Can SME Managers Learn from Games?

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ABSTRACT
Serious Games are especially useful for training because they offer immersive and engaging environment where users ‘learn by doing’. This trial and error based approach supports well learning and is able also to improve teamwork, social skills, leadership and collaboration. This article presents an ongoing project that was meant to design and develop a serious game that fosters the improvement of internationalization and language skills of SME managers. Initial results have been quite promising but there are still improvements to be made.

Categories and Subject Descriptors
H.5.1 [Multimedia Information Systems]
K.8.0 [Games]

General Terms
Algorithms, Design, Human Factors

Keywords
Game-based Learning, Serious games

1. INTRODUCTION
In the current socio-economic framework, there is a need for European businesses to show competitive capacity for development, for instance by establishing joint ventures with SME’s in other countries as there is a direct relation between more international SMEs and more growth and jobs. Internationalized SMEs show better performance and are more competitive, than non-internationalized SMEs, therefore internationalization supports business sustainability in the long term. This concern, evidenced in the EU policy, is also expressed by entrepreneurs and leaders of European businesses:

“A significant percentage of European SMEs loses business every year as a direct result of linguistic and intercultural weaknesses” [1]

“Longer-term business partnerships depend upon relationship-building and relationship-management. To achieve this, cultural and linguistic knowledge of the target country are essential “. [2]

In this sense, it is very important to develop intercultural and inter-communication skills of the current European managers, who intend to internationalize their companies to facilitate employability and European competitiveness. But at the same time it is necessary to alert and train future entrepreneurs (still in their role as Higher Education (HE) students) so that they are aware of this requirement.

However new forms of training are required to cope with the stress and speed of our society and the technological challenges if produces [3]. Serious Games focus on the specific design of games for the learning process, creating virtual scenarios representing professional contexts with interactive and immersive graphical environments [4]. Normally, these games follow a story, situation or context lines that portray a real issue. The added interactivity makes possible to assess the impact of the player’s actions, through its reaction to those specific situations in the virtual scenario[5]. But the most striking effect in the use of Serious Games is an increased motivation and engagement. This was seen in the all the sectors that currently use Serious Games like education, defense and health.

The GLOBALL game addresses SME managers and provides a context for the development of internationalization and language competences and skills. The game provides an innovative solution for self-based learning, related with identified needs of the target groups at international contexts.

2. GAME BASED LANGUAGE LEARNING
The GLOBALL game (Figure 1) has the following objectives:

- Reinforcing interpersonal and intercultural competencies relevant to the SMEs internationalization and e-marketing/e-commerce in order to facilitate competitiveness;
- Bridging the worlds of personal and cultural valorization within work by supporting SMEs managers and HE students throughout individual and flexible learning pathways;
- Developing the integration of learning with working life, promoting learning conducive environments at the workplace and work-placed training as the basis for the development of vocational skills relevant to the labour market.

![Fig. 1 The GLOBALL game](image-url)
The design and development of the game followed a set of stages, based on common development methodologies:

- Determining the crucial learning needs for SMEs internationalization (research and analysis phase), the basis for design the more relevant and common professional and cultural situations in that process;
- Designing and producing the role-playing scenarios, using real situations in professional contexts, meeting the needs of SME’s managers and other staff in international business-oriented enterprises;
- Developing the game platform and the game scenarios, available on online and mobile technologies;
- Ensuring the quality, functionality and suitability of the learning digital scenarios and platform by piloting testing actions involving key end-users.

2.1 Research and analysis
The objective of the initial research process was to characterize theoretically the six most relevant and common professional and cultural situations, in processes of SMEs’ internationalization. This was done by literature review, personal contacts (with academic experts, SME’s representatives and governmental business entities) and a focus group approach.

The major skills areas identified as required to do business abroad were the following:

- Legal and institutional environments;
- Markets and innovation;
- Tax and finances;
- International networking;
- Culture;
- E-commerce and e-marketing.

Specific situations (scenarios) identified for the above areas were mainly associated with cultural aspects when negotiating with firms from different countries/regions and with international networking when participating in international trade fairs. Depending on the countries/regions, the scenarios can vary completely (ex: logistics in Africa, transport in Eastern Europe, cultural aspects in Asia). In the end, the selected scenarios were:

- Diagnosing and awareness raising scenario to identify voids in the skills and competences of the managers and students
- Planning the participation in a fair
- Managing an international network
- Business culture and negotiation
- On-line communicating and collaborating
- Understanding funding, taxes and other legal aspects

In relation to the need for foreign language training, the situation seems to be difficult for the majority of Portuguese SMEs that might select Brazil and Angola as preferred markets for doing business, only because these entrepreneurs do not speak English. All agree that internal human resources assigned to work with international markets need to have a good level of English.

2.2 Design
The background story is of an entrepreneur that wants to internationalize his/her company into a specific market (Europe, Brazil). When the player starts the game he can choose between six different scenarios:

1. Pre-Internationalization / Situation: Diagnostics, Awareness
2. International Networking / Situation: Participation in fairs
3. Culture / Situation: Business and local culture
5. International Networking / Situation: On-line communication and collaboration
6. Legal environment / Situation: Institutional negotiation

Each scenario is independent (Figure 3), and is expected to take about one hour to be completed. Players can follow any scenario at any given point, and their status in each scenario is saved so that they can interrupt it, start a new one, and then restart the previous one where he/she left. They can also opt to reset a scenario and start from the beginning. Each scenario is composed...
by 4 to 6 locations, each corresponding to a horizontal scrolling background, containing characters and/or items.

In each location there are 3 to 4 challenges for the player to overcome, which can consist, for example, of speaking with other characters, interacting with the environment or solving custom mini-games. In order to progress to a new location the player must complete all the challenges of the current location. After 3 failed attempts to complete a challenge, a tip will be available to the player. The player will receive a score per challenge which will add up to give the player the complete score for each scenario. This way the player can repeat a scenario to achieve a higher score.

There is no losing situation. The player can always progress through the tip system. However the score reflects the choices of the player. In each challenge he receives an explanation on what he/she should have done, so that he/she can learn and score higher in the next attempt.

The game adopts a first-person point of view (POV) and the game play style is based on a mix between a point & click graphic adventure, a visual novel, and an RPG (Figure 4).

The game design style is based on a combination of photo realistic backgrounds and rendered 3D models of characters and objects. The idea is to get an environment as close as possible to reality but give the feeling of a game, at the same time.

The game is available in multiple platforms, like mobile devices (iOS and Android), desktop and online platforms.

It was also necessary to define a few technical requirements relating to the used media. Some examples of these requirements are presented next:

- Images in PNG with a maximum size of 2048x2048 each. The background always has 2048 pixels (height) but can have more than 2048 pixels wide to allow scrolling.
- Sound files in WAV with a sampling rate of 44.1 KHz and bit depth of 16-bit linear
- AVI format with the highest possible quality
- 3D Models should be supplied as backup for rendered images of objects and characters. Format should be .3ds or in an equally largely accepted format

Fig. 4 GLOBALL scenario 1

2.3 Development

The game development was done using the following tools:

- Unity3D
- C#
- .NET Framework
- Windows Forms
- Microsoft Visual Studio
- Git / BitBucket
- Audacity
- Blender

Fig. 3 GLOBALL navigation

2.4 Testing

An initial alpha testing stage allowed compiling some data concerning the assessment of the initial prototypes. This stage was conducted independently in 5 different countries but here we summarize the conclusions of all those tests. Participants were mainly researchers (30), students (18) and SME managers (17), 62% male and 38% female. Average academic age was 30.3 years-old and the managers were 38.6 years-old on average.

The main areas evaluated relate to the content, playability and usability:

Fig. 5 Content evaluation

All the aspects were considered positive. The lesser scored aspects relate to the development of skills and knowledge obtained from playing the game.
Fig. 6 Gameplay evaluation
The game play aspects were, once again, positive. The use of video and audio was the most negative aspect, logically, because the tested version did not include video clips.

Fig. 7 Usability evaluation
Again, the point related to video and audio usage was the most negatively marked one. The other aspects are positive although there were a few issues about the game installation.

Some qualitative comments related to what players liked more in the game:

- The mini-games
- Learning other cultures and the importance of entrepreneurial concepts
- How the actions are related and evolve throughout the game
- The game idea

And qualitative comments related to what players liked less in the game:

- Some parts can be very static
- The game can become repetitive
- The 3D models do not look natural
- Too much control of the user actions

3. CONCLUSIONS
The choice of a Serious Game approach as the basis for the development of language and internationalization skills ensures achieving a remarkable impact because Serious Games facilitate motivation and engagement. Without motivation there is no learning and the engagement that games produce is hard to match by any other training methods.

When the game structure is directly related to the learning objectives it is even more effective, since it combines the challenge of a game with a safe place to practice real-life skills, and most importantly to make mistakes and to fail. The contextual nature of digital game-based learning highlights its effectiveness partly because the learning takes place within a meaningful (to the game) context.

The GLOBALL game resulted from the combination of the expertise and experience of various qualified organizations active in the field of Higher Education, business and VET. This ensured the active involvement of key actors which will enhance the usage/adoption in the professional spheres. The game responds to actual needs in terms of promoting competencies for supporting the internationalization of Micro and SMEs. These identified needs are reflected in national policies where counteracting actual situation by means of innovative learning strategies of high quality and tailored to the characteristics and needs of SME managers is a vital aspect.

Initial testing results were positive but nevertheless some negative issues must be addressed. During September and October a new, more extensive testing stage will take place.

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Serious Game on Sign Language

ABSTRACT
The quantity of educational digital content available for the hearing impaired community is very scarce. However, due to extraordinary progress of the new technologies, remarkable opportunities to bring a better quality of life to the public in general arose. Making these opportunities available to those who endure handicap and disabilities is a core concern in today’s society and a must to promote equity and inclusion.

The target community addressed by our work, the hearing impaired community, has its own language, known as Sign language. The work presented in this paper consists in the development of a game to make the process of learning sign language enjoyable and interactive. In order to do this, a game was created in which the player controls a character and interacts with various objects and non-player characters with the aim of collecting several gestures from the Portuguese Sign Language. These gestures can then be represented by the character. This allows the user to visualize and learn or train the various existing gestures. To raise the interactivity and to make the game more interesting and motivating, several checkpoints were placed along the level. This will provide the players a chance to test the knowledge they have acquired so far on the checkpoints by using Kinect. A High Scores system was also created as well as a history to ensure that the game is a continuous motivating process as well as a learning process.

Keywords
Educational game, Gesture language, Sign Language Game development, Portuguese Sign Language

1. INTRODUCTION
The project consists of a didactic game about Portuguese sign language, where the player can enjoy the game while learning gestures simultaneously[1].

Kinect has also been integrated into the game [2] in order to make it more interactive and appealing.

The main objective of this project is to facilitate the learning of the Portuguese sign language and to improve the dexterity of those who already know it, making learning a pleasant experience.

The deaf community in Portugal is around 100 000 individuals and yet the digital content available for this community is still rather low. With this project, not only we are promoting the knowledge for this restricted community, but we are also encouraging other people to learn and become able to better understand this community [3].

The game is played in first person view. The player controls a character on the map.

Each map represents a level and each level has several scattered objects through the map for the player to interact with. All objects collected by the player will be stored in his inventory and can be accessed at any point during the game. Most of these gestures and objects can be used through the inventory; the character will then perform the gesture so that the user can visualize how it is done.

To progress in the game you must collect all the gestures scattered around the level [4]. The faster the player manages to collect all the gestures the higher his score will be.

The player could choose to play using Kinect but previously he must have first obtained all the gestures in the level and perform themselves.

It’s possible to find some projects related to this theme/area but none of them implies automatic bidirectional translation process as this game does.

1.1 Some of the related work being carried out by institutions and organizations are: CopyCat; ProDeaf; Beijing University; Faceshift.

1.2 CopyCat
The game CopyCat is the most similar project in comparison to this one. It consists of a game where sign language gestures need to be executed properly in order to proceed. The movement analysis is done through gloves with sensors. However, the researchers from the CopyCat project have published a video where they show their intention to use Kinect for movement detection.

1.3 ProDeaf
ProDeaf is a Software that does the translation of Portuguese text or voice to Brazilian gesture language.

The objective of the ProDeaf is to make the communication between mute and deaf people easier, making the digital content of companies accessible in Brazilian gesture language.

1.4 Beijing University
In Beijing a project which allows the recognition of gestures in gesture language through the Kinect was developed.

1.5 Faceshift
This software analyzes the facial expressions, the orientation of the user’s head and eyes. The information analyzed by the application is used to animate virtual characters that can be used in videos or games

2. FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS
In this session the functional requirements of the application will be described. Functional requirements represent the features available to the user.

2.1 Functional Requirements
The functional requirements were identified in the early process of the development of the project, and include the following:

Start Menu where the player can choose the type of game he wants (with or without Kinect), consult the options or exit;
Menu options where you can change the graphics quality, volume, save or load the game and see the table of high scores.

The game requirements within the levels are:

- Handling and control of the character;
- Interact with NPCs (Non-Player Characters);
- Consult the inventory and use the items in it;
- Interaction with map objects;
- Access to the above options menu;

### 2.2 Non-Functional Requirements

Regarding non-functional requirements, our work focused on the following:

#### 2.2.1 Usability

Usability is the ease of use of the application and its accessibility to the user [6].

With this in mind this project should be fairly intuitive, allowing easy adaptation and learning. The user interfaces must be simple so anyone can use them easily. The character controls must be simple, and throughout the game there should be explanations of what needs to be done.

The accessibility is guaranteed because it is only necessary to run an executable file in order to play while Kinect is not in use.

While playing using the Kinect two applications are required as well as the necessary drivers and assuring that the Kinect is properly plugged in.

#### 2.2.2 Performance

The gaming performance is always a factor of the utmost importance, because the response time from the game to the user is always immediate, any delay or decrease of the number of frames per second can affect the gameplay making the game frustrating rather than fun.

To maintain the performance this game was tested to never run less than 60 frames per second on an optimal computer. The ideal frame rate for a game must be around 40 frames per second. The essential functions must be constantly executed and the code must be optimized to avoid the waste of resources.

Besides the code all the factors that constrain the performance of the game should be taken into account, such as textures, bumps, number of vertices of the 3D models among others.

Based on all these factors the performance of the game is assured.

### 3. GAME ARCHITECTURE

For this project there were two applications developed, the game in Unity 3D and the interface that connects the VirtualSign to Unity. The interface was developed in Microsoft Visual Studio. The project is divided into layers, given its high degree of complexity.

At the top level there is the interface. All the functionalities of the project can be accessed through this layer by the user. This layer is responsible for forwarding the actions of the user to the next layers.

On the lower level there are three layers. The sockets layer is responsible for linking the Unity game application to the Kinect that is why this layer is below the interface in order to provide the layer above with the player input. Another layer of the lower level is the game engine; this layer is responsible for the execution of the game itself, representing the functions of Unity. Finally, there is the business layer, which is where the game functions are available to the player.

Figure 1 shows the layers of game.

![Fig 1. Layers of game](image)

### 3.1 Development

For the development of this project it was decided to start with the implementation of the basic functionality and then proceed to the animation of the avatar, which was later replaced by an animated avatar now available at GILT.

In the development of this project a draft was first developed implementing the basic functionalities, as shown in figure 2. After that the player avatar was animated, however it was then replaced by the one provided by GILT.

![Fig 2. The basic functionalities of the game](image)

After having a basic scenario created the development phase of the scripts started.

### 4. GAMEPLAY

The first script developed was the inventory script. The inventory stores the items acquired by the player and provides access to them at any time.

Then scripts to interact with the objects were created. These scripts were optimized to be reused for multiple objects without having to change the code [6].
Having been established some objects on the map with the script to be added the inventory proceeded to the creation of this graphical interface.

The map has objects and those objects contain scripts on them, the scripts the objects contain allow them to be added to the inventory of the player. Creation of the graphical interface was then started. The inventory consists of forty-two spaces that are empty upon initialization.

With the inventory set up and ready to receive the objects that the user can acquire, the handling of collisions with these objects was created in order to detect when the user is within a reasonable distance to perform the interaction.

4.1 Score
Players’ score are incremented during the game as they acquire new gestures.

The shorter the time it takes between the acquisition of two objects, the greater the score. If the delay is less than one minute, one hundred points are acquired, if it is between one and two minutes, fifty points are acquired, if the delay exceeds two minutes, twenty-five points will be obtained regardless of time spent.

Figure 3 shows the score of game.

![Score of the game](image)

4.2 Connect to Kinect
After finishing the structure of the game, the application to connect to Kinect was started.

Since this application would be an adaptation of the VirtualSign project, it was necessary to be developed in C# on the Microsoft Visual Studio environment due to compatibility reasons.

The VirtualSign application detects and translates the gestures that the user makes, saving the one with higher probability of success. With this in mind we needed access to this part application code in order to be able to send the necessary content to Unity. The connection method used was the socket as Unity supports .NET Framework. For this connection the use of an API that makes the connection in Unity and Development was needed.

An application where relevant text would be sent was also developed.

For this application the official Unity Sockets example was adapted, and a window was created where the user could see the connection status. This window runs on the thread so it does not directly affect the performance of the recognition application.

To make the connection, the IP address and port are needed. This information is sent to the API and this will make the connection which will return a message acknowledging the success or failure of the operation. This API is entitled SharpConnect.dll. This DLL file was slightly modified in order to work properly based on the functionalities that were developed.

After the connection has been established, the information from Kinect is received and analyzed. This then confirms if it is the information we were expecting. If it is not, then the user will be notified of what gesture he did and which gesture was expected.

It will only be possible to proceed when the user manages to perform the requested gesture correctly.

5. CONCLUSION
The development of a game is always a complex task to do and many adversities were faced along the way. A lot of effort and time were needed to get outdo this challenges, and a fair amount of knowledge was acquired during this process.

The selection of this target population arises due to the growing number of students with special needs who complete the elementary and high school and come to higher education. This situation demands for new means that allow these individuals to have easy access to educational digital content. In order to motivate them towards the learning process we have created a game that combines the sign language learning process with the pleasant feeling of playing a digital game.

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7. REFERENCES
A Model for Implementing Learning Games on Virtual World Platforms

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ABSTRACT

The virtual worlds can be used to achieve different purposes according to the intended use. The design of games for learning under platforms virtual worlds has been an important research field for several years. However, the research in this specific field has shown that in most of the cases, the environments do not have appropriate technical characteristics. The development of the games for learning under platforms virtual worlds has as goal to produce environments that encourage users to achieve effective learning. In this sense, the current study presents a development model for implementation of games for learning under platforms virtual worlds. This model is based on the engineering software techniques and methods. It is supported by a spiral cycle that allows us to develop applications. The process is divided into a set of activities that are being carried out throughout each cycle, producing several work products, with the aim to provide each team member a set of guidelines and tools necessary for to make intelligent decisions about what they do.

The model includes five steps, namely: Conception, Analysis, Design, Implementation and Evaluation. Each step contains a set of diagrams to support the developer team in their tasks. With this model, the applications are developed in a series of incremental releases, that is, the final system is constructed, based on the refined prototype. These steps include activities that enable to quantify the quality of games for learning. It is based on the Quantitative Evaluation Framework developed by Escudeiro [2], and allows us to have a degree of freedom in the selection of quality criteria. Thus, we can obtain a single quantitative value of quality for any domain in analysis, i.e., we can adapt it in any domain and valence.

Categories and Subject Descriptors
H.5.1 [Multimedia Information Systems]
K. 3.0 [Computers and Education]

General Terms
Design, Measurement, Human Factors

Keywords
Engineering software, assessment, game based learning.

1. INTRODUCTION

Games for learning refer to different kinds of software applications that use games for learning or educational purposes. These games applications can include fully immersive environments (or ‘metaverses’), such as Second Life where 3D graphics capabilities are providing opportunities for learners to take on virtual presence in virtual worlds [1]. Based on these assumptions, the games must be built taking into account some characteristics, such as instructions strategies, activities learning, communication, interactivity, type of media, contents, and met In most games for education, these characteristics do not exist or have only some of them. This situation is mainly due to the lack of a organized systematic development process that assure the stimulation of new ideas, supported by the communication among the different elements of the development team or also because the developer team usually does not take account all phases of the software life cycle.

In order to overcome these gaps, we decided to propose a design strategy that meets the purpose of the software process, i.e., that determines the order of the different system development phases and the evolution and the transition criteria between them. It is our intention that the design model covers all the development needs and provides a sufficient semantics of how to work properly all critical aspects of games for learning. The model must be easy of use and it must aid to understand the system design; to stimulate new ideas, supported by a language that facilitates communication among the different actors of the development team; to promote the good practices, namely those that rules the engineering software.

The present paper is structured in three sections. The section 2 describes our design strategy and in section 3, we draw some conclusions about the design strategy.

2. DEVELOPMENT METHOD

The games for learning developed in virtual worlds platforms typically include complex information, and may allow sophisticated navigation behavior. The Method of Development of Games for Learning implemented in virtual worlds platforms uses abstraction and software engineering techniques to, on one hand, allow a concise description of complex information items, and on the other hand, allow the specification of the complex navigation patterns and interface transformations. It is based on several assumptions, namely: promotes an organized structure by steps, where the activities are identified and also their rules; provides an adequate semantics of how to work properly all the critical aspects that have been highlighted in games for learning in virtual worlds; and encourages the creation of new ideas supported by the communication among the different elements of the development team.

Given the complexity of games for learning in virtual worlds platforms, it is important to do several revisions during the conception phase. The modification of some game aspects leads us to different dynamic behaviors in order to have a life cycle model that allows modifications throughout its specifications. Also, it is necessary to look for the previous phases as well as for the improvement and exploitation of the solution space.
The Model includes a series of five main steps, each of which breaks down into subtasks giving rise to a set of diagrams: The model is supported by an iterative process that will help us to produce candidate solutions that we can further refine by repeating the steps, creating an application that best fits our needs. At the end of the process, we can review and communicate your game to all interested parties. Figure 1 summarizes the steps, products, mechanisms and design concerns in MDGL.

Figure 1. Method Design for Games form learning

The model is based on the spiral model and the game will be evaluated on each iteration. The goal of this step is to minimize the risks and the consequences of any change that may arise during the developing process.

The game for learning will be assessed by using the evaluation model proposed by Escudeiro [2], called Quantitative evaluation Framework (QEF). We chose this framework because it allows us to identify a set of requirements for the game. The figure 2 shows the evaluation process of the MDGL.

Figure 2. Model of process evaluation

The model considers that the assessment should be carried out by a multidisciplinary team of evaluators, which comprises:

- Teacher (Educator) – The teacher is responsible for making the evaluation of instructional aspects;
- Development Team – The team will be responsible for the technical assessment, such as adaptability, interoperability and security access;
- Users (students) – They will assess the features that are able to assess, for example the environments’ usability and functionality.

3. CONCLUSION

The development of games for learning under virtual world platforms is a complex task since it requires knowledge on different fields such as human-machine interface, design, and education. In this sense, we decided to develop a model that (1) facilitates the communication between all team members and (2) whose flexibility can be used for the whole game lifecycle or just for a set of processes.

The model covers all phase’s lifecycle of software development, using different software engineering techniques.

Also, the model is supported by an evaluation model, which is applied during the assessment step. The main objective is to structure the process of assessment based on the Quantitative Evaluation Framework [2], because it allows measuring quality of the final product, and evaluating the systems quality at any moment during its lifecycle.

However, we recognize the need for perform a rigorous evaluation of the influence of these games (developed by this model) in respect to success or failure of students;

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A serious game development process using competency approach. Case Study: Elementary School Math

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ABSTRACT
Development of digital resources is difficult due to their particular complexity relying on pedagogical aspects. Another aspect is the lack of well-defined development processes, experiences documented, and standard methodologies to guide and organize game development. This research proposes a Game Development Process founded in the traditional Software Engineering paradigms and complemented by previous efforts on large scale development of digital learning resources. This process matches a formal competency to an educational digital resource (video game), with which the formal learning process will be complemented to improve the way students learn in Mexico. Through a case study will be demonstrated its utility by implementing the process in the whole of mathematics competencies for sixth grade of elementary school. The result of applying the proposed process for study case, is producing a collection of video games attached to the competencies and knowledge areas specified for sixth grade of elementary school in Mexico by the Ministry of Public Education.

Keywords
Game development process, serious games, software engineering, development process design.

1. INTRODUCTION
“A large scale development of digital learning resources involves the creation of a large number of these educational resources with a time limit, usually with the aim of supporting one or more educational courses.” [1]

As mentioned in [2] and [1], a large scale development of digital learning resources involves the creation of a large number of these educational resources with a time limit, usually with the aim of supporting one or more educational courses. Some of the reasons why it is not often the large scale development of digital resources is the difficulty of developing these resources, as they are resources with particular complexity by relying on pedagogical aspects.

Another aspect is the lack of well-defined development processes and experiences documented [2] [1]. Lack of standard methodologies to guide and organize game development can result in longer and less predictable game production processes.

Moreover, the need for interaction among domain experts (providing the instructional content) and game developers is a peculiar aspect of educational games that makes their development more difficult [3].

Game development in an educational environment have to face some severe restrictions in the development process compared to professional game development. Obviously, students have to get along with far fewer resources. This implies manpower, development time, and budget. Additionally, they are less experienced and some of them never worked in a team before, which introduces some extra demands on the collaboration aspect of the software. [4]

However, despite the existing difficulties, in video games lies a viable means to solve the current problems of education, creating materials that support the knowledge acquired in the classroom, extending the classroom beyond the physical limits of the educational institution and allowing students to have an improvement in the way of learning through the use of these resources.

This research is focused on large-scale production of games, the resolution of problems related to such production and present a solution to the lack of production processes for large-scale games.

2. SOFTWARE PROCESSES
An ideal process is one that “is a set of activities, which consist of tasks specified by procedures how people should use tools / equipment and apply these procedures to produce a final result expected.” [5].

A software process from the point of view of Software Engineering is a set of activities and associated results that produce a software product on time and rationally [6]. The software process forms the basis for the control of the management of the software projects and provides the context in which the technical methods are applied, the work products are generated, the fundamentals are established, the quality is ensured, and the change is handled appropriately [7].
There are four fundamental activities of processes that are common to all software processes [6]: Software specification, Software development, Validation of the software and Evolution of software.

Software quality is the set of attributes that characterize and determine its usefulness and existence. Quality is synonymous with efficiency, flexibility, accuracy, reliability, maintainability, portability, usability, security and integrity. Software requirements are the basis of the quality measures. The lack of consistency with the requirements is a lack of quality [7], and a project meeting all the requirements is a quality project.

Standards or methodologies define a set of development criteria that guide the way we apply software engineering. If there is still no methodology will always be poor quality. In other words, high quality process will produce high quality products.

There are some implicit requirements or expectations that are often not mentioned, or are mentioned in an incomplete way (e.g. the desire for a good maintenance) may also imply a lack of quality.

3. GAME DEVELOPMENT

3.1 Game Types

Clark Aldrich [8] establishes that there is some overlap in the uses and structures of virtual worlds, games, and simulations and the three often look similar, their differences are profound.

1. Educational simulations use rigorously structured scenarios with a highly refined set of rules, challenges, and strategies which are carefully designed to develop specific competencies that can be directly transferred into the real world.

2. Games are fun engaging activities usually used purely for entertainment, but they may also allow people to gain exposure to a particular set of tools, motions, or ideas. All games are played in a synthetic (or virtual) world structured by specific rules, feedback mechanisms, and requisite tools to support them – although these are not as defined as in simulations.

3. Virtual worlds are multiplayer (and often massively multiplayer) 3D persistent social environments, but without the focus on a particular goal, such as advancing to the next level or successfully navigating the scenario.

He suggest all three are points along a continuum and all of them belong to highly interactive virtual environments (HIVE’s).

Alke Martens and his colleagues believe that game-based training (their terminology for serious games) requires a game, simulation and learning aspect in almost equal measure.

Mike Zyda believes serious games can be distinguished from leisure games by the addition of pedagogy to the three main elements of computer games: story, art, and software. However, unlike Martens et al. he also states the pedagogy, which educates or instructs, must be subordinate, rather than equal, to the game play and story in his definition. Serious games rely on the relationship between these factors, the learning is dependent on the pedagogy and game. [9]

3.2 Game Development Processes

Masuch establishes that a typical game development process consists of the following steps [4]:

1. Developing the core idea
2. Writing a game concept
3. Producing the artwork
4. Programming the game engine
5. Game content production
6. Play testing
7. Balancing and bug fixing

Ibrahim in [10] proposes an Educational Game Design Model that indicates that the game production is divided into the main stages (a) Game design, (b) Pedagogy, and (c) Learning content modeling. But this proposal do not clearly indicates how those stages interact and which are their inputs and outputs.

Zin et al. in [11] proposes an Educational game design that consists of four main elements: interaction, knowledge, engine and level. But they do not have a structured process that guides to the reader from a starting point in the process to the end where a game is a finished product.

In[9] is presented the RETAIN Model which “was developed to support game development and assess how well educational contain academic content.” This model proposes a work schema based upon six areas (see Table 1) the designer or teacher/trainer needs to consider once the learning goals have been defined.

In 2004 Sara deFreitas and Martin Oliver proposed a set of four interrelated elements that could be used by: (1) educators to select appropriate simulations and games as teaching tools, (2) researchers to assess serious games, and (3) educational designers to consider educationally specific factors.

| Table 1. Required aspects for appropriate serious games |
|-------------------|--------------------------------------------------|
| Aspect            | Description                                      |
| Relevance         | i) presenting material in a way relevant to learners, their needs, and their learning styles, and ii) ensuring the instructional units are relevant to one other so that the elements link together and build upon work |
| Embedding         | assessing how closely the academic content is coupled with the fantasy/story content. |
| Transfer          | how the player can use previous knowledge in other areas |
| Adaption          | a change in behavior as a consequence of transfer |
| Immersion         | the player intellectually investing in the context of the game |
| Naturalization    | the development of habitual and spontaneous use of information derived within the game |

Although a number of proposals exists, none of these proposals has clarified how to produce a video game from the initial need for pedagogical considerations (deFreitas and Oliver’s framework), considerations of the game play and story (Mike Zyda), the design of game-based training (Alke Martens) or the implementation of HIVEs (Clark Aldrich). In addition to this, it has not reached an agreement on the components that integrate a serious game.

4. SERIOUS GAMES DEVELOPMENT PROCESS

In the next figure (see Figure 1) can be seen the Serious Game Development Process proposed by this research, which one is described in the next paragraphs.
This Game Development Process is founded in the traditional Software Engineering paradigms and complemented by previous efforts on large scale development of digital learning resources.

The game development process proposed provides developers and game designers with a process that will lead them clearly through the production of an educational video game, and in this way, have a map of the steps from conception of an idea to the release of the game, something that until now it was available only in internal documents of the major game development companies.

The game development process also provides a framework for the integration of experts from different disciplines to develop an educational video game, such as graphic designers, programmers, instructional designers, content developers, educators, project managers, project leaders, to name a few.

Based on the literature review and previous research in the field of digital educational resources, this process establishes a serious game must have the following elements, regardless of their purpose (training, education, etc.) and its competencies:

1. **Pedagogic aspects**, which include: learning needs of the individual or group of individuals, the social and cultural context of the individual or group of individuals and learning methodology (includes consideration of the learning model and learning styles). This aspect covers the elements "Pedagogic considerations", "Learner specification" and "Context" proposed by deFreitas and Oliver. All these aspects are covered by the Requirements Stage.

2. **Technical aspects** including considerations for game-play and story (Mike Zyda), and level of fidelity, interactivity, immersion, fun, etc. All these aspects are covered by the Requirements Stage.

3. **Integration aspects** including considerations for game-based learning (Alke Martens), considerations for inclusion of materials in formal classes, and considerations of context for the implementation of digital educational resources (deFreitas y Oliver). All these aspects are covered by the “Integration and Implementation of Games” activity.

The game development process proposed has a unique feature against other proposals, is developed from the point of view of Software Engineering, which allows to implement the process in a transparent way because the game is considered as a software product, so that a company dedicated to software development can deploy it easily and efficiently. It is important to emphasize that the process is independent of the development platform to be used, the specific techniques and pedagogical models to be implemented in the game, in other words, the game development process was designed to be implemented independently the type of product to be developed.

Finally, the game development process also provides, at the stage of requirements, the ability to develop products that tell teachers how to integrate the game with their classes.

### 4.1 Process Stages and Activities

#### 4.1.1 Requirements Stage

The objective is to set goals that will cover the game; to establish the pedagogic mechanisms, across which the knowledge will be transferred to the students; to determine the competences and the knowledge areas that must be covered; and to create storyboard and concept art. Inputs: Game objectives, Pedagogics, Required competencies. Outputs: Game Design Document [12]


4.1.2 Diseño del Juego Serio

Sus objetivos son crear todos los recursos digitales necesarios para la creación del juego. Estos recursos digitales incluyen: ilustraciones 2D, modelos 3D, Mapas, Objetos, Materiales, superficies, etc., sonidos y música; y crear el motor del juego si es necesario. Input: Documento de Diseño del Juego. Outputs: Documentación de Arquitectura, Recursos digitales, especificaciones del motor.

4.1.3 Desarrollo del Juego

El objetivo de este paso es crear el juego incluyendo: Layout, Events, Shader, y AI; para jugar el juego; y combinar todos los elementos con menús, opciones, etc. Inputs: Documentación de Arquitectura, Recursos digitales, especificaciones del motor. Outputs: Juego Serio.

4.1.4 Prueba del Juego

Sus objetivos son probar el juego en los siguientes aspectos:

Técnico, absorción del conocimiento, Usabilidad, Útil; para obtener eficiencia estadística; y para mantener el juego. Inputs: Juego Serio, plan de prueba. Outputs: Resultados de la prueba, plan para mejorar, plan de acciones correctivas.

4.1.5 Postmortal de Juego

El objetivo es analizar todo el proceso y la información recogida durante el desarrollo del juego para mejorar el futuro desarrollo. Inputs: Resultados de la prueba, plan para mejorar, plan de acciones correctivas. Outputs: Mejoramiento de las acciones correctivas.

4.2 Calidad de los Juegos Serios

Velázquez en [14] menciona que la calidad de un recurso educativo digital cubre varios aspectos del desarrollo de software usando un paradigma orientado a objetos, y los aspectos relacionados con la pedagogía. Por lo tanto, se identifica la existencia de parámetros pedagógicos y técnicos, y los aspectos de usabilidad y contenido, que se consideran como aspectos que determinan la calidad.

Los aspectos pedagógicos incluyen todo lo que facilita el proceso de enseñanza-aprendizaje, como ejemplos, evaluaciones, autoevaluaciones, retroalimentación, y una objetividad pedagógica expresada bajo cualquier taxonomía, como Bloom’s Taxonomy.

La relación entre los métodos de enseñanza y la calidad del recurso depende del estilo del usuario, por lo que se recomienda que los recursos digitales incluyan audiológicos, visuales y cinestésicos, recomendación de que los videojuegos cubran perfectamente.

En los elementos, los que dan información sobre la complejidad del tema y el nivel de detalle que aborda el contenido.

Los aspectos técnicos incluyen reutilización y adaptabilidad, así como aquellos establecidos por el ingeniería del software y utilidad, confiabilidad, y otros.

Los aspectos de usabilidad (establecidos en Ingeniería del Software) de un recurso digital se centran en la presentación de información (letras, colores, tamaños, etc.) y la disposición de los mismos (simétricamente, asimétricamente, utilizando espacio positivo y negativo, etc.). Desde el punto de vista del software, la usabilidad de los videojuegos es el uso eficaz y el aprendizaje de un objeto creado por los humanos.

Teniendo en cuenta los aspectos de la calidad para los juegos serios, y el análisis literario de los videojuegos y los objetos de aprendizaje, un conjunto exhaustivo de características que representan un buen punto de partida para lograr un producto usable con una buena calidad de calidad se identifican:

1. Corto y enfocado en un solo área de conocimiento para garantizar la portabilidad del videojuego. En el caso de un Juego de Escenario se puede implementar todo el conocimiento de una competencia a través de un juego de mini-juegos o en un solo juego.
2. Interfaz gráfica del usuario con diseño estético y minimalista, amistoso, y pedagógicamente evaluado;
3. Casos con razonamiento formal;
4. Casos aleatoriamente generados para evitar que el estudiante memorice las respuestas a los problemas;
5. Desafíos de contenido y generación de competencia entre estudiantes usando el juego, es decir, casos con diferentes niveles de dificultad.

Entonces, el cumplimiento de los requisitos debe ser asegurado para garantizar la calidad del producto. La cumplimentación con los requisitos debe ser asegurada desde diferentes perspectivas: pedagógica, educativa y lúdica.

Este “Gestión de Requisitos de Juegos Serios” no fue encontrado en la revisión de la literatura, pero en la próxima sección se presenta un proceso para matizar un competencia con un formato no-formal, identificando los aspectos y factores que deben ser implementados en la producción de un juego que satisfacientemente cubra la expectativa de la competencia dentro de un grado de calidad y garantice la calidad del videojuego a través del cumplimiento de los requisitos. Este proceso se conoce como descomposición de competencias, y es un camino probado para lograr la producción de un recurso educativo digital.

4.3 Descomposición de Competencias

Para llevar a cabo la producción de videojuegos, la descomposición de competencias debe ser implementada como se muestra en la siguiente figura (ver Figura 2). Basado en la revisión de trabajo en [13] y [14] la definición usada en este estudio para competencias es la siguiente: “Competencias son recursos mentales de los individuos que son usados para realizar tareas, adquirir conocimiento y lograr un buen desempeño en algunas habilidades con un nivel de competencia.”

<table>
<thead>
<tr>
<th>Competencia</th>
<th>Competencia</th>
<th>Competencia</th>
</tr>
</thead>
<tbody>
<tr>
<td>K.A. 1</td>
<td>K.A. 2</td>
<td>K.A. 3</td>
</tr>
<tr>
<td>K.A. 4</td>
<td>K.A. 5</td>
<td>K.A. N</td>
</tr>
<tr>
<td>Game Scenario (integración de n mini-juegos, uno por cada área de conocimiento)</td>
<td>Game 4</td>
<td>Game K</td>
</tr>
</tbody>
</table>

*Figura 2. Descomposición de competencias.*

Para lograr la portabilidad de videojuegos y ser capaz de integrarse de manera independiente en clases formales, se busca que se encuentre enfocado en una área de conocimiento. En este caso, un escenario (que integra diferentes juegos a través de un formato comunes) se crea para cubrir una competencia. Incluso un escenario podría integrar varias o solo una fracción de diferentes competencias, dependiendo del caso concreto.
In the next figure (see Figure 3) an example of the implementation of the competency-based decomposition process is shown.

5. DEVELOPING SERIOUS GAMES
As a proof of concept of the presented process the research team conduct a study case using as scenario “the competency-based decomposition of all the official math competencies for sixth grade Math for elementary school in Mexico”.

![Image](image-url)

**Figure 3. Competency-based decomposition example.**

The first step to develop a serious games is identify the objectives, pedagogic aspects and the competencies to implement in the serious game, so the team identified a set of competencies for mathematics learning for sixth grade in elementary school in Mexico. This activity consisted in a deep review of syllabi and textbooks contents distributed by the Mexican Ministry of Public Education. After that, the team applied the Competency-based decomposition approach in order to establish the set of knowledge area, which should be covered by the developed serious games, see Table 2.

<table>
<thead>
<tr>
<th>Competency</th>
<th>Knowledge area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The numbers, relationships and operations</td>
<td>Operations</td>
<td>Use basic operations to reach a particular goal. Resolve operations mentally and prioritize them.</td>
</tr>
<tr>
<td></td>
<td>Decimal system</td>
<td>Operations and use the decimal point.</td>
</tr>
<tr>
<td></td>
<td>Fractions</td>
<td>In relation to a unit, determine what fraction corresponds to certain questions.</td>
</tr>
<tr>
<td>Geometry</td>
<td>Shapes and polygons</td>
<td>Relate the figure appearing under his name respectively.</td>
</tr>
<tr>
<td></td>
<td>Handling of solid figures</td>
<td>Creation of new figures from points or other basic shapes</td>
</tr>
<tr>
<td></td>
<td>Cartesian plane</td>
<td>Find an objective from the motion within a plane.</td>
</tr>
<tr>
<td>Measures and Conversions</td>
<td>Lengths</td>
<td>Application and comparison of the measurement units of length.</td>
</tr>
</tbody>
</table>

Once competencies are identified the next step is to set objectives, pedagogical, content and learning activities that will be integrated into the serious game. With this information proceeds to develop the conceptual art and game play. Subsequently, the digital resources for programming the games, including characters, environments, levels, items, etc. are made. Then, these resources are integrated into the graphics engine or game production tool, and performs programming of the products. Finally, testing is performed and the collected information is analyzed.

Competencies shown in Table 2 lead us to create a through the presented process a collection of 50 serious videogames oriented to increase learning encouraging appropriation of specific math-competencies. An extract of this list is shown in Table 3.

<table>
<thead>
<tr>
<th>Video game</th>
<th>Competency</th>
<th>Knowledge area</th>
</tr>
</thead>
<tbody>
<tr>
<td>pokeMath</td>
<td>The numbers, relationships and operations</td>
<td>Operations</td>
</tr>
<tr>
<td>Math Challenge</td>
<td>The numbers, relationships and operations</td>
<td>Operations</td>
</tr>
<tr>
<td>DS3A</td>
<td>The numbers, relationships and operations</td>
<td>Operations</td>
</tr>
<tr>
<td>SpaceMath</td>
<td>The numbers, relationships and operations</td>
<td>Operations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume</th>
<th>Application and comparison of volume measurement units.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight/mass</td>
<td>Application and comparison of the measurement units of weight/mass.</td>
</tr>
<tr>
<td>Perimeters</td>
<td>Determining the shape of geometric figures from its dimensions.</td>
</tr>
<tr>
<td>Areas</td>
<td>Determining the area of shapes based on its dimensions.</td>
</tr>
<tr>
<td>Time</td>
<td>Application and comparison of the measurement units of time.</td>
</tr>
<tr>
<td>Information processing</td>
<td>Graphic representation of results</td>
</tr>
<tr>
<td>Processes of change</td>
<td>Patterns</td>
</tr>
<tr>
<td>Values of unity</td>
<td>Find an objective from certain indications of a plane.</td>
</tr>
<tr>
<td>Cross product</td>
<td>Application of operations using the cross product.</td>
</tr>
<tr>
<td>Percentages</td>
<td>Use percentages for achieve goals.</td>
</tr>
<tr>
<td>The prediction and chance</td>
<td>Combinations</td>
</tr>
<tr>
<td>Odds</td>
<td>Application of operations through chance games.</td>
</tr>
</tbody>
</table>
5.1 Testing the Games

After the initial production phase of educational video games, the team proceeded to test them in order to study the impact on the learning level of students exposed to this learning strategy. Participants consisted in a group of 29 students from sixth grade of elementary school from the “Federal Rural Cuauhtémoc Elementary School” (Figure 8) located in La Paz, Ojuelos, Jalisco. Children studying in this school come from families just as scarce resources. This community has many needs, and to increase the use of IT access to information technology helps to alleviate some of them.

The process performed for the test was as follows [15]:

1. Identify potential schools.
2. Tests were designed for initial and control evaluations. The tests were designed to evaluate knowledge level of students in the next knowledge areas: Areas, Handling of solid figures, Fractions, Shapes and polygons, and Crossed product.
3. School was selected.
4. Students group was selected. The group was divided into two parts; taking into account that in both groups, students’ average grade must be equally distributed, i.e., the group was divided according to the average grades of the students.
5. Initial evaluation was applied to all students.
6. The test group used video games in one-hour sessions twice a week for four weeks.
7. At the end of eight sessions, a control test was applied to identify the impact of video games use.
8. The collected data were analyzed with SPSS software.

The team obtained linear regressions of each knowledge area by applying statistical analysis on collected data. This information allow the team to determine trends in scores comparing the results before and after educational video games use.

The overall findings of our study are graphically depicted in Figure 9 where dotted line displays the results obtained in the first examination. Solid line displays the results of the evaluation performed after serious games use.

The team was able to observe significant improvements in three knowledge areas (Handling of solid figures, Areas, and Shapes and polygons). Meanwhile, the area of knowledge “Fractions” has a slight rise in the scores. These enhancements are strongly related to the use of serious games that helped both, decreasing the frequency of low scores, and increasing the frequency of higher scores. The bigger discrepancy was found in the scores from knowledge area Crossed Product where we observed a mild decrease in the scores.

5.2 Discussion
We think that the improvement in the scores achieved in knowledge areas “Handling of solid figures”, “Areas”, and “Shapes and polygons” shows that the use of video games help to improve the knowledge level of students who use them. The results mentioned above show a strong trend of improvement in the level of knowledge in the considered knowledge area.

Related to knowledge areas with low scores we observed some interesting aspects that certainly could have a negative influence in the scores. In the case of “Fractions”, the staff responsible for conducting the tests observed that the video game graphic design was unattractive to kids, resulting in little interest in using the game by the students. The game related to the knowledge area “Crossed Product” had a different condition, in this case the problems presented by the game were not randomly generated, but the game had a question bank which students were able to memorize. This specific situation allowed students have high scores when they played the game, but getting the opposite in the test.
6. CONCLUSIONS
This research focuses on the creation of a serious game development process, which, through a competency-based decomposition approach has succeeded in producing a collection of serious games that have achieved an improvement in student learning.

This research has also shown that the production of serious games can be managed from the point of view and with techniques of Software Engineering, achieving a successful integration of the different actors in the production of a digital resource.

The literature states that a quality process generate quality products, therefore the questionnaire SUS (System Usability Scale) was performed, showing that the product has quality so the process is well designed.

The results obtained from the study case show that serious games represents suitable resources for teaching in elementary schools, since children are very interested in their use. Similarly, we could observe that the use of serious games increases the level of knowledge of students significantly in a short period of time. In this vain, it is possible to visualize higher learning levels in students if this strategies were applied in a continuous way by teachers and along the scholar year.

The research also reflected the importance of ensuring well-designed serious games, from internal code through the user interface, which directly impact on the interest of kids on the game having repercussions on the level of use. All details must be carefully considered, analyzed, developed, and evaluated, otherwise the generated products will not ensure student learning, resulting in low absorption of knowledge and poor performance by students, even worst, the videogame content could confuse kids and prejudice over helps.

7. REFERENCES
TimeMesh: Producing and Evaluating a Serious Game

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ABSTRACT

Serious Games are specifically designed to develop mental abilities and skills such as strategy, mental calculation and decision making but the acquisition of deep knowledge with Serious Games is less well understood. To improve this understanding, a game called TimeMesh, as well as the needed graphic engine, called TimeMesh engine, -a multiplayer graphical adventure engine inspired by the 90s graphic adventures created by LucasArts- have been developed. Time–Mesh has been designed to impart knowledge and competences in the area of History and Geography.

To test the acquisition of knowledge with Time-mesh a complete process of evaluation was designed, divided in three parts, always with user intervention: first, with the game developers, then with teachers and lastly, but most importantly with students.

In this paper we present our experience in designing, implementing and evaluating TimeMesh and formulate the conclusions of this study.

Categories and Subject Descriptors
L.0 [Assessment/Evaluation/Measurement]: L.3.5—Online Education

General Terms
Design, Measurement, Human Factors

Keywords
Serious Games, Graphic Adventures

1. INTRODUCTION

Computer games have wide acceptance among younger learners for their challenging design but also for the social interactions they generate (especially web through online games). Serious games are specifically designed to change behaviors and impart knowledge and are widely used with adults in training situations, such as emergency preparedness, training for leadership and even citizenship [2] [1]. The use of Serious Games with an younger audience has also emerged as a wide field of experimentation, too. As an example, the repository of a new association on serious games shows games and all kind of resources (see [4]).

In this paper the authors firstly present the game TimeMesh as the main result of the European Union funded project SELEAG (2009-2011), the basis for this work. The two next sections refers to educational evaluation of TimeMesh: a general frame on questions and instruments of evaluation and finally the results in the case of a secondary school in a rural area in Spain. The paper ends with a section on discussion and conclusions.

2. THE GAME TIMEMESH

The game TimeMesh was one of the main results of the project SELEAG (Serious Learning Games), that was aimed to evaluate the use of Serious Games for learning history, culture and social relations.

To accomplish this goal a game named TimeMesh was developed. The game is a multiplayer and configurable graphic adventure online system with three game scenarios (2nd. World War, Industrial revolution and History of Discoveries). A methodology was also developed to evaluate the multidisciplinary learning (history, geography, economics, etc.), social awareness and changes in attitudes towards learning and towards an European identity.

The assessment took place in several European countries with children aged 11-16 in order to determine the value of serious games for this age group and context.

The main characteristics of the online game platform are the following:

- Online point-and-click 2D graphic adventure, with collaboration and peer gaming
- Online lobby to make teams, select games, talk with friends, etc.
• 3 scenarios for the Industrial Revolution, Maritime Discoveries and Second World War

Upon its use in Slovenia, students and teachers were so interested in the game that they asked for a scene that included Ljubljana as well. Then, a different version of the Second World War scenario was developed, using Ljubljana as one of the focal points of the game play. This also showed that the game platform is extensible and new scenarios can be added to it.

The game is available online at TimeMesh website. You can learn how to play, register and play for free at [7]. There are already more than 5000 registered users of the game. The game has been extensively used in several schools and more than 400 students were already involved in playing it as part of curricular or school activities. Several teachers involved in the teachers workshops have proposed new scenarios, to be developed as curricular activities with their students. Some of these proposals are quite creative and show other possibilities to use the platform. A few examples:

• Platos cave (Philosophy)
• Shakespeares life (English Language)
• The 1929 financial crisis (Economy, Social aspects)
• World geography

As part of the project, a State of the Art on Serious Games [5] and a State of the Art on Adventure Game Engines [6] were produced.

2.1 Game paradigm and architecture

The TimeMesh engine is a graphic adventure online system inspired in the 90s graphic adventures created by LucasArts: the SCUMM approach [3] (see figure 1). Verb-object paradigm is used in this kind of games in which user is in control of a character that walks and interacts with a number of other characters, objects and fixed perspective scenarios. An inventory is also available to store objects that the character collects through the game: the interaction with these objects (combine, inspect or use them with other game elements or characters) is necessary to successfully finish the adventure.

User-driven actions are defined by using a click&point approach:

• First click: Some verbs available: Give, Pick Up, Open, Close, Look, Push, Pull, Talk etc.
• Second click: on an active element on the scenario or the inventory
• Last click triggers an action that can have different consequences:
  • Characters talking, moving.
  • Triggering of conversations with a character that may trigger other actions
  • A new addition to the inventory
  • Adding achievements and flags to an invisible inventory that will unlock further parts of the adventure.

As an online system, TimeMesh is composed by two main elements:

• Adobe Flash based Front end: Executing on the user's web browser. It creates the virtual theatre were the game happens, characters interact. It includes Main game logic, Virtual 3D visual system, Game code interpreter, Communication Layer and Audio System.

• Server System. PHP/Apache server with a MySQL back-end. It gives support to allow:
  • Game persistence: each of the user actions is instantly recorded in the database: game status is kept even if the browser is closed.
  • Game files serving: XML and SWF files composing the scenarios.
  • Game saving. Create save-points of the game.
  • Multi-user: support to multiple users sharing goals.

An overview diagram of the system modules is shown in Figure 2: The diagram on the right describes the data generation and processing, from the authoring tools (XML editor and Flash editor) used to generate the input files to the final user screen, passing through the SCUMM engine which processes all the data. On the left diagram, the SCUMM engine and the data flows are shown in more detail.

Finally the system incorporates a PHP engine which is ready to support multiple languages at the same time (based on a GETTEXT system). The idea is to keep untouched the reference version of the scenario no matter how many languages are added (the set of sentences in the initial language
acts as a lookup reference table for new translations). Anytime a new language is added, we only need to generate a new translation file for the new language. In this fashion, we can easily keep a control of change propagation through languages whenever any modification is done on the original scenario XML scripts.

2.2 Multiplayer-MultiWorld Philosophy

The TimeMesh engine was designed so a number of multiplayer features were possible. To our knowledge this is the first time that the graphics adventure paradigm is redesigned into a collaborative multiplayer setup. The scenario of use is a learning scenario were collaborative teams would share an adventure and somehow help each other to advance in the game. After some analysis, these are the features that were chosen to be added to the TimeMesh engine to support the Multiplayer-Multiworld philosophy:

1. The whole game is divided in scenarios. A Set of scenarios become a Chapter. A set of chapters a world. A set of worlds, the whole game.

2. Each chapter has two versions of it.

3. A set of users become a team.

4. Two teams in a pair become a match

5. There are cross-bars in the adventure game. A cross-bar is a shared blocking between two teams playing a match. Until both teams have gone through two parallel challenges neither of them can progress in the adventure game.

2.3 Management

This structure and relation of players, teams and parings is stored in a the central database and accessed through the PHP layer. However, for educational and safety reasons the filling of the structures is done through the admin-only side of the TimeMesh site. In particular it is the mission of the teachers to create, manage and pair the teams.

3. THE EVALUATION PROCESS: WHAT TO ASK AND WHO IS ASKED

A game implementation and evaluation report, that was also produced as a result of SEGAN project, was applied. The evaluation methodology can be seen in detail in [8]. In summary the methodology is divided on three stages:

- First, it was extensively applied to all the implementations. Results allowed validating the SELEAG approach but also allowed to validate the evaluation methodology itself.
- Second, it can be replicated for other Serious Games. Therefore, it has been extensively published in conferences and other events.
- As such, this document can extensively reused by other Serious Games projects, even for benchmarking purposes.

Following this methodology, the design process of TimeMesh included three phases. In the first of them a first set of prototypes, including various graphic design styles and educational settings, was proposed to members to be evaluated following the preestablished questionnaire (alpha test). The result was a functional single player first version of the game with three historic scenarios (Second World War, Maritime Discoveries and Industrial Revolution) with quite different design aspect, that was sent to a broad number of educators from all the countries engaged with the project in order to collect a significant number of opinions (beta test). Finally, the fully operational final version was open to public audience and some gamefests, seminars and sessions of evaluation with students took place (gamma test). The game is still available in Timemesh.eu, and over 5000 players have completed at least one of the scenarios.

3.1 Evaluating within partners: Alpha testing

The objective of an Alpha Testing procedure is to emulate an actual operational testing. It is performed by members of the development team that have not been involved in the development of the particular features to be tested. Alpha Testing allows anticipating, internally, problems that
would only be detected by external testers in the Beta Testing phase. This stage is more rewarding if qualitative data collection is used because it provides richer information. Following the evaluation protocol, partners must

1. Identify participants (staff from partners) which have not been involved in the development (at least 4 elements)

2. Have participants playing the scenario and trying to finish it. Participants should
   (a) Measure how much time it took to finish each scene
   (b) Identify learning outcomes addressed. Check if they match what was proposed
   (c) Identify other learning outcomes that should be addressed
   (d) Assess if the game is motivating. Identify problems
   (e) Assess if the graphical environment / usability is adequate. If not, identify the issues

3.2 Evaluating with educators: Beta testing

Beta testing already involves samples of the end-users that are brought in to comment the game. Focus on the game play, mechanics and interaction with the game allows leaving learning aspects to the last stage, gamma testing performed during the first implementation with the end-users. Following the evaluation protocol, partners must

1. Identify participants (teachers from associated partners: at least 2 per partner)
   (a) Name, school, discipline he/she teaches, e-mail (this info should be collected independently from the questionnaire – nevertheless you can use the questionnaire to guide the interview –)

2. Explain the concept of the game and of the scenario (they won’t have access to the main scenario). Explain how to use the game interface.

3. Have participants playing the game and trying to finish it

4. Participants should
   (a) Measure how much time it took to finish each scene
   (b) Answer the questionnaire

5. Interview the participants using the semi-structured interview guide

6. Report the results

Teachers played the game in a controlled environment (at the University). On one side, this ensures that they had no other tasks in parallel (like it would happen if they do it from home or school), that they are focused on the game and that they are immediately available for the interview. They can also help each other to solve the game which can be funnier.

3.3 Evaluating with students: Gamma testing

The last stage of the evaluation is performed with the end-users, during the first round of implementations. Following the evaluation protocol, partners need to

1. Identify the schools that are going to participate in the testing (information about teachers: name and subject they teach; information about students: age group and number of students)

2. Explain the testing procedure to the teachers
   (a) First part of testing, which is conducted before the game is played, deals with students motivation for history and for playing the game, as well as their knowledge (Knowledge Test 1 and Motivation Questionnaire)
   (b) Second part of testing takes place after the game is played. The test focuses on students view on the game and their knowledge. (Knowledge test 2 and Satisfaction Questionnaire)
   (c) Students are asked to give us their own opinion about the game.
   (d) Teachers answer a questionnaire about the activity.

3. Carry out the testing in classroom with computers. Each student should have his own computer. Students can help each other while playing the game and use internet to find hints for solving game problems.

4. Carry out the poll before and after the gameplay. Students individually answer the questionnaires provided.

5. Report the results to the coordinator (including info about how many students participated, major problems they were, and what were the biggest problems students had while playing the game).

In the next section, which has been separated from it by its length, one of the evaluation sessions with students is described. The session took place in a grammar school in a village in Spain. The different questionnaires are also shown.

4. EVALUATION RESULTS: THE CASE OF A SECONDARY SCHOOL IN A RURAL AREA IN SPAIN

The case study took place in the secondary school of Mallén, a small rural village of Zaragoza, Spain. The class was composed by 22 students, mostly 15 year-old (68%). The rest of the students were 14 and 16 years-old. Students were predominantly female (59%) but the difference to the number of men is not large and allows comparing results.

There was no personal information of students stored during the study for legal reasons. Students were identified in the study by a 2-letter code chosen by themselves. This allowed to get individual correlations between pre and post-game data.

The exercise was conducted during a normal class period so students were not volunteers. Therefore students played the game instead of having the normal class activities in information systems and technologies. This could lead to an increase in motivation by the students.
Students were previously informed that they would be involved in this study but they had no previous information about the game and the historical context of the story. The students did not have any curricular information about World War II.

4.1 The evaluation process

The organization of the study was done as follows:

- Students were seated in teams of two in front of a computer. Students had to collaborate with the teammate to play the game;
- Each team was paired with another team so that they could collaborate online, through the collaboration mechanisms (chat) embedded in the game;
- Before starting the game students answered, individually, a diagnostic questionnaire to assess their knowledge of the facts and ideas of the Second World War;
- At the same time students answered a questionnaire about their competence in History, their motivation towards this discipline and their use of computer games;
- The computers were already prepared, so students immediately entered the game without the need to register themselves or the need to understand the online game platform;
- For this study the first scene of the Second World War scenario was selected due to the closeness to the History curriculum of the students. This scene was designed to take about 45 mnts to be completed by a player with minimal experience in adventure games;
- Students played the game for 45 min. They were monitored (but not helped) by two researchers and a teacher. Teams were allowed to communicate with other teams through the chat or face-to-face;
- In the end students answered the same knowledge questionnaire to assess pre and post-game evolution. Students also answered a questionnaire on their perception of the game usability, play and interest for learning;
- Observations of the two researchers and the teacher were collected in the end;
- Data about the success of the teams in the game was collected automatically by the game platform.

In relation to the use of the game in a normal curricular learning methodology there were a few relevant changes that limited the learning aspects:

- When the game is integrated as a curricular activity, the game complements the normal teaching and learning processes. Therefore there is an added effect of repetition that reinforces the acquisition and retention of the information;
- In an integrated curricular learning methodology, the after game can be a class discussion where students present their own views on what they learned from the game. By doing so students can reinforce their own knowledge and can benefit from peer learning by listening to their colleagues;

Both these aspects were absent from this study. Therefore study results reflect probably a lower level of knowledge construction than would have happened in a curricular integration situation.

The knowledge test presented eight questions that (all but one) related to situations and facts that were contextualized in the scene that students played. The last question was intentionally difficult to answer by these students because it is not a common knowledge question and it refers to a specific geographical area (Balcans) that is not addressed in spanish schools when the effects and facts of the second world war are studied. By comparing pre and post test answers to this question it was possible to assess if students used any other form of access to information, like a search engine.

The questions asked to the students were:

1. Name two countries that were involved in the Second World War
2. During that time who was Great Britain’s Prime Minister?
3. What was the Enigma machine?
4. What was the importance of the Enigma machine?
5. When was Paris invasion by the German troops?
6. What was the French Resistance?
7. Name one of the words of the French motto
8. Who was the leader of the partisan fighters in Yugoslavia, at that time?

4.2 Results

The results of pre and post-tests can be seen in figure 3. It is clear from the graph that the knowledge level of the students increased between the pre and post-game questionnaires. This is especially evident in the two questions related to the Enigma machine, the focus of the game. This evidences that contextual information can be converted in knowledge. This is not just factual information.

What students were required to answer related to the nature of this machine and its importance to the war. These are questions that require students to reflect and give their opinion. It is obvious that the answers were not perfect, in terms of accuracy, language and semantics. Nevertheless we have considered as correct all the answers were students showed that they had understood the main ideas about the machine.

The first question is an interesting case. Although all
the students gave a correct answer in the pre-game test at that moment only seven students mentioned Germany and France as two of the countries involved. After the game, fifteen students mentioned Germany and France, so there was a clear impact of the game in the way students answered this question.

In the fifth question there was also a curious evolution. In the pre-game answer students mentioned only the year. In the post-game questionnaire, students mentioned the day and month of the invasion. The control question was not answered in any of the situations by any of the students. That shows that students did not try to answer questions by using other sources of information.

In the remaining questions there was a slight improvement in the number of students that correctly answered the questions.

Overall there was a clear improvement in the level of the students knowledge.

Looking individually at boys/girls differences (see figure 4) we see that the end result is quite homogenous and boys, who had initially worst results, were able to benefit from the game to get at the same level and event better than the girls.

Figure 4: Looking at boys/girls differences

To analyze the predisposition and motivation of the students towards History, students answered 6 questions pre-game, when they were still unaware of the game they would be playing:

1. I am good in History
2. I am good in History in comparison with other disciplines
3. I am satisfied with my performance in History, compared to other disciplines
4. I think History is an attractive subject
5. I think History is interesting
6. I think History is fun

Answers were given through a 7-point Lickert scale, from 1 (Strongly disagree) to 7 (Strongly agree), with 4 as the average score.

The scores in the six questions (see figure 5) are quite balanced what could be expected because the questions were very close in the formulation. It is clear that students are quite neutral about History but nevertheless they prefer it to other disciplines. However they don’t see it as a “fun” subject. The most interesting (and totally unexpected) aspect about this issue is the clear difference between boys and girls. Boys are clearly more motivated than girls to study historical subjects. This had clearly influence in the game development, later on.

Concerning the use of computer games, the predisposition of students towards games was assessed by the following four questions:

1. Computer games are fun
2. I play frequently computer games
3. I can learn through computer games
4. When I have a problem in a game I try to solve it independently

These results can be considered quite surprising (see figure 6). Above all, the fact that students say that they don’t play frequently computer games. It is possible to think that students were reluctant to accept that they play lots of games and therefore lied on this question. Nevertheless in the first question it would be expected that students would be more enthusiastic about games. Therefore this is a group of students for whom games are not fundamental. This can be related to the rural characterization of the village of Mallén which predisposes kids to play more physical activities rather than computer games.

Figure 5: Interest in History

Figure 6: Predisposition of students towards games

Students were also doubtful that they could learn with games and they are neutral in terms of autonomy in games. This is an important aspect considering that afterwards they would have to play the game collaboratively.

As expected boys were more positive about playing games, they had more experience and considered them more fun than the girls.

About students’ perception on the game, after the game played students answered a questionnaire about their perception of the game. Firstly aspects related to the fun were assessed with the following questions:
1 I liked playing this game
2 This game was fun to play
3 This game did not attract me

The last question was negative to catch students that were answering randomly the questions. Looking at the results of this question (see figure 7) that confirms the previous ones, it was again clear that students answered the questionnaires with intention and honestly.

Student’s impression was positive, but not overly positive which again shows that students were honest in filling the questionnaires. Boys were more satisfied than girls but girls considered that they were more impacted by the game.

The second part of the post-game questionnaire relates to the game play and learning through games. The questions used were the following:
1 I’m good at this game
2 I did well in this game, compared to my colleagues
3 After I started playing I knew what I had to do
4 I liked learning with the game
5 I identified myself with the main character
6 After playing the game I can picture better the second world war
7 When I started playing I knew what had to do
8 It took me some time to figure out how to play the game
9 There was enough feedback to know what I did wrong and what I should have done

Students have a positive view of their performance in the game (see figure 8). That includes the ability to solve the problems that they faced, including the fact that they received (purposely) very little information to start with. They were unable to identify themselves with the character which is an aspect to be studied. The most positive aspect in fact was the consideration that students liked to learn this way, using games. Boys were again more positive than girls in the evaluation of the game.

Finally students perception on collaboration was assessed through the following questions:
1 I collaborated with my team partner
2 I collaborated with other team
3 These forms of collaboration worked very well
4 I was satisfied with this collaboration

This was the most positive aspect (see figure 9. Students enjoyed immensely working with a colleague and with the other teams. This was an aspect viewed very favorably by the students. There was no clear distinction between boys and girls in this aspect.

The observation during the game showed some very interesting aspects:
- When boys were told that they would be playing a game about the second world war they were thrilled. They immediately thought it was going to be a shoot’em-up game where they could shoot the other players. When they realize that it was a much more quiet adventure game they lost momentarily their interest. Nevertheless when they started playing they regained their interest and started competing between themselves to see who could solve more quickly the challenges. Later all the teams started collaborating and giving clues to the other teams.
- Looking at the records of the game platform it was interesting to note that many of these students reentered the game after they left the class to try to complete the other scenes of this scenario. This shows that they were motivated by the game and tried to use it on their own.

5. CONCLUSIONS AND DISCUSSION

Serious games are games that exploit the motivation and attractiveness of games for other purposes like learning and skill and competence development. However, to demonstrate the effectiveness of a serious game, an holistic evaluation process is required.
In the scope of the SELEAG project, a serious game was designed, developed and tested, meant to develop and promote knowledge and skills related to history and geography. This game, Timemesh is now being used by more than 5000 students and what we showed in this article was a small part of the evaluation process conducted to ensure its quality.

From our experience, the serious game teams can enhance the playfulness of education by treating the learning process as an exploration field. In each case of our games, there is no prior "course content" to be learnt. The player or players team start the game with just a rough specification of the general situation to be considered. It has been evident that student-players explore their relations through the process of playing.

A possible challenge of serious games might be to drive the student to actually think that the learning process is a game. Or, it would be interesting to introduce the basic elements involved in game design as an element of the curriculum of the teacher.

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7. REFERENCES