with the technical level, including a set of tools to design and develop the game. The practical level is tackled in the last step, including a set of recommendations to reduce complexity in the game structure, gather student feedback and give a representation of the game elements.

Higher education is possibly the educational level where more educational video games can be found. However, these video games usually focus their attention on the educational content to be taught, which usually involves a lack of playful elements, which contradicts the Egenfeldt-Nielsen's balancing theory [13]. This occurs, for example, in [27], in which the platform development Puzzle-it is proposed. Although it is still a work in progress, authors propose four main modules for the architecture in order to separate different aspects of game development. The authoring module deserves special attention, because it is expected to offer authoring tools to teachers. However, although the *manual* part of this module is intended to be used by teachers, the contents they have to define are not related to education. In contrast, they have to design and / or create scenarios and rules related to their didactic plans. In our opinion, teachers should be given authoring tools for educational contents rather than game contents.

For her part, Sauvé [28] presents a pedagogical-centered proposal to make the design of on-line educational video games easier, allowing for the creation of different games all starting from the same general structure. To do this, several tools are provided to fix particular parameters in the game, generate the rules, create the educational contents, define criteria for winning and ending the game, and revise the game process.

More aligned with our proposal, we find the work of [29], who includes an authoring tool for teachers that intends to facilitate the design of educational contents to be included in the educational video games supported by Affective Teachable Agents [34]. In that work, authors propose to divide the knowledge to be taught in goals. In addition, these contents are characterized according to different difficulty levels. After this process has been undertaken, lists of tasks are added to transitions between goals. Although we agree with the need to structure the educational content similarly to the way it is structured in traditional classes, we find this particular structure to be too difficult to maintain. The process of splitting the content should be easier and more intuitive for teachers, as well as facilitating the association between goals and tasks without, for example, repeating tasks in several transitions.

As stated in [35], the teachers and parents' opinion about using video games as educational tools is quite positive and they accept that video games can be a powerful tool to improve learning processes. In addition, we found that the most useful information from that report is the explanation provided by teachers about why video games are having problems in being incorporated into classrooms, as well as the proposals they have in order to overcome these obstacles: a) integrating the use of video games as educational tools as part of teacher training; b) having practical guides to use video games as educational tools (as proposed in [14]); c) fostering teachers' involvement in educational video games design; d) fostering collaboration between editorial and video games industry; and e) promoting the use of video games as governmental educational tools.

Table 3. Design Process Summary.

1 Educational Content Design	*Knowledge Areas Design*	Knowledge Areas [D1.1]
	Educational Goals Design	Educational Goals [D1.2]
	Educational Tasks and Activities Design	Educational Tasks [D1.3] Educational Activities [D1.4]
	Educational Model Design	Educative Itinerary [D1.5]
2 Entertaining Content Design	*Game Basic Design*	Definition [D2.1] Interaction features [D2.2]
	Video Game Challenges Design	Game Challenges [D2.3]
	Game Stages and Levels Design	Game Stages [D2.4] Game Levels [D2.5] Game Activities [D2.6]
	Game Model Design	Game Itinerary [D2.7]
3 Relating Educational and Entertaining Content	Relating Educational and Entertaining Content	Inter-level relationships [D3.1]
4 User Modeling	Characterizing the User	User model: general perspective [D4.1] User model: educational perspective [D4.2] User model: game perspective [D4.3] User model: interaction perspective [D4.4]
	Characterizing the Group	Group model: general perspective [D4.5] Group model: educational perspective [D4.6] Group model: game perspective [D4.7] Group model: interaction perspective [D4.8]

Source: The authors

With the proposal we present in this paper (detailed in section 3), we intended to make advancement in several of the topics presented in this section. Specifically, this proposal fosters the teachers' involvement in the design process since the educational content design will be the first step in video game development and, of course, they are experts in this. In addition, in order to provide a comprehensive framework to design educational video games with collaborative activities, this proposal: a) allows collaborative activities to be designed; b) provides mechanisms to separately design both educational and entertainment elements; c) allows a relationship between educational and recreational contents in order to relate achievements in the game to achievement at an educational level; and d) offers modules for teachers and for developers, each of them intended for their particular field of knowledge, because which contents are explicitly separated.

3. Design process for educational video games: our proposal

In a similar way to the design of other kinds of software, video game design should respect the principles of re-use and re-engineering of elements. It is therefore important to consider both educational and entertaining elements separately so that curriculum contents and games can be maintained more easily (item 2 in the *list of addressed limits and trends*). In addition, from the teacher perspective, by keeping elements on different levels they can be analyzed and dealt with independently from one another. And, this separation makes it possible to ascertain whether a problem that a student has during the learning process is related to the game activity, the educational concept, or to both (item 1 in the list).

We introduce collaborative activities into educational video games in order to enrich the learning processes (item 5). For this reason, it is convenient to incorporate monitoring to analyze the interaction between students, for example in group composition. To facilitate the subsequent analysis of information related to collaboration, we propose a set of models to record student and group information (items 3 and 4). These models are also used to perform adaptations [40].

The design process that we propose has four incremental and iterative phases, which are summarized in Table 3.

3.1. Phase 1: Educational Content Design

As previously stated, the focus of an EVG should be placed on educational content to be taught and subsequently be wrapped with the different layers of the game. For that reason, as other authors have also suggested, for example, [36] and [37], the design process proposed here starts with the Educational Content Design. This phase must be performed collaboratively by teachers and the entire educational team, and is composed of four activities, each of which generates one or several design documents. These activities, in order of execution, are: 1) Knowledge Areas Design, 2) Educational Goals Design, 3) Educational Tasks and Activities Design and 4) Educational Model Design.

Defining the Knowledge Areas (document [D1.1]) consists of identifying what each of the areas will be, for example, a subject or a specific set of contents of a subject. For higher education, we could define the subject "Algebra I", while in primary school an area would be "Mathematics 2º". The educational team is free to define the knowledge areas in the way that they see fit. Information to be included about Knowledge Areas is: name of the area, educational age to which it is appropriate and a general description of its contents. This first activity establishes the educational context of the video game.

Then, for each of the previously created areas, a set of Educational Goals ([D1.2]) must be completely defined. To fully describe an Educational Goal it is necessary to specify enough information to understand the contents and how they must be achieved. Therefore, for each goal we must include the name, the Knowledge Area to which it belongs, transverse Knowledge Areas (other secondary Knowledge Areas which are partially dealt with), recommended educational age (in the range of the age specified in the Knowledge Area), a natural-language description explaining the content that the student will learn, and a set of tasks whose realization contributes to achieving that goal. Once we have created all the Educational Goals, we have to define which goals are in the highest level of this structure and which are classed as sub-goals of these.

After defining Educational Goals, we have to define Educational Tasks ([D1.3]) and Activities ([D1.4]), which will allow for these goals to be achieved. Information to be specified about tasks and activities is very similar to the information detailed for goals, except that, in this case, the key is not what the student will learn but how they will learn. Again, relationships between tasks and activities are established in order to specify hierarchical relations between them. Thus, this information completes a tree of educational goals, tasks and activities, in which each level is someway related to the previous and the next one.

The last activity in phase 1 is delimiting the Educational Model. The Educational Model is a sub-set of the goals and tasks of a specific Knowledge Area. By means of an Educational Model, the teacher determines the educational content to be learnt through the video game in a particular case, such as training for exams for advanced students or first approximation for novice users. The document from this activity is called Educative Itinerary ([D1.5]) and it comprises a selection of tasks that students must complete to achieve each goal included in the Educational Model. The teacher can include mandatory and optional tasks. In each Educational Model, several alternative itineraries can be included in order to provide the student with different sets of tasks to learn a concept. Information detailed at this stage is: the Knowledge Area that will be taught; recommended educational age; prior knowledge needed in order to understand the content expressed in terms of Educational Goals and Tasks and the relations between them.

3.2. Phase 2: Entertaining Content Design

The second phase in this design process is intended to construct the entertainment content. This phase is divided into four main activities: 1) Basic Game Design, 2) Video Game Challenges Design, 3) Stages and Levels Design, and 4) Game Model Design. In order to maintain homogeneity in the design process, the recreational aspects are structured in a similar way to the educational content. This results in a similar hierarchical tree where the Game is composed of a set of Challenges, which can be achieved by means of a set of Stages and Levels.

The first activity in designing a video game is to define its general characteristics (Basic Game Design): 1) the game story (narrative) according to the content that teachers want to teach (for example, a war game with landscapes of countries for teaching the history of the Second World War), the video game genre (platform, social games, graphic adventure, role playing games, etc.), the device which will run the video game (PC, PlayStation, Nintendo DS, Xbox 360, etc.), multimedia elements and interaction modes (important if, for example, the student has a hearing impairment, in order to select a game without sound effects ([D2.1]); and 2) how characteristics of group learning will be applied (competitive, collaborative, or cooperative) ([D2.2]).

The design of Video Game Challenges ([D2.3]) is fairly similar to the design of Educational Goals in activity 2 of phase 1, but it focuses on game confrontations rather than instructive objectives. To define these challenges, designers use elements in the main story of the video game, including: a name for the challenge, a natural language description explaining what the player must do, relations to other challenges included in the game and a Stages and Levels sub-model, which concrete game activities to achieve the goal.

The last step in the Entertaining Content Design is to define which Video Game Stages ([D2.4]), Levels ([D2.5]) and Activities ([D2.6]) are needed to overcome each of the challenges. The programming of Stages and Levels for a challenge is called Video Game Itinerary ([D2.7]). A stage is described as each of the tasks that a player has to complete in order to overcome the challenge. A stage can be divided, recursively, into more sub-stages (if is complex), or be composed of levels. The same applies to levels, which are composed of sub-levels or activities. The activity is the atomic unit in the video game (for example, jump on a cloud, run down a block, grab a gun, etc.).

In order to define Stages and Levels completely, designers must also specify: the name for the stage or level, which must be descriptive; a natural language description of the stage or level; the number of players; the difficulty; the type of stage (strategy, puzzle, etc.); if it has group activities, if they are simultaneous (if all levels in the stage must be completed at the same time by group members), ordered (if levels are linked through an order relation and one level cannot be started until the previous one is completed) or non-ordered (if all levels in the stage can be completed in any order); resources available and resources needed to complete the stage or level (for example, a key to open a door, a potion or a game tool) and the sub-stages and Level Model in order to divide the stage into easier parts.

Once the Challenges, Stages and Levels in the video game are designed, all that remains is to decide which Video Game Itineraries ([D2.7]) will be available, similarly to the Educational side.

3.3. Phase 3: Relating Educational and Entertaining Content

In the third phase, relationships between elements in both levels (educational and entertaining) are established. Relations established in this phase determine the students' evaluation process, since relating a level or stage in the video game to a task or activity in the educational side means that completing the stage in the video game is approximately equivalent to learning the content in the educational task or activity. When we relate a Stage or Level in the Video Game to an Educational Task or Activity, a relation called Inter-level relationship ([D3.1]) is established between them.

Each Educational Task or Activity must be related to one or more Video Game Stages or Levels. However, not all Stages and Levels have to be related to a Task or Activity, since it is possible (and also necessary) that video games include Stages or Levels just for fun in order to maintain the interest and motivation of players.

Graphically, the result of this phase can be seen in Figure 1. In this figure, the lower level (LE) corresponds to Educational Contents (Educational Level). Oval elements in this level represent Educational Tasks or Activities, called Te_i, shown in Figure 1. As can be seen, relationships between these oval elements are established to squared elements from the Educational Level itself. These last elements represent Educational Goals and they are related to tasks and activities that contribute to overcome them with certain flexibility. As can be seen in Figure 1, relationships between tasks and goals are labeled with numbers and symbols. Numbers represent different paths to overcome a goal, and symbols represent if

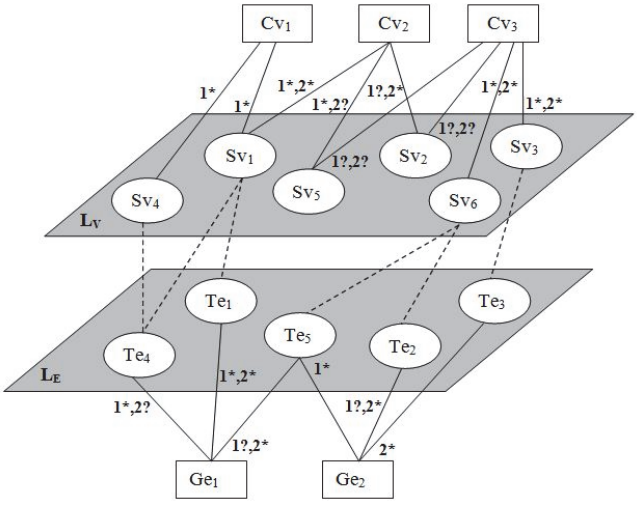

Figure 1. Relationships established between Educational and Entertaining Levels (Inter-level relationship, [D3.1]).
Source: The authors

the task or activity is optional (?) or mandatory (*). Moreover, since a task can be mandatory in one path but optional in another, 1* means that this task is mandatory in path number 1, but 1? means that the task is optional in this path. In the example in Figure 1 there are two paths for each Educational Goal (Ge_1 and Ge_2). For the Educational Goal Ge_1 in path number 1, Te_1 and Te_4 are mandatory but Te_5 is optional; and in path number 2, Te_1 and Te_5 are mandatory and task Te_4 is optional. This means that to achieve the Educational Goal Ge_1, a student must succeed in the tasks Te_1 and Te_4 or Te_1 and Te_5, with the remaining task being optional. Contents at this level have been defined in phase 1, but they could be modified in this phase according to the needs of a particular game.

The upper level (LV) corresponds to the Video Game Level, and it includes contents related to the video game being designed. Similarly to Educational Level, oval elements represent Video Game Stages and Levels, while squared elements represent Video Game challenges. Relationships between elements at Video Game Level also represent Stages and Levels that contribute to overcoming Video Game Challenges. Labels placed in the relationships have the same meaning as Educational Level.

Finally, relationships between both levels are represented in Figure 1 by dashed lines. For example, to learn content in Te_4, Levels Sv_1 and Sv_4 have to be played. On the other hand, Sv_6 contributes to learning contents both in Te_2 and Te_5. And, Sv_2 and Sv_5 have been included only for fun. As we can see, several situations can be represented by using the Inter-level Relationship.

3.4. Phase 4: Relating User Modeling

In the last phase, user modeling is performed, including information from the users and groups who will play the video game. These models are the internal representation of the individual users and users' groups inside the video game. And, in order to perform a far better adaptation, the users must be modeled from all possible perspectives. Since a user is a person, a student, a player and a member of a team, four perspectives are taken into account in our user models:

- General perspective: includes data that characterizes the student or group in a generic way. For example, name, age and gender of a person and number of members or date of creation for a group);
- Educational perspective: registers information that is useful in order to personalize the learning process a student or group will face. For example, some attributes in this perspective can be: proposed goals, faced tasks, etc.;
- Game perspective: details student's or group's characteristics and preferences in the game process. For example, in which devices the student has experience, what kind of game tasks he or she prefers, or, type of tasks in which the group obtains better results.
- Interaction perspective: shows how the student works when faced with a group task. In order to perform an analysis based on Social Networks (SNA) (e.g. [38]), we here record information about messages that students send and receive. However, information in the individual and group models is different. In the individual model, we only record the number of messages sent and received by the students, classified according to a previously defined messages categorization [39]. In this categorization, different categories designed on the Johnson and Johnson [33] proposal are presented: communication, collaboration and coordination. However, information for groups is focused on messages exchanged within the group, also classified according to our messages categorization [39]. For that reason, we store three matrices one for each of the categories (communication, collaboration and coordination), where the position ij represents the number of messages that member i has sent to member j.

This set of attributes is a general profile to maintain data about users. However, for each particular video game, more specific attributes can be added; as well as some of those previously explained can also be disabled if they are not needed.

During operation of the video game, some adjustments will be made based on the user model's attributes. Some of these adaptations can be seen in the Table 4.

The full design process is formally supported by a set of models presented in [40]. These models are divided into four categories: 1) Models for educational content, 2) Models for entertaining content, 3) General Goals and Task Model, and 4) User Modes. Of course, each of these sets of models is elaborated during the corresponding phase of the design process. complete and organize the required information. We currently have an earlier prototype of that tool.

6. Authoring tool to support the design process

Applying any design process can be difficult for inexperienced users. For this reason, we intend to develop a software tool to assist both teachers and designers to

Table 4. Some adaptations supported in the user modeling phase.

Perspective	Adaptation
General	Choosing an avatar with which the player feels identified. Choosing a visual interaction mode if the player has auditory dysfunctions.
Educational	Determining the educational itinerary that better fits the previous student's knowledge. Choosing a different educational itinerary if student's achievements are not as good as expected.
Game	Determining the game itinerary that better fits player preferences. Changing the game itinerary if student's abilities cannot match the difficulty of challenges proposed.
Interaction	Creating groups according to characteristics and motivation of members. Suggesting a role change between group members if results for the group are not positive. Changing a student from one group to another.

Source: The authors

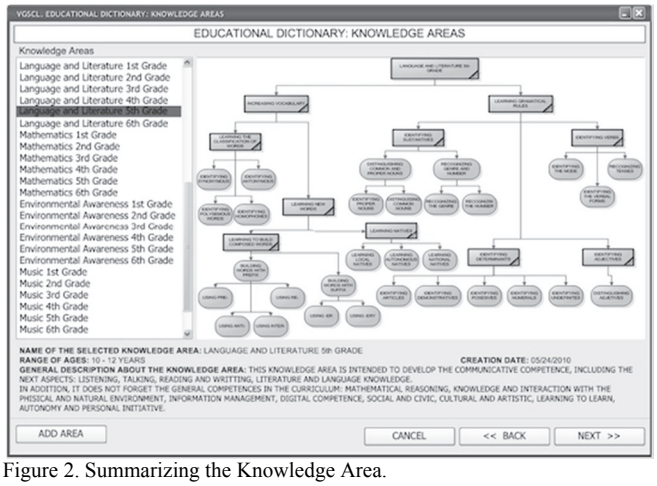

Figure 2. Summarizing the Knowledge Area.
Source: The authors

The tool we are proposing supports the complete design process and allows teachers and designers to include information about every item by typing information and dragging-and-dropping elements to relate each other. For example, supposing we have a Knowledge Area (phase 1, document D1.1) called "Language and Literature 5th grade", information about goals, tasks, challenges, etc. is also included by using specific interfaces (phase 1, documents D1.2, D1.3 and D1.4).

Documents D1.1 to D1.4 are defined, and the information can be seen summarized at the bottom of the Fig. 2. This representation shows the current state of the Knowledge Area and presents Educational Goals, Tasks and Activities as well as relationships between them. Goals are represented as squares (for example, "Learning Grammar Rules") while tasks and activities are represented as ovals (for example, "Recognizing the Genre"). When an element in this graphical representation is selected, its information is displayed in the lower side of the screen: name, range of ages, general description and, in general, the most relevant information, depending on the item that is selected.

In addition, a friendly interaction mechanism has been included in order to relate these elements (Knowledge Areas, Educational Goals and Educational Tasks), as is shown in Fig. 3.

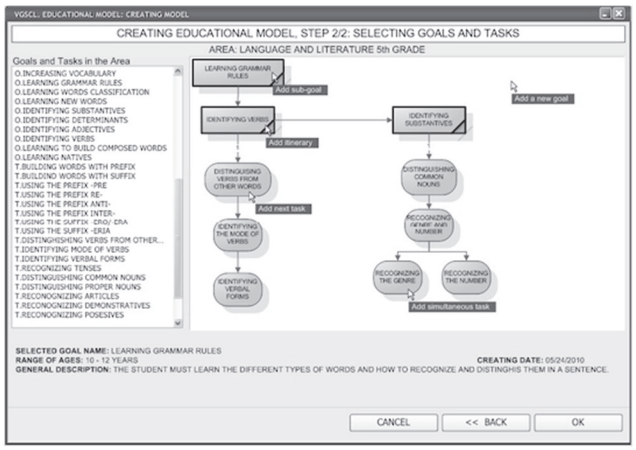

Figure 3. Building a new Educational Model.
Source: The authors

Fig. 3 illustrates how goals and tasks in the area "Language and Literature 5th grade" are being selected to complete a specific itinerary, which will form an Educational Model. In this figure, we can see "Step 2/2", since it is the last step in defining the Educational Model (phase 1, document D1.5). The previous step, "Step 1/2", had the objective of identifying the Educational Model by basic information such as name, description and the Knowledge Area to which it belongs.

In the above screenshot (Figure 3), several options to show how to relate elements are being displayed (only one of them can be accessed in the real tool, by clicking the bottom right of the mouse). For example, the option "Add sub-goal" has allowed the sub-goal "Identifying verbs" to be included in the educational goal "Learning grammar rules". The option "Add itinerary" has allowed itinerary 1 to be created for the educational sub-goal "Identifying verbs". Next, with the option "Add next task" the three tasks needed to achieve the sub-goal have been incorporated into the itinerary. Finally, the option "Add a new goal", which is not represented in any specific element, will allow other educational goals to be included in the Educational Model that is being defined.

In this example, only one itinerary has been created for each of the two educational sub-goals ("Identifying verbs" and "Identifying substantives"). Tasks in each itinerary are defined as sequential or simultaneous. Both options are represented in Figure 3: the first one with the aforementioned option "Add next task" in the "Distinguishing verbs from other words" task and the second one with the option "Add simultaneous task" in the "Recognizing the genre" task. The proposed tool will also support the definition of several Educational Models for a single Knowledge Area and the inclusion of several itineraries for each of the goals in an Educational Model. If several ways to achieve the goal are possible then each of the itineraries will be named using consecutive numbers.

To resolve the second phase of the design process, that is, the entertainment aspects, similar interfaces are used (phase 2, documents D2.1 to D2.5). The third phase, Relating Educational and Entertaining Contents, is then addressed by the prototype in the form shown in Figure 4. The right side of the figure shows the

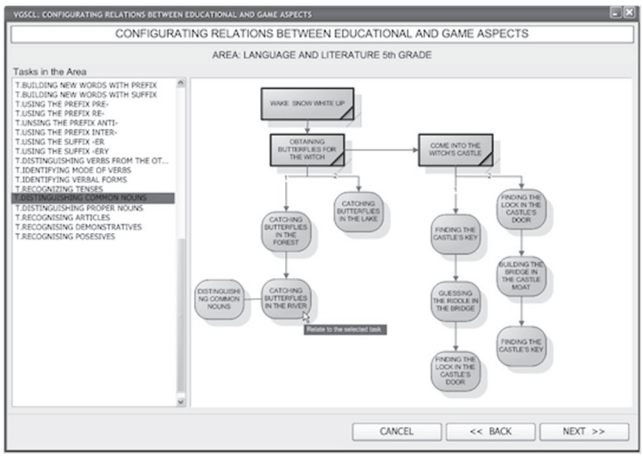

Figure 4. Defining the relations between Educational and Video Game Contents.
Source: The authors

entertainment contents, represented by means of a tree, where the rectangles represent Challenges and the ovals represent Stages and Levels of the game (leaf nodes are Levels). The left side shows the educational contents, presenting only the Educational Tasks in the current Educational Model (previously created). Teachers and designers work together by selecting a level in the Video Game Level and relating it to a task in the Educational Level. When an educational task is associated to a video game level, the educational task is included on the right side, joined by a line to the video game level and painted in pink to visually distinguish the instruction part from the entertainment part (phase 3, document D3.1).

When this phase has been carried out, the educational video game with collaborative activities will have been completely defined. The fourth and last phase in our design process is to model the users. To do this, personal data of each of the students must be included into the system. This process can be performed manually, but could be also supported by the designed tool. If the teachers want students to train for a specific goal or set of goals, then they can use the tool to assign goals to one or more students or groups in one step, simply by selecting them from the corresponding lists.

7. Conclusions and further work

The field of educational video games is being studied by different research groups around the world, for example by [41-45]. Studies have proved that using these kinds of tools is beneficial for students on both a personal and an educational level.

In this work, we have made an in-depth study of the state of the art to compare the strengths and weaknesses in the efforts currently being made to generate truly effective educational games. Consequently, we have argued the main elements that we consider necessary to design and model a learning system supported by educational video games with collaborative activities. Based on these, we have presented a design process specific to educational video games, with two main aims: 1) facilitating the work of the designer, which is in line with the trends proposed in [33]; and 2) involving teachers in the design, and, by doing so, promoting them to use educational video games as learning tools. By using the design process proposed in this paper, teachers and video game designers can obtain more balanced video games, in terms of educational and recreational contents, as they are independently designed and latter combined. Furthermore, features in this design process allow the teacher to maintain a record of educational achievements and group performance.

The design process presented here establishes a methodology that is divided into four phases, each of which is further divided into several steps. As result of each of these steps, we obtain one or more design documents. These documents describe the educational video game from different perspectives: educational objectives, game challenges, communication between players, etc.; and are a key resource in the design, development and subsequent maintenance of the educational video game.

In addition, in order to assist users in using our proposal, we intend to develop a software authoring tool. Thus, we have presented the first prototype in order to facilitate users understanding of how the design process is applied and to detect weaknesses in the further tool.

Our immediate future work is to refine and implement improvements to obtain the final version of the authoring tool as soon as possible. In addition, although this design process is independent of the platform, we are developing a specific platform based upon it called PLAGER-VG [17], which will integrate the presented tool as a design module. Accordingly, PLAGER-VG will allow for the design, execution and analysis of educational video games with group activities using the proposed models. Having a well defined design process allows the platform to maintain information about the educational progress of students as they use the different games included in the system.

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