Development Process for Educational Games

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Abstract. Many students find mathematics a difficult subject. In the context of Mexico, the failure rate in mathematics has been very high. This paper discusses the creation of an educational computer-game system using a virtual environment. The objective of this application is to motivate and encourage students to practice mathematics. The videogame environment aims at making fun the learning process. Using User Centered Design, this game has to satisfy different students who may have very different likes. In this paper we present a first approach of a proppосed model for this videogame development processes, considering that videogame development consists of much more than developing only software. This process is based on the *Game Unified Process* methodology and *User-Centered Design*. The processes are organized in phases and composed by more specific activities and also it uses artifacts to improve software development.

Keywords: Game-based learning, virtual environment, component based design, problem solving, development process.

1 Introduction

Last years, the use of computers has been essential on daily life as well as in education. Personal computers are being introduced on many levels of education: primary, secondary and high school [9]. Nowadays, the use of technology, especially computer games, provides a propitious environment for learning process, which takes place in a virtual world. Players create their own knowledge through the interaction with the virtual environment [5]. This kind of tools, used actually for teaching, are called: Educative Software (ES). The term Educative Software is denominated to a group of informatic resources confined to teaching and autonomous learning, and is used on teaching-learning process context [16]. The ES is created for the specific purpose of being used as a didactic media that facilitates teaching-learning processes. ES includes a wide variety of tools and resources, from learning oriented programs to complete operating systems. The use of technology makes easy the learning process by giving high interactivity, chance to practice many times, fault tolerance, and increase imagination and achievement sense [3], moreover, they become more popular since they are an important part of children and youth' lifestyle [17, 18]. Educative Videogames create fun, motivation

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and interactive learning virtual environments, so they are a resource that gets students attention and invites to use it, providing teaching-learning processes, and attacking one of the biggest problems of traditional teaching: keeping motivated and engaged students to continue learning and applying knowledge [5].

This work consists on the design and development of an educative videogame called "Museo Virtual de Geometría" for teaching-learning process for third grade of secondary school. With the objective of answering to the noticed problematic on national and international studies: Exámenes de la Calidad y el Logro Educativos (EXCALE), Evaluación Nacional de Logro Académico en Centros Escolares (ENLACE), and Programme for International Student Assessment (PISA) which have demonstrated the educative lag presented by mathematics students at a world-wide level [7, 8]. Actually the mathematics problems solution is considered the most important part of mathematics teaching, and it requires the students to have necessary abilities to solve them. However, there are many troubles the students have to face when they try to solve problems; some of the troubles are: the students don't understand the problem due to plenty of phrases, lack of linguistics keys that help students to select appropriate arithmetic operations, absence of practice applications, poor lecture and understanding skills, lack of motivation, limited mathematic problems solution experience, hardness on converting textual problems into appropriate numeric formats, lack of skills, tools and resources access needed, to mention some of them.

By the mentioned above, it's evident the need of the students to improve their mathematics performance. The proposed educative videogame motivates the students to learn methematics, through fun, responding to world continuous social transformations for the teaching-learning process. Thus, educative videogames have an enormous potential to improve mathematics teaching; also, these videogames can be used to reinforce student' study and help on mathematical concepts development [10].

Videogame development implies a complex duty that requires specialized knowledge on areas like graphics processing, programming, animation, sound, etc [14]. This causes the development to be interdisciplinary and parallel. Moreover, there is little research in educational videogames development field [4]; is well known that developers implement their methods, but their use is not organized, so it takes to a less structured software developing for this kind of applications. All this makes us to require software engineering techniques and tools for the design and development. Actually, the Software Engineering process on videogames development is not defined clearly, which makes hard the practices and processes development less reliable on this field [2]. A videogame could fail because of poor management of the entire process implied in the development elaboration, so videogames developers need very different skills, compared to previous designers, to lead this process with caution and efficiency [6], according to the needs of society.

2 Development Process of "Museo Virtual de Geometría"

In most current game projects, the development process is the area that needs the most attention. In many recent projects, it can be seen that hasn't been used a real develoment model. With the integration of software engineering for developing the game, we get some benefits like: everyone involved in the game development reduces his effort, becasuse it allows software developer to identify and apply solid practices. Thus, the system interdisciplinary development is taken into account and propitiates a good team communication of development by the established guidelines and the making of the project documentation on each phase. The goal of Geometry Virtual Museum (MVG) Project is to develop a software tool to support the geometry teaching on secondary school level.

For design and development of the MVG it was proposed a software development process according (See Table (1)) to the educative videogame needs, incorporating the most important characteristics and elements of User Based Design (UBD) and Game Unified Process (GUP). The proposed development process defines its phases, activities and artifacts, by mentioning *what to use?*, *how to use it?* and *when to use it?* The phases of the development process are: Planning, Requirement specification, Game Design, Design Development, Test and Relase.

Table (1) shows four of the seven phases of the process with the activities for phase and artifacts. As for the MVG software development, it was used the approach "Component Based Design". The component based design basic steps are: requirements gathering, component partitioning, inner design, component evolution and component interconnection. Moreover, the component based design lets the reuse of code "pieces" pre-elaborated to make a variety of tasks, leading to different benefits like the quality improvements, development cycle reduction and a greater return of investment. Among the advantages of using this design approach we found: software reuse, tests simplification, system maintenance simplification, better quality, and shorter development cycles. With the purpose of establishing development team tasks, the MVG has divided into units, as show on Fig. (1).

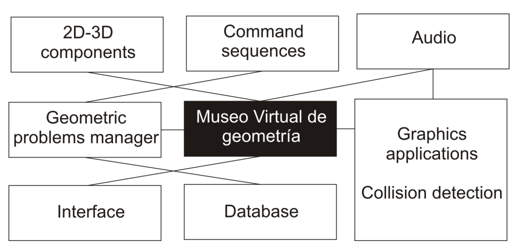


Fig. 1. Geometry Virtual Museum Units.

Based on this division, there was specified the set of activities to do, to guide the developers during the whole development cycle. The MVG planning started with requirements elaboration that defines the project. The planning includes the estimation of aspects related with the products and tasks to develop, the determination of the necessary resources to build the system, and the project risks identification and analysis. The project planning is checked according to project advance to deal with the requirements and the obligations changes, inexact estimations, corrective actions, and process changes. Fig. (2) presents project plan designed for planning and requirement specification phases.

Once the project planning was developed, it was chosen the development strategy, to have a guide for developing the product. This implies the identification of the software components to be reused and also includes decisions about the architecture characteristics. The project work plan was organized around the product and its software components.

Table 1. Identified activities for the development process of the MVG.

PHASE	DESCRIPTION
Planning	Guide to stablish and mantain the plans that define the project activities
Activities	To develop a project plan Developing time management
Artifacts	Project plan
Requirement specification	Gives neccesary activities for requirements developing and management. Education, analysis, needings validation, expectatives and game restrictions
Activities	Analisys and understanding of learning complexity Identifying interface requirements Requirements analysis and validation
Artifacts	Developing strategy, user case diagram, sequence diagram
Game Design	Involves decisions about game characteristics
Activities	To choose the platform and tools to use Possible graphics from user perspective Graphics and art styles to use
Game design	Refers to a collection of operations, classes, and components that embody the functionality of system
Activities	Game script elaboration Didactic goals identification Characters choice Navigation diagrams definition

The activities structure allows a first sight over the following elements: Possible risks by activity and mitigation tasks, Identification of tasks for user value products and Tasks for additional plan development (such as Configuration Management and Process Quality Assurance, Product and Validation). Fig.(3) shows the software components on which the project is divided and its functionality. For development team it was important to do this step because it lets us to identify the component limits to implement.

The MVG was made into an iterative process, so, during the whole project life the product needings are identified and understood, which may causes requirements to change. The designed development process uses the User Case Diagrams (UCD) to capture the system functions and the entities outside the system (actors). With the UCD, the system functional requirements specification is obtained and the interactions between the system and external factors are shown. The use case is a way to specify:

Table 2. Identified activities for the development process of the MVG.

Template for Project Planning (PROJ)
Software system to reinforce geometry learning-teaching process, on medium basic level on Veracruz Date:September 2010

Weekly data			Planned	Actual
Project's hours for week				
Project's hours for cycle to current date				
Earned value by week				
Earned value by phase				
Data for Team members	Planned hours	Actual hours	Planned value	Earned value
Team leader				
Project manager				
Planning leader				
Quality leader				
Support leader				
Total				

what the system has to do and to guide the construction of the MVG. On Fig. (2) is presented the MVG User Case Diagram general diagram. To the analysis and understanding of the difficulty of learning, it is proposed the methodology presented on Fig. (3) for geometric problem teaching-learning. Thus, on the information treatment axis there were designed activities to grow on the students, the ability to solve geometric problems through analysis and selection of information established into a step set, as shown on Fig. (4).

The student obtains information to solve the problem through the steps; if he is not able to solve the step, he will get an advice as feedback. The proposed methodology for developing geometric problems is integrated by eight stages, with the objective of guiding the student to find the problem solution. So, the student skill to solve geometry problems is increased trough analysis and information selection proposed into steps, as shown on the next example (see Fig. (4)). The student, trough the steps, gathers information to solve the proposed problem and, if he is not able to complete the step, he will get a recommendation or tip to solve it.

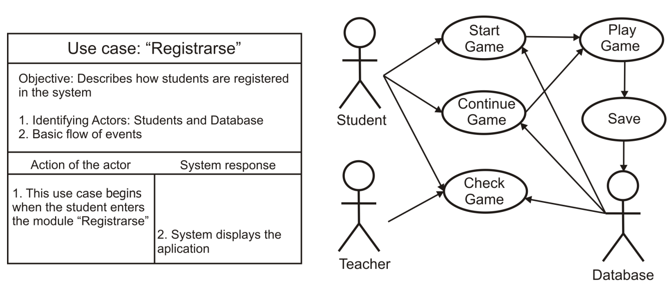


Fig. 2. "Museo Virtual de Geometría" General Diagram.

Table 3. Identified activities for the development process of the MVG.

Project name:	Software system to reinforce geometry learning-teaching process, on medium-basic level on Veracruz
Date:	September 2010

General description of functionality.	
The ”Museo Virtual de Geometría” is an educational software tool designed for high school geometry teaching-learning. The MVG is a possible solution that can assists students with mathematics and also, it is a tool for to motivate students by fun and interesting games that encourage them to play and holds their attention.	
Component or system modules	
Store statistics	Solved problems are stored into a local database This component is responsible of: Error count: the component will count the noumber of tries when solving a problem Solution time: to solve a problem, it is, a limit time given by this component Points (score): each solved problem has asigned an amount of points which will be registered in this component, to know the student performance
Database	Manage the Museum information, so, is in charge of: Locate and obtain object characteristics that will be used in the Virtual Museum Read related problems with an object, as well as properties for specific object related information storage Read steps related to a problem

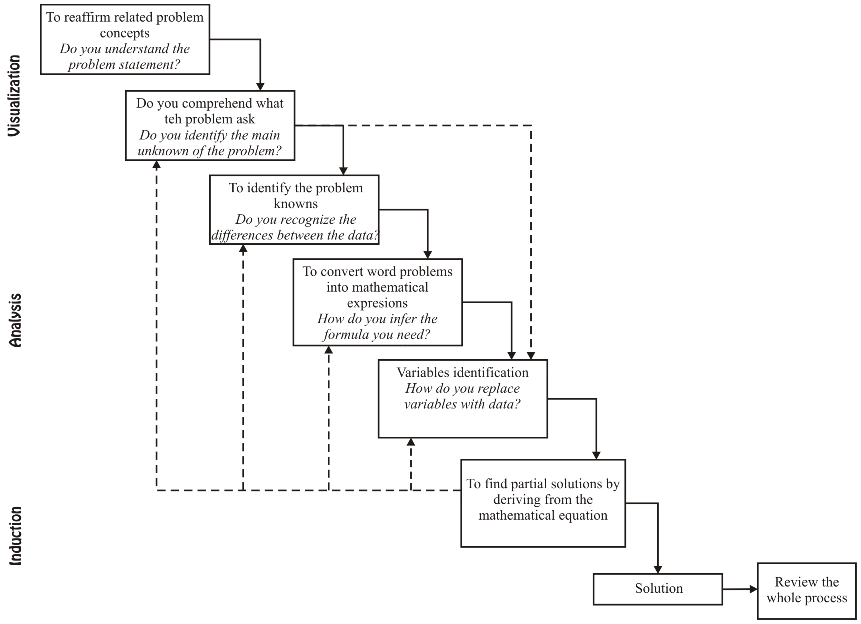
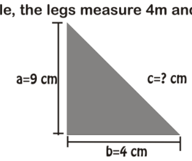


Fig. 3. Steps for the analysis and understanding of geometry learning difficulty.

The methodology starts with the reaffirmation of problem associated concepts. The objective of this point is that the student understands what the problem is asking for. On Fig. (4), steps one, two and three fulfill with this stage (stage one of visualization phase). On a particular way and based on the shown problem, it is clearly visible that the concepts the student must have to solve the problem are associated with the concepts of: triangle, right triangle, legs and hypotenuse. Once the student can answer to the question of "Do you understand everything said on the problem?" the methodology stimulates the student to understand what the problem is asking for and so, he can answer the question "Do you know what the goal is?" Step four and five from Fig. (4) belong to the second stage of the visualization phase. The last visualization phase helps the student to identify the data he has to solve the problem; step six is an example of this. The next phase proposed by the methodology is the analysis phase, integrated by the stages of "converting verbal expressions to mathematical ones" and "identifying the problem variables". With this, the student can answer "How will you express the mathematical formula to use?" and "What numeric data must be used?" On step seven and eight the first phase of analysis is fulfilled; here, the formula of the problem variable is found. The last stage of the analysis phase is shown on step nine and ten, where we identify the values of the variables to be used. The last stage proposed by the methodology is the induction, with the aim of consolidating knowledge produced trough the steps.

On the shown problem, this stage phase is represented with the steps eleven, twelve and thirteen; with this steps the student find partial solutions that makes easier the answer for the problem. So, the methodology concludes with the solution stage, where the student answers the initial proposed problem. Step fourteen exemplifies the way to find the problem solution. It is important to remark that the methodology is iterative, so it let

Problem. In a right triangle, the legs measure 4m and 9m respectively. Calculate the hypotenuse.



Step 1. What name receives the triangle which has one angle of 90° and its two other angles are acute?

- ☐ Obtuse ☐ Scalene ☐ Isosceles ☐ Right

Step 2. What is a leg?

- ☐ One of the two shortest sides ☐ Lower side ☐ Longest side ☐ Left side

Step 3. What is the hypotenuse?

- ☐ One of the two shortest sides ☐ Lower side ☐ Longest side ☐ Left side

Step 4. What do we need to obtain?

- ☐ Hypotenuse ☐ Height ☐ Leg ☐ Bisector

Step 5. Which Theorem you must know to solve the problem?

- ☐ Pythagorean Theorem ☐ Tales Theorem ☐ Venus Theorem ☐ Apu´s Theorem

Step 6. Taking into account the data about the problem's triangle, which data do you know to solve it? (Focusing on the triangle problem data, which data do you know to solve it?)

- ☐ The legs value ☐ The hypotenuse ☐ The height ☐ The legs and hypotenuse values

Step 7. To applying the Pytagorean Theorem, which relation you must use if *c* is the hypotenuse and *a* and *b* the legs?

- ☐ $c=\sqrt{a^2+b^2}$ ☐ $c=\sqrt{a^3+b^3}$ ☐ $c=\sqrt{abc^2+b^2}$ ☐ $c=\sqrt{a^2+ab^2}$

Step 8. To obtain the leg a value, I must use the next phrase:

- ☐ $a=\sqrt{b^2+c^2}$ ☐ $a=\sqrt{b^3+c^3}$ ☐ $a=\sqrt{abc^2+b^2}$ ☐ $a=\sqrt{a^2+ab^2}$

Step 9. How much is leg *a*?

- ☐ 9 ☐ 6 ☐ 5 ☐ 4

Step 10. How much is leg *b*?

- ☐ 4 ☐ 16 ☐ 5 ☐ 10

Step 11. How much is the squared leg *a*?

- ☐ 81 ☐ 20 ☐ 10 ☐ 100

Step 12. How much is the squared leg *b*?

- ☐ 16 ☐ 20 ☐ 10 ☐ 100

Step 13. How much is the sum of legs a=16 and b=81?

- ☐ 97 ☐ 30 ☐ 5 ☐ 100

Step 14. How much is the hypotenuse from the problem's triangle?

- ☐ $c=\sqrt{16+81}$ ☐ $c=\sqrt{10+15}$ ☐ $c=\sqrt{100+10}$ ☐ $c=\sqrt{5+5}$

Fig. 4. Steps for the analysis and understanding of geometry problem solving.

us to improve the problem development and its elaboration to be flexible and adaptable to the problem needings. On Fig. (5) we can see a screenshot showing an example of a problem using the proposed metodology.

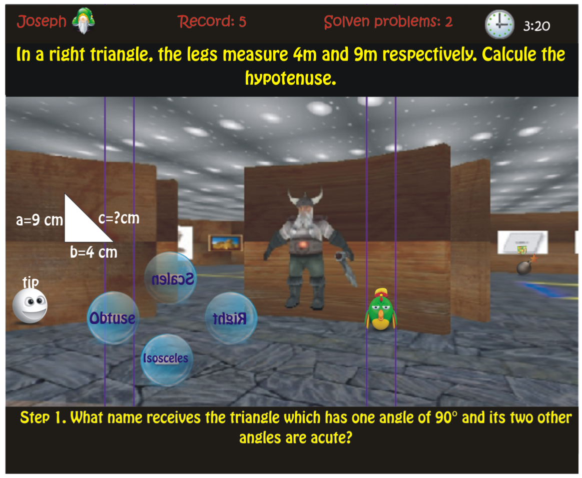


Fig. 5. Screenshot showing how is presented a problem into the game.

The “Museo Virtual de Geometría” was designed in this way because videogames with labyrinth environments are very popular between teenagers. For the design we consider the following points: Interface, Rules, Levels, GamePlay and Features. The MVG has been created using Irrlicht (an open source 3D engine written in C++). In MVG there are three difficulty levels: basic, intermediate and advanced. To obtain a right scenarios design it is necessary to take into account the likes and preferences for colors and textures of the final users. To achieve this, there was designed and added different scenarios (shown on Fig. 6) and contextual surveys applied on January 2011 to students from the secondary school: Secundaria Técnica No. 27 , in Ciudad Ixtepec, to know likeness and preferences of the final user.

3 Conclusions and Future Work

The structuration of a developing process for game design is a very important fact to coordinate the developing team and minimize time and effort.

The MVG is very interesting among secondary school students and has the potential to relax evaluations, introduce chaos, create conditions to improve sharing of tacit knowledge, and increase the bonds between organizational members. It can support the platform for knowledge creation and organizational learning. With the MVG, the students learned and reaffirmed mathematic concepts by playing. Answering the problem by steps, the students felt that they dominate a complex game, because they solve a problem using steps that manage its complexity. The application was an interesting tool for students and teachers from secondary schools, as they have fun and learn through

Fig. 6. Different MVG scenarios.

activities based on curricula and methodologies for teaching proposed by the Secretaría de Educación Pública. It is convenient to conduct a more extensive usability study that allows the feedback to improve the application. On the information treatment, we consider that is suitable to feedback with problems proposed by teachers of the subject, so, we require to make an interface on which the teacher can incorporate problems of the issues they consider are complicated to learn.

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