UNIVERSIDAD AUTONOMA DE AGUASCALIENTES

Interinstitutional Doctorate in Computer Sciences

Aguascalientes, México. January 2016

Catrina Project

A Software Engineering Process for Developing Short Serious Games based upon Competencies

M. en CESI. Arturo Barajas Saavedra
Doctoral Degree in Computer Sciences

Director
Dr. Francisco J. Álvarez Rodríguez
Co-Director
Dr. Jaime Muñoz Arteaga
Tutoral Committee
Dr. René Santaolaya Salgado
Dr. Julio Ariel Hurtado Alegría
Dr. César Alberto Collazos Ordóñez

Authorizations

UNIVERSIDAD AUTONOMA
DE AGUASCALIENTES

M. EN C. JOSÉ DE JESÚS RUÍZ GALLEGOS
DECANO (A) DEL CENTRO DE CIENCIAS BÁSICAS
P R E S E N T E

Por medio del presente como Tutor designado del estudiante ***ARTURO BARAJAS SAAVEDRA*** con ID *6415* quien realizó *la tesis* titulada: ***A SOFTWARE ENGINEERING PROCESS FOR DEVELOPING SHORT SERIOUS GAMES BASED UPON COMPETENCIES***, y con fundamento en el Artículo 175, Apartado II del Reglamento General de Docencia, me permito emitir el **VOTO APROBATORIO**, para que *él* pueda proceder a imprimirlo, y así como continuar con el procedimiento administrativo para la obtención del grado.

Pongo lo anterior a su digna consideración y sin otro particular por el momento, me permito enviarle un cordial saludo.

A T E N T A M E N T E
"Se Lumen Proferre"
Aguascalientes, Ags., a 13 de Noviembre de 2015.

Dr. Francisco Javier Álvarez Rodríguez
Tutor de tesis

c.c.p.- Interesado
c.c.p.- Secretaría de Investigación y Posgrado
c.c.p.- Jefatura del Depto. de Ciencias de la Computación
c.c.p.- Consejero Académico
c.c.p.- Minuta Secretario Técnico

UNIVERSIDAD AUTONOMA
DE AGUASCALIENTES

M. EN C. JOSÉ DE JESÚS RUÍZ GALLEGOS
DECANO (A) DEL CENTRO DE CIENCIAS BÁSICAS
P R E S E N T E

Por medio del presente como Tutor designado del estudiante ***ARTURO BARAJAS SAAVEDRA*** con ID *6415* quien realizó *la tesis* titulada: ***A SOFTWARE ENGINEERING PROCESS FOR DEVELOPING SHORT SERIOUS GAMES BASED UPON COMPETENCIES***, y con fundamento en el Artículo 175, Apartado II del Reglamento General de Docencia, me permito emitir el **VOTO APROBATORIO**, para que *él* pueda proceder a imprimirlo, y así como continuar con el procedimiento administrativo para la obtención del grado.

Pongo lo anterior a su digna consideración y sin otro particular por el momento, me permito enviarle un cordial saludo.

A T E N T A M E N T E
"Se Lumen Proferre"
Aguascalientes, Ags., a 13 de Noviembre de 2015.

Dr. Jaime Muñoz Arteaga
Tutor de tesis

c.c.p.- Interesado
c.c.p.- Secretaría de Investigación y Posgrado
c.c.p.- Jefatura del Depto. de Ciencias de la Computación
c.c.p.- Consejero Académico
c.c.p.- Minuta Secretario Técnico

M. EN C. JOSÉ DE JESÚS RUÍZ GALLEGOS
DECANO (A) DEL CENTRO DE CIENCIAS BÁSICAS
P R E S E N T E

Por medio del presente como Tutor designado del estudiante ***ARTURO BARAJAS SAAVEDRA*** con ID 6415 quien realizó la tesis titulada: ***A SOFTWARE ENGINEERING PROCESS FOR DEVELOPING SHORT SERIOUS GAMES BASED UPON COMPETENCIES***, y con fundamento en el Artículo 175, Apartado II del Reglamento General de Docencia, me permito emitir el **VOTO APROBATORIO**, para que él pueda proceder a imprimirlo, y así como continuar con el procedimiento administrativo para la obtención del grado.

Pongo lo anterior a su digna consideración y sin otro particular por el momento, me permito enviarle un cordial saludo.

A T E N T A M E N T E
Cuernavaca, Morelos, a 2 de diciembre de 2015.

Dr. René Santaolaya Salgado
Tutor de tesis

ESTADOS UNIDOS MEXICANOS
S. E. P.
CENTRO NACIONAL DE INVESTIGACIÓN Y DESARROLLO TECNOLÓGICO
CIENCIAS COMPUTACIONALES

c.c.p.- Interesado
c.c.p.- Secretaría de Investigación y Posgrado
c.c.p.- Jefatura del Depto. de Ciencias de la Computación
c.c.p.- Consejero Académico
c.c.p.- Minuta Secretario Técnico

Universidad del Cauca

Investigación y Desarrollo en Ingeniería de Software

M. EN C. JOSÉ DE JESÚS RUÍZ GALLEGOS
DECANO (A) DEL CENTRO DE CIENCIAS BÁSICAS
P R E S E N T E

Por medio del presente como Tutor designado del estudiante ***ARTURO BARAJAS SAAVEDRA*** con ID *6415* quien realizó *la tesis* titulada: ***A SOFTWARE ENGINEERING PROCESS FOR DEVELOPING SHORT SERIOUS GAMESBASED UPON COMPETENCIES***, y con fundamento en el Artículo 175, Apartado II del Reglamento General de Docencia, me permito emitir el **VOTO APROBATORIO**, para que *él* pueda proceder a imprimirlo, y así como continuar con el procedimiento administrativo para la obtención del grado.

Pongo lo anterior a su digna consideración y sin otro particular por el momento, me permito enviarle un cordial saludo.

A T E N T A M E N T E
Popayán, Colombia., a 13 de Diciembre de 2015.

Dr. Julio Ariel Hurtado Alegría
Tutor de tesis

c.c.p.- Interesado
c.c.p.- Secretaría de Investigación y Posgrado
c.c.p.- Jefatura del Depto. de Ciencias de la Computación
c.c.p.- Consejero Académico
c.c.p.- Minuta Secretario Técnico

Universidad
del Cauca

Investigación y Desarrollo en Ingeniería de Software

M. EN C. JOSÉ DE JESÚS RUÍZ GALLEGOS
DECANO (A) DEL CENTRO DE CIENCIAS BÁSICAS
P R E S E N T E

Por medio del presente como Tutor designado del estudiante ***ARTURO BARAJAS SAAVEDRA*** con ID *6415* quien realizó *la tesis* titulada: ***A SOFTWARE ENGINEERING PROCESS FOR DEVELOPING SHORT SERIOUS GAMES BASED UPON COMPETENCIES***, y con fundamento en el Artículo 175, Apartado II del Reglamento General de Docencia, me permito emitir el **VOTO APROBATORIO**, para que *él* pueda proceder a imprimirlo, y así como continuar con el procedimiento administrativo para la obtención del grado.

Pongo lo anterior a su digna consideración y sin otro particular por el momento, me permito enviarle un cordial saludo.

A T E N T A M E N T E
Popayán, Colombia., a 13 de Diciembre de 2015.

César A. Collazos

Dr. César Alberto Collazos Ordoñez
Tutor de tesis

c.c.p.- Interesado
c.c.p.- Secretaría de Investigación y Posgrado
c.c.p.- Jefatura del Depto. de Ciencias de la Computación
c.c.p.- Consejero Académico
c.c.p.- Minuta Secretario Técnico

UNIVERSIDAD AUTONOMA
DE AGUASCALIENTES

ARTURO BARAJAS SAAVEDRA
DOCTORADO INTERINSTITUCIONAL
EN CIENCIAS DE LA COMPUTACION
P R E S E N T E.

Estimado alumno:

Por medio de este conducto me permito comunicar a Usted que habiendo recibido los votos aprobatorios de los revisores de su trabajo de tesis y/o caso práctico titulado: **"A software engineering process for developing short serious games based upon competencies"**, hago de su conocimiento que puede imprimir dicho documento y continuar con los trámites para la presentación de su examen de grado.

Sin otro particular me permito saludarle muy afectuosamente.

A T E N T A M E N T E
Aguascalientes, Ags., a 12 de enero de 2016
"Se lumen proferre"
EL DECANO

M. en C. JOSE DE JESUS RUIZ GALLEGOS

c.c.p.- Archivo.
JJRG,yscd

TESIS TESIS TESIS TESIS TESIS

Acknowledgements

To Dr. Francisco Javier Álvarez Rodríguez for all the support to conduct this research before and during the course of this Doctorate.

To CONACYT for the financial support provided for the realization of this Doctorate and research stay at the CENIDET.

To Basic Sciences Center, headed by M. C. Ruiz José de Jesús Ruiz Gallegos, to Department of Computer Science, headed by Dr. Eunice Esther Ponce de León Sentí, and to Department of Research and Postgraduate Programs for financial support for the research stay in the UNICAUCA.

To Computer Systems Academic Department of the Universidad Autónoma de Baja California Sur, headed by M.S.C. Mónica Adriana León Carreño, for the invitation to carry out a research stay in their institution.

Dedications

To God for the strength, vision and ability to make the decisions that led me to this point.

To my wife and kids for all the support in the hard times.

To my family for the advice that was given.

To Dr. Francisco Javier Álvarez Rodríguez for all the support and coaching that was given.

To my Tutoral Committee for all the coaching that was received.

Index

Table Index

Figure Index

Resumen

Los videojuegos serios juegan un rol sobresaliente en la adopción de competencias educativas ya que proveen inmersión, diversión, motivación y un alto grado de compromiso en los usuarios. La correcta implementación es extremadamente importante para asegurar un alto nivel de adopción de las competencias por parte de los usuarios de los recursos debido a que su producción es una tarea compleja porque involucra dominios multidisciplinarios, tales como pedagogía, diseño de arte e ingeniería de software. La falta de procesos de desarrollo sistemáticos amenaza la producción de estos recursos educativos digitales en términos de calendarización, costo y confusiones causadas en diferentes etapas del desarrollo. Esto afecta la calidad de los recursos expresada en términos de su utilidad pedagógica y diseño gráfico. Esta investigación presenta la formalización de un proceso de desarrollo de videojuegos serios cortos como resultado final de la experiencia de ocho años en proyectos de producción de recursos digitales educativos para el Gobierno Mexicano, la Secretaría de Educación Pública, el Proyecto UMBRAL y las escuelas de Aguascalientes. Esta formalización fue llevada a cabo utilizando paradigmas de la Ingeniería de Software para alcanzar un proceso de software extensible y reutilizable para terceros. Esta formalización fue aplicada a seis proyectos de desarrollo de videojuegos serios cortos en un caso de estudio embebido, y fue evaluada usando un modelo basado en trazabilidad de requerimientos e inspecciones para verificar y validar la correcta implementación de los requerimientos y la producción exitosa de los videojuegos serios cortos de calidad.

Abstract

Serious games play an outstanding role in the adoption of educative competencies given that they provide immersion, fun, motivation and a high level of engagement to users, especially young users. The correct implementation is extremely important to ensure a high level of adoption of the competencies by the users of the resources due to their production is a complex task because engage multidisciplinary domains, such as pedagogics, art design and software engineering. The lack of systematic development processes threats with the digital educative resources production in terms of scheduling, cost, and misconceptions caused at different stages of the development. It affects the quality of the resources expressed in terms of its pedagogical utility and graphical design. This research presents the formalization of a short serious game development process as final result of the last eight years of experience in educational digital resources development projects for the Mexican Federal Government, Ministry of Education, UMBRAL Project and Aguascalientes' Schools. This formalization was realized using Software Engineering paradigms in order to achieve a reusable and extensible software process for third-party entities. This formalization was applied to six short serious game development projects in an embedded case study, and was evaluated using a model based upon requirements traceability and inspections to verify and validate the correct implementation of requirements and the successful production of quality short serious games.

Introduction

Nowadays, the use of digital educative resources has become a very common practice, in way that, in the diverse commercial applications platforms the offer of these resources is vast. In 2015 Ariel through appfigures (Ariel, 2015) reported that Apple and Google offered in the 2014, respectively, 1.21 million and 1.43 million applications in their stores. Game and Education applications are among the top five fastest growing in number categories in the Apple store, meanwhile Game applications is the top fastest growing in number category in the Google store (Ariel, 2015). In addition to this, the Apple store is composed of 21.45% of Game applications and 9.95% of Education applications (Statista, 2015), and Google store is composed of 14.8% and 6.1% of Game and Education applications, respectively (Statista, 2015). Therefore, the market for these applications is comprised of approximately 678,810 applications.

All these applications promotes the adoption of some “competences” by the users. An example of these “competences” can be found in the applications developed by Toca Boca (Toca Boca, 2015), where, in the section For Parents of its Web site (Toca Boca, 2015) presents the promoted “competences” of each one of its applications. However, it is unknown whether these applications have been developed with quality control to ensure the adoption of competencies. The promoted “competencies” are given in general terms and not in terms consistent with a systematic educational development in the area.

Through the experience gained by the different entities of software developers has identified the need to manage a software project for it to be successful. To manage a project, four desirable characteristics of a software development team are identified (Reyes Delgado, 2005): the creation of a set of defined processes, the quality of products and, efficacy and efficiency efforts. To achieve the proper management of a software project should be performed in the first instance, the creation of the defined processes of the organization through the use of best practices and formal software engineering methods and matured to match to the actual process of the organization.

Formal methods and processes defined software development receive much attention in research, but are rarely used in industry for the development of software systems. One of the main reasons is that very little is known about the integration, interpretation, definition and adoption of formal methods in the software process and the precise role of formal methods and processes in the lifecycle of software remains very diffuse (Plat & J. Toetenel, 1992).

Despite all the stresses generated in research centers, as mentioned in (Plat & J. Toetenel, 1992), there is a significant percentage of software development companies that do not use formal methods for the development of projects and software processes. This problem can also be attributed to the fact that many entrepreneurs and software developers ignore the potential benefits of using formal methods and the definition of software development processes for both quality of product and the quality of the process, and therefore the project (Chatzoglou, 1997).

A large-scale resource production of any kind of digital resources involves the creation of a set of software products through a development process based on standards, methodologies, process guidance and best practices of software engineering (Oktaba & Ibargüengoitia González, 1998). At this point, the Software Engineering provides a mechanism for the development of affordable software systems, and through organizations such as the Software Engineering Institute – SEI (Carnegie Mellon University, 2014) and International Standardization Organization – ISO (International Standardization Organization, 2014), have generated international standards for assurance of quality in software development processes and the management of resources and models to measure the maturity of software development processes, such as Capability maturity Model Integration – CMMI (Carnegie Mellon University, 2014), Rational Unified Process – RUP (IBM, 2014), Software process Improvement and Capability Determination – SPICE (International Organization for Standardization, 2014), Process Model for Software Industry – MoProSoft (Normalización Y Certificación Electrónica A.C., 2014) (International Organization for Standardization, 2014), Personal Software Process – PSP (Carnegie Mellon University, 2014) and Team Software Process – TSP (Carnegie Mellon University, 2014). (Sommerville, 2005) (Pressman, 2006) (Kulpa & Johnson, 2003)

When talking about digital educational resources, Barajas-Saavedra et al. (Barajas Saavedra A. , Muñoz Arteaga, Álvarez Rodríguez, & García Gaona, 2009) and Velázquez-Amador et al. (Velázquez Amador, et al., 2011) mention that a large scale development of digital learning resources involves the creation of a large number of these educational digital resources with a time limit, usually with the aim of supporting one or more educational courses. This kind of development is not very often (Barajas Saavedra A. , Muñoz Arteaga, Álvarez Rodríguez, & García Gaona, 2009), (Velázquez Amador, et al., 2011), (Vidani & Chittaro, 2009), (Masuch & Rueger, 2005) because these applications are difficult to produce, due to the production involves experts from very diverse knowledge areas and, as far as we know, there are not development processes or methodologies explicitly defined for their development. Therefore, it is impractical that resources have been developed under pedagogical supervision to support correct operation and adequate acquisition of the competencies (UNESCO, s.f.).

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 man power, 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. (Masuch & Rueger, 2005)

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 providing solution to the lack of well-defined development processes for large-scale production of short serious games[1], presenting a proposal for a development process with fundamentals in software engineering practices (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, Santaolaya Delgado, & Collazos Ordóñez, A serious games development process using competency approach. Case Study: Elementary School Math, 2014), the results of using this process for the production of various video games (Álvarez Rodríguez, Barajas Saavedra, & Muñoz Arteaga, 2014), and the results testing of video games with students (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, Santaolaya Delgado, & Collazos Ordóñez, A serious games development process using competency approach. Case Study: Elementary School Math, 2014), and the identification of software requirements (Barajas Saavedra A. , Álvarez Rodríguez, Mendoza González, & Oviedo de Luna, 2015) (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, & Oviedo de Luna, Process for Modeling Competencies for Developing Serious Games, 2016). Solving, in this way, the problems identified within this subject of investigation (Barajas Saavedra A. , Muñoz Arteaga, Álvarez Rodríguez, & García Gaona, 2009), that is to say:

1. the experts in contents have not been provided with simple and intuitive tools that automate the large scale production;
2. the game producers do not have the rationale that supports the structuring or design of the serious game, or the experience in the competencies in which the videogame applies;
3. for the production of a serious game neither a structured nor based on software engineering process exists that guarantees the consistency and standardization of the production to increase and to guarantee the quality of products.

[1] A short serious game (SSG) is a game whose purpose is to teach an area of knowledge of a competency to the user.

Chapter 1

1 Thesis Project Description

In this chapter, the reader can find all information about objectives, hypothesis, research questions, and the thesis project itself.

1.1 Thesis objectives

1.1.1 General objective

To facilitate the efficient and quality production of short serious games through the use of a software engineering process. Quality is given in terms of user satisfaction and full requirements implementation (learning contents, learning activities and pedagogical aspects). Efficiency is given in terms of rework.

1.1.2 Specific objectives

1. To identify the best practices for producing digital learning resources from reports in the literature and from empirical production.
2. Define a reusable development process to support short serious games development with the use of software engineering practices to achieve quality games and project efficiency.
3. Evaluate the process in a set of serious game development projects using the case study method

1.2 Research questions

1. Can a development process to support short serious games quality with the use of software engineering practices be defined?
2. Can the designed process ensure that the time, cost and quality of the production of short serious games will be estimated accurately and that a greater degree of assimilation of competencies will be given?

1.3 Hypothesis

The implementation of a software engineering process can facilitate production of quality short serious games.

1.4 Variables

Fig. 1. Variables.

1.5 Project description

1.5.1 Background

Previous efforts on this topic have been made in order to improve the adoption of competencies by users of digital educational resources, the implementation of software development processes, and the analysis of software requirements. Among this efforts you can find the next publications:

1. Barajas Saavedra, A., Álvarez Rodríguez, F. J., & Muñoz Arteaga, J. (2007, Mayo). Póster Interpretación del Área de Proceso de Administración de Requerimientos de CMMI. Octavo Seminario de Investigación del Noveno Verano de la Ciencia. Aguascalientes, Aguascalientes, México.
2. Barajas Saavedra, A., Álvarez Rodríguez, F. J., Muños Arteaga, J., & Muñoz López, J. (2008). RADIP: A Software Development Process for Mexican PyMEs. (G. Sidorov, B. Cruz, M. A. Martínez, & S. Torres, Eds.) Advances in Computer Science and Engineering, 34, 311-322.
3. Barajas Saavedra, A., & Álvarez Rodríguez, F. J. (2009). Enseñanza de Matemáticas a través de objetos de aprendizaje móviles. CcITA 2009 (pp. 51-60). Mérida: Yucatán.
4. Barajas Saavedra, A., Álvarez Rodríguez, F., Muñoz Arteaga, J., & Bautista Villalpando, L. (2009, Agosto 25). Redes internacionales de OVAs: Proyecto Videojuegos para Matemáticas.
5. Barajas Saavedra, A., Muñoz Arteaga, J., Álvarez Rodríguez, F., & García Gaona, M. (2009). Developing Large Scale Learning Objects for Software Engineering Process Model. 2009 Mexican International Conference on Computer Science, 203-208. doi:DOI 10.1109/ENC.2009.46
6. Barajas Saavedra, A., Muñoz Arteaga, J., Álvarez Rodríguez, F. J., & Bautista Villalpando, L. E. (2010). Educational Videogame e-Library. Design and

Engineering of Game-like Virtual and Multimodal Environments (DEnG-VE). Berlín.

7. Barajas Saavedra, A., Álvarez Rodríguez, F. J., Muñoz Arteaga, J., & Bautista Villalpando, L. E. (2011). Uso de objetos de aprendizaje en dispositivos móviles. In F. J. Álvarez Rodríguez, & J. Muñoz Arteaga (Eds.), Avances en Objetos de Aprendizaje - Experiencias de redes decolaboración en México (pp. 131-157). Aguascalientes, Aguascalientes, México: Universidad Autónoma de Aguascalienes.
8. Barajas Saavedra, A., & Álvarez Rodríguez, F. J. (2012). Mathematics Game e-Library for Elementary School, Study Case: Mexico. Proceedings of the SPDECE-2012. Ninth nultidisciplinary symposium on the design and evaluation of digital content for education, 123-134.

1.5.2 Justification

General basic education is oriented to contribute in achieving better levels of intelligence, feelings and personality in students. Aimed to complement these efforts, several strategies has been implemented to incorporate technology (equipment, educational software, Web 2.0 tools, among others) within both, public and private schools from elementary to higher education. (INEGI, 2009)

However, and despite the efforts, it is clear – based on the ENLACE (by its acronym in Spanish, National Assessment of Academic Achievement in Schools) assessment results – that educational level of students is barely improving in elementary school students, considering basic topics on Math, Science, and Spanish (Secretaría de Educación Pública, 2013).

The article by Tejada Fernández (Tejada Fernández, 2005) emphasizes that education should appoint a special economic resource for the production of learning materials, and stresses the importance of using digital learning resources. It also establishes the means and strategies for assessment of learning by competencies.

Dávila Balcarce et al. (Dávila Balcarce & Velásquez Contreras, 2007) show the positive results of an evaluation as a methodological resource for education of two collaborative games. In addition, the improvement of the tested ludic applications for learning is necessary to create better educative contents.

Garrido Miranda (Garrido Miranda, 2013) states that video games are a systems environment that shows one way to configure a set of features that are pedagogically desirable and expected.

Almiron et al. (Almiron & Porro, 2014) established that the use of ICT in education is a good learning strategy. In addition, the authors establish that students have changed and they are not subjects for the actual teaching system.

Mechanisms more efficient in non-formal environment for students are necessary, as well as more learning opportunities beyond the classroom. Mechanisms with great potential are video games.

One of the aspects that must be solved is to produce content that "*provide immersion, motivation, fun and high level of engagement*" (Ibrahim & Jaafar, 2009). In recent years, this problem has become topic of discussion among the international research community, for which it is proposed the use of serious games to remedy this lack, researchers have proposed multiple models, frameworks, including development processes.

The literature review reveals that there is a need for the production of digital educational resources with a focus on quality because, such is the case, that a number of assessment tools are proposed in different educational levels, implying that the community is concerned about the usage of this resource, and even the different actors are involved in the teaching-learning process (teachers, professionals are evaluated, students, and even parents). However, to the best of our knowledge, no paper proposes how to properly develop the resources, assuming that the production of educational (digital) resources is a competence completely acquired by teachers. In addition to this, to the best of our knowledge, there is no research that has explicitly clarified how to implement the pedagogical aspects in educational digital resources, neither have clarify how to manage the development of these resources in order to finish projects efficiently and with a quality production. Quality is given in terms of user satisfaction and full learning needs implementation (learning contents, learning activities, expected learning, pedagogical aspects and competencies). Efficiency is given in terms of rework.

1.5.3 Problem statement

Short serious games produced with ad-hoc processes do not guarantee the efficient completion of the development, neither the quality production of the resources, nor that the learning needs are implemented entirely to facilitate the adoption of competencies; because the development depends on the degree of experience of developers in different areas of knowledge (pedagogy, digital content design, game design, process management, etc.).

1.5.4 Thesis project requirements

Is required to design a software engineering process for the development of short serious games containing guidance documents, roles, phases, activities, tasks, steps and process quality measures.

1.5.5 Solution approach

Identify the most important activities of game development and design of digital content to integrate them into a software engineering process to control, in general, the development of a software product, in particular, a short serious game.

Once the activities are integrated, the process will be applied in order to perform the establishment of its structure in phases, tasks and steps required for the production of a video game. Added to this, the roles and process guidance documents to support the implementation of the process will be established.

1.5.6 Results assessment and analysis

The assessment will be done experimentally by implementing and applying the development process for the production of short serious video game and comparing the results, in terms of products generated, with other team using an ad-hoc process.

1.6 Results and expected product

1.6.1 Results

A specific-domain software process for short serious games in order to achieve high levels of productivity and quality.

1.6.2 Expected product

The expected product of the thesis is a software engineering process specific to short serious game development including guidance documents, phases, activities, tasks, steps and roles to successfully manage a project to produce short serious games.

1.6.3 Final result

Ensure that the time, cost and quality of the production of short serious games are estimated accurately and that a greater degree of assimilation of competencies is given.

1.6.4 Contributions

1) Scientific
   a) Definition of a development process to support short serious games quality through the use of software engineering practices
2) Technology
   a) Production of a collection of video games for specific purposes to support learning.
3) Social
   a) Improve the way of adoption of competencies of students.

1.7 Publication opportunities

1.7.1 Congresses

1. LACLO
2. CcITA
3. INTERACCIÓN
4. Jornadas Chilenas de Computación

1.7.2 Journals

Table 1. Journals for submitting papers.

Journal	Language
Creative Education	English
IEEE Transactions on Education	English
IEEE – RITA (IEEE Education Society)	Spanish

REDIE	Spanish/English
Journal de Computación y Sistemas (CyS)	Spanish
Journal of Applied Research and Technology – JART	English
Revista Ingeniería, Investigación y Tecnología	Spanish/English

Chapter 2

2 Basic Concepts

In this chapter the reader can find all the rationale for this research work.

2.1 Software systems

Currently, most countries use software systems that are faster, more powerful, more complex and cheaper, leading to software development companies to produce software minimizing the resources used to produce them (Reyes Delgado, 2005), so it is necessary to use more advanced software engineering techniques to generate and define processes to produce designs and implementations more mature and with more detail.

Systematic methods and software development processes defined receive much attention in research, but are rarely used in industry for the development of software systems. One of the main reasons is the lack of knowledge about the integration, interpretation, definition and adoption of formal methods in the software process and the precise role of systematic methods and processes in the lifecycle of software remains very diffuse (Plat & J. Toetenel, 1992).

A quality development process is the unique viable way for producing no simple software products. (Chroust, 1996)

2.2 Software processes

There are several definitions for a software process, some are set out below:

1. A set of activities whose goal is the development or evolution of software (Sommerville, 2005).
2. According to IBM, a software process is a method that defines who does what, when and how it is done to achieve a specific goal. (Rational, 1998)
3. According to the SEI, is a means of integration of staff, procedures, methods, equipment and tools to produce a desired result. (Software Engineering Institute, 1992)

According to (Fuggetta, 1995), a software process is the team of people, organizational structures, rules, policies, activities and procedures, software components, methodologies and tools used or specifically created to conceptualize, develop, offer a service innovate and extend a software product.

Consistent with the above, (Oktaba & Ibargüengoitia González, 1998) propose the static structure of a software process (Fig. 2) through a class diagram. This structure establishes that a software process is a composition of phases, activities and resources (including human resources).

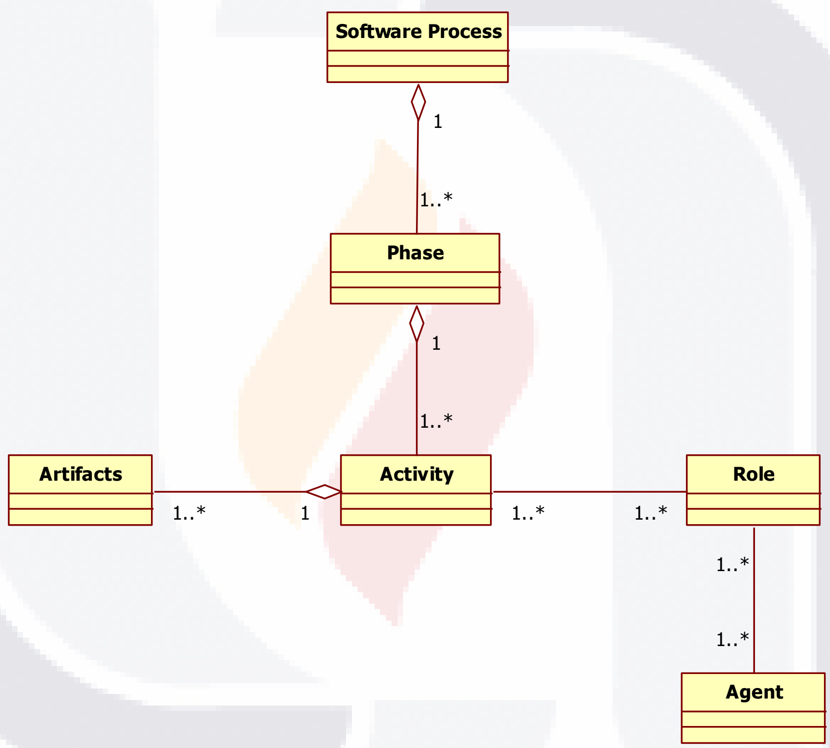


Fig. 2. Software process class diagram (Oktaba & Ibargüengoitia González, 1998)

Accordingly to Sommerville (Sommerville, 2005), the software processes that perfectly fit the needs of all businesses and all software projects do not exist. Thanks to the extensive research and experience generated by researchers in Software Engineering, it has been achieved a collection of best practices for software development.

It is also important to note that Sommerville (Sommerville, 2005) mentions that if you have a quality process, you can build a quality product.

2.3 Software engineering from industry point of view

Despite all the stresses generated in research centers, as mentioned in (Plat & J. Toetenel, 1992), globally there is a significant percentage of software development companies that do not use systematic methods for the development of projects and software processes. This problem can also be attributed to the fact that many entrepreneurs and software developers ignore the potential benefits of using software engineering methods and the definition of software development processes for both quality of product and the quality of the process, and therefore the project (Chatzoglou, 1997).

At this point, the Software Engineering provides a mechanism for the development of affordable software systems, and through organizations such as the SEI (Software Engineering Institute) and ISO (International Standardization Organization), have generated international standards for assurance of quality in software development processes and the management of resources and models to measure the maturity of software development processes, such as CMMI (Capability maturity Model Integration), Rational Unified Process (RUP), Software Process Improvement and Capability Determination (SPICE), Process Model for Software Industry (MoProSoft), Personal Software Process (PSP) and Team Software Process (TSP).

Establishing and adopting a disciplined development approach is necessary in order to produce a quality software system, i.e., that meets the needs of the client, performs flawlessly and is easy to modify and use (Pressman, 2006).

Although the software industry and software development companies are aware of the need to establish disciplined approaches for developing software systems, besides quality development processes, the discussion about what are the best practices to implement it still remains.

This discussion continues because the software development processes are complex and rely on human analysis to judge and create (Pressman, 2006). Because of these properties is extremely complex automating software development processes. There are other reasons why an automation of software development processes (Sommerville, 2005). One is that there are multiple approaches to the development of a software system. That is, there is a wide range of systematic methods that can be used to solve many problems established in different software projects, so the possibilities are too many, and the problem becomes even more complex when noticing that every software development project creates a particular need for their development, so that a process based on a systematic method might not work properly for that project.

The focus on organizational processes can increase the ability of the company to compete by improving the use of available resources; effectively manage their relationships, offer a vision of what could be the good organization and defining how to achieve that goal, also provides a method to prepare the organization to meet future challenges. (Harrington, 1998)

The quality of processes has an important influence on the quality of software since the quality management process includes standards for defining processes, reviews, deadlines, monitoring of development processes to reports. Or in simpler terms, “is the degree to which a customer or user perceives that software matches the composition of their needs” (Chroust, 1996).

Focus on processes makes organizations reduce redundant work and improve work organization, facilitating its administration. However, well-managed processes are not the only answer; process management should be supported by training, enough money, enough skilled staff, appropriate tools and management support (Kulpa & Johnson, 2003).

However, it can be perceived by other studies that there is a lack of process management, originating as a result, impairment in the quality of products and services due to the lack of a set of steps to build.

As an alternative solution to these problems, there appear different standards and models of development and quality created by groups of individuals or organizations to align product specifications, interfaces, processes, terminology, etc. The standards cover a wide range of topics and are recognized by various groups of people and countries (Margain Fuentes & Durón Rosales, 2002). Some standards are formally developed by organizations while others are imposed on the market (SPICE, 1998). Namely, some of these models and methodologies include:

1. Rational Unified Process (RUP)
2. Software Process Improvement and Capability dEtermination (SPICE)
3. Modelo de Procesos para la Industria de Software (MoProSoft)
4. Capability Maturity Model Integration (CMMI)
    a. Personal Software Process (PSP)
    b. Team Software Process (TSP)

Where, CMMI shows the "what" should be performed, while RUP, SPICE and MoProSoft establish the "how" activities should be performed to develop a software product.

2.4 An ideal process

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*." (Oktaba & Ibargüengoitia González, 1998).

A software process is a set of activities and associated results that produce a software product on time and rationally (Pressman, 2006). 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 (Sommerville, 2005).

There are four fundamental activities of processes that are common to all software processes (Pressman, 2006):

1. Software specification where customers and engineers define the software to produce and restrictions on its operation.
2. Software development where software is designed and built.
3. Validation of the software where the software is validated to ensure that it is what the customer requires.
4. Evolution of software where the software is modified to adapt to the changes required by the customer and the market.

2.5 Software quality

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. (Sommerville, 2005)

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.

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.

According to the literature, (Pressman, 2006) and (Sommerville, 2005), in a software project can be controlled only three variables:

1. Scope. The quality results in percentage of user requirements that were included in the software product.

2. Cost. The amount of money consumed product software development.
3. Time. It is the period of time it took to release the product.

Each of these variables can be handled according to the needs of the project, but it is important to note that when adjusting one of those variables, the other two will suffer an increase or decrease that could adversely affect the project. For example, if the development budget is reduced, the time may increase and the project would not be released to the due date; or scope may decrease and the product will not cover customer expectations.

2.6 Importance of software processes

Software development processes are necessary because they allow developers to monitor and control a project in all of its phases, activities, task and steps through guidelines and documentation, so quality can be achieved by guarantying that the product will be developed to meet all client needs with a minimum resource waste.

2.7 Games types

Clark Aldrich (Aldrich, 2009) 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.

Clark suggest that educational simulations, games and virtual worlds are points along a continuum and all of them belong to highly interactive virtual environments (HIVE's) (see Fig. 3):

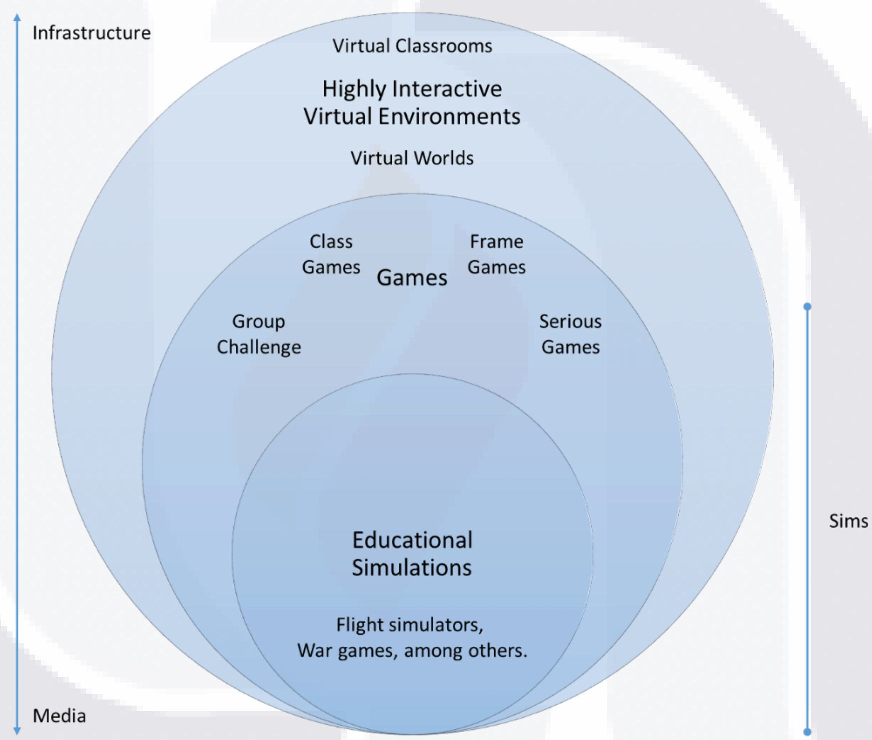


Fig. 3. The HIVE continuum. (Aldrich, 2009)

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 (see Fig. 4).

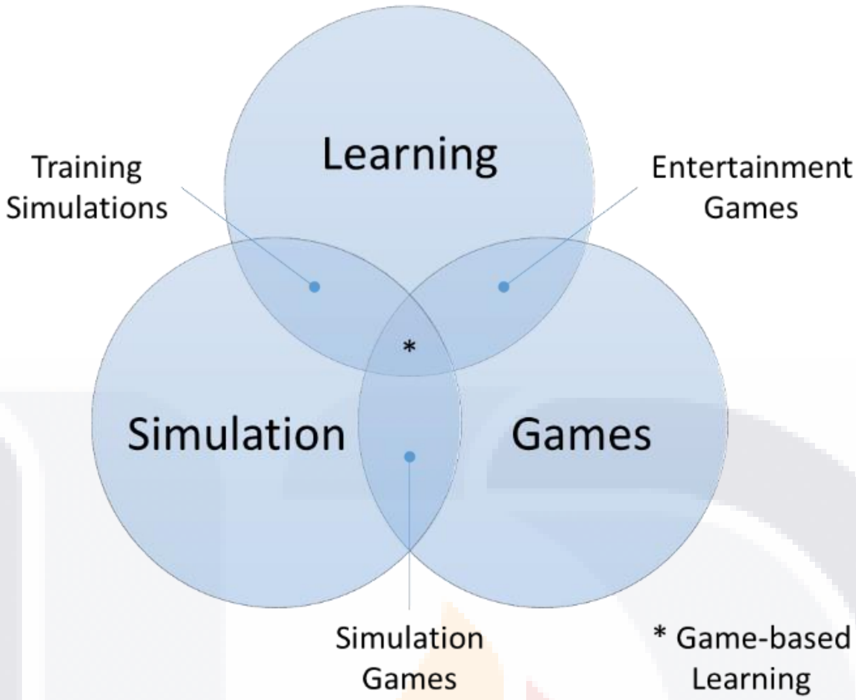


Fig. 4. Interplay of pedagogy, computer science and games (Martens, Diener, & Steffen, 2008).

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 (Zyda, 2005). 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.

2.8 Serious games

The way in which students are being educated is evolving; modern individuals require an ongoing learning due to the technological changes (UNESCO, s.f.). The profile of the modern student has changed with the "information age" Individuals evolve in an environment strongly influenced by the presence of diverse artificial and technological elements. (McGinnis, Bustard, Black, & Charles, 2008)

The traditional teaching paradigm, where formal and non-formal education are treated as a mutually exclusive, must be changed and turned into a new learning paradigm where formal and non-formal education are treated as one in order to achieve a meaningful and relevant learning.

"*Learning is not restricted to the time spent at school. It begins at birth and continues all your life*" (UNESCO, s.f.). A truly meaningful education should also be built on the student's non-formal experiences (tacit knowledge) that happen before or at the same time that school. Daily, students have a vast number of opportunities to have meaningful and relevant tacit-knowledge, which, in many cases turns formal education into a secondary source of information for them. (Vázquez Alonso & Manassero Mas, 2007)

Many authors (e.g. (Aghabeigi, Calvert, El-Nasr, & Riedewa, 2012), (Critelli, Schwartz, & Gold, 2012), (Emam & Mostafa, 2012), (Huang, Dong, & Liu, 2011), (Hwang, Wu, Huang, & Huang, 2012), (Jovanovic, Starcevic, Minovic, & Stavlja, 2011), (Mao, Yi, JianGang, & Guo-tao, 2010), (Cai, Liu, & Liang, 2010), (Chuang, You, & Duo, 2010)) establish that video games are effective learning mechanisms that provide "*immersion, motivation, fun and high level of engagement*" (Ibrahim & Jaafar, 2009). Also, it has been observed in many studies, like (Barajas Saavedra & Álvarez Rodríguez, Mathematics Game e-Library for Elementary School, Study Case: Mexico, 2012), (Barajas Saavedra A. , Muñoz Arteaga, Álvarez Rodríguez, & Bautista Villalpando, 2010), and (Virvou, Katsionis, & Manos, 2005), that the video game phenomena can be used in advantage to the formal learning process outside school, because video games are very attractive to kids, and their use as teaching tools is plausible.

"*Computer games are very effective in the just-in-time delivery of new competencies and knowledge*". Engagement and immersion is kept by the game system continually delivering optional, achievable, new challenges and/or experiences to the player. Effectively, a computer game immerses a player in a temporary world. This virtual world provides a safe environment where the player is continually challenged to complete tasks which ultimately lead to the overall outcome or "winning state". (McGinnis, Bustard, Black, & Charles, 2008)

"Playing" is a close activity with "learning". During "playing", one can often learn many things to improve his/her "playing" with high motivation. However, the "playing" is usually excluded from "learning" from the educational point of view, because of the following two difficulties, the one is the difficulty in grasping individual learner's playing and the other is the difficulty in providing adequate feedback for each playing. Such adaptive interaction is impossible to realize in usual classroom. (Umetsu, Hirashima, & Takeuchi, 2002)

2.8.1 Statistics from the games industry

Entertainment Software Association found that about 67% of American head of households play computer or video games. Computer Entertainment Software Association reported that in Japan, almost 80% of the general public and almost 70% of women have at least one games machine in their homes. Similarly in Korea, Korean Game Development and Promotion Institute stated that more than 50% of their population play online games. Previous studies done on preschool children, primary and secondary school children, and college and university students have shown that there is a lot of interest among students in using the games for learning purposes. Those studies indicate that students showed a high interest in gaming activities. Rubijesmin's research on Malaysian primary and secondary students reported that about 96% of male students are playing computer games either at school or outside school, while about 90% of female students claimed to do so. Roslina reported that about 90% of university students agree with the idea of using games as a learning approach. (Ibrahim & Jaafar, 2009)

In addition, others studies like (Procuradía Federal del Consumidor, 2009) have shown that video games are widely used in daily life of Mexicans kids, showing that 64% of the surveyed people own a video game console since three years ago, 55% play from one to three days a week and 72% play between one and three hours daily.

Nowadays, the use of digital educative resources has become a very common practice, in way that, in the diverse commercial applications platforms the offer of these resources is vast. In 2015 Ariel through appfigures (Ariel, 2015) reported that Apple and Google offered in the

2014, respectively, 1.21 million and 1.43 million applications in their stores. Game and Education applications are among the top five fastest growing in number categories in the Apple store, meanwhile Game applications is the top fastest growing in number category in the Google store (Ariel, 2015). In addition to this, the Apple store is composed of 21.45% of Game applications and 9.95% of Education applications, and Google store is composed of 14.8% and 6.1% of Game and Education applications, respectively (Statista, 2015). Therefore, the market for this applications is comprised of approximately 678,810 applications.

All these applications promotes the adoption of some “competences” by the users. An example of these “competences” can be found in the applications developed by Toca Boca (Toca Boca, 2015), where, in the section For Parents of its Web site (Toca Boca, 2015) presents the promoted “competences” of each one of its applications. However, it is unknown whether these applications have been developed with quality control to ensure the adoption of competences. The promoted “competences” are given in general terms and not in terms consistent with a systematic educational development in the area.

On the other hand, the rapid growth of wireless and mobile technologies has resulted in the mobile learning that has been gradually considered as a novel and effective form of learning because this inherits all the advantages of e-learning as well as breaks the limitations of learning time and space occurring in the traditional classroom teaching (Chen & Hsu, 2008).

2.8.2 Serious game definition

In first instance, the term Serious Gaming involves a mechanism that provides new ways of communicating knowledge within a game-like environment. (Froschauer, Seidel, Gärtner, Berger, & Merkl, 2010)

Mike Zyda describes Serious Games as “*a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives*” (Zyda, 2005). deFreitas and Jarvis consider the term as a synonym with "*game-based learning*", because both are used to refer to a digital game with a specific educational or training purpose. Serious Games go beyond entertainment and attempt to educate players about less traditional learning topics, such as health care or political issues. The goal for the design of Serious Games is the successful integration of learning objectives with the elements of entertainment, play and fun. Therefore, in addition to disciplines like game design, visual artistry and programming, the design of a Serious Game also involves pedagogical concepts to become a successful mediator of knowledge. In this context Zyda created the term "*collateral learning*" - the learning that happens by mechanisms other than formal teaching. (Froschauer, Seidel, Gärtner, Berger, & Merkl, 2010)

In order to build better connection between digital games and education, "serious games" were widely developed to enhance the games' educational value; but unfortunately it sacrifices their entertaining value when the form of game becomes too "serious". (Shih, Chuang, Tseng, & Shih, 2010)

Froschauer in (Froschauer, Seidel, Gärtner, Berger, & Merkl, 2010) describes the following thematic classification for Serious Games based upon Zyda's definition of Serious Games: Military Games, Government Games, Educational Games, Corporate Games, Healthcare Games, Political and Religious Games. Educational Games look for ways to use Serious Games as an effective teaching medium.

Serious Game was first emerged in America in 2004 which is a comparatively new research field. Because of its combined ability of entertaining in games and seriousness in education, it is now applied not only to computer games but also to skill training, virtual explore, theory analysis, visual art, status simulation, education health care and so on. Serious game owns the user interface of games and simulation based on actual event or process and also features and characteristics of games. The core purpose of serious game is not entertainment but used in training and education for skill coaching, which is an especially practical training assistant for some fields which won't allow anything go wrong. (Cheng, Hao, JianYou, & Yun, 2010)

Serious Games has a major design feature that must be included - the aspect that is to be taught in an educational game, for example, or the message in a political or advertising game. This will be called the focus, and it must usually be weaved carefully into the design in order to achieve the maximum effect. A second key aspect in serious game design is the nature of the client. The buyer/publisher of a serious game is often the individual or group with the message to be communicated. Thus, the entire chain of design documentation that concerns the commercial aspects of the game needs to be modified. (Parker & Becker, 2011)

Dondlinger in (Dondlinger, 2007) distinguishes the difference between Edutainment and Educational Games, where the former are those which follow a skill and drill format in which players either practice repetitive skills or rehearse memorized facts. As such, Edutainment often fails in transmitting non trivial knowledge, calling again and again the same action patterns and not throwing the learning curve into relief.

In the other hand, educational video games require strategizing, hypothesis testing, or problem-solving, usually with higher order thinking rather than rote memorization or simple comprehension. Characteristics of such games include a system of rewards and goals which motivate players, a narrative context which situates activity and establishes rules of engagement, learning content that is relevant to the narrative plot, and interactive cues that prompt learning and provide feedback.

In (FutureLab, 2010) a review of different definition of serious games is presented, concluding that there is no agreement in definition. However, there is a consensus that serious games must have the next elements and characteristics:

1. a learning objective (whether explicit or not),
2. being an engaging interactive media, and
3. having some game element.

2.8.3 Importance of serious games

Serious games then are important because they are a very powerful tool to reach students (particularly young students) and achieve the so called "*collateral learning*" so they can learn more stuff in less time, and without them even noticing it.

2.9 Short serious games

Based on the review of the literature, and based on previous research in the field of digital educational resources, this research establishes a short serious game must have the following elements (Fig. 5), regardless of their purpose (training, education, etc.) and its competencies:

1) **Pedagogic aspects**, which include the next elements:
   a) Learning needs of the individual or group of individuals.
   b) The social and cultural context of the individual or group of individuals.
   c) 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 in (de Freitas & Jarvis, 2006) and (de Freitas & Oliver, 2006).
   d) **aspects** including:
   e) Considerations for game-play and story (Zyda, 2005).
   f) Level of fidelity, interactivity, immersion, fun, etc.
2) **Integration aspects** that include:
   a) Considerations for game-based learning (Martens, Diener, & Steffen, 2008).
   b) Considerations for inclusion of materials in formal classes.
   c) Considerations of context for the implementation of digital educational resources (de Freitas & Jarvis, 2006).

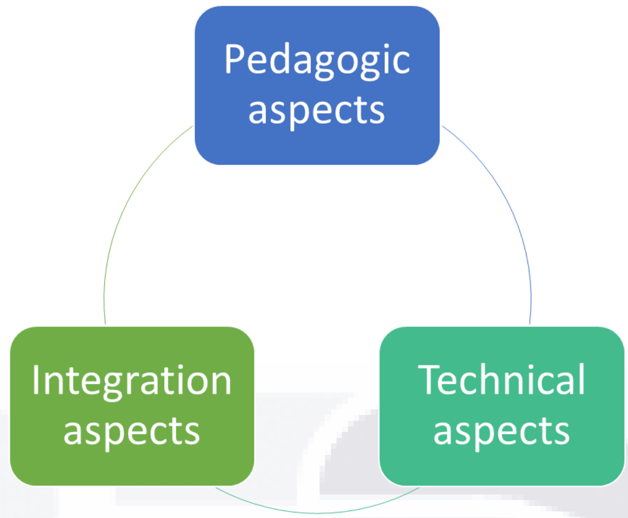


Fig. 5. Serious games elements.

Bearing in mind the analyzed literature on games and learning objects, a non-exhaustive set of basic features that represent a good starting point to achieve a usable product with a good grade of quality were identified:

1. Short and focused on a single area of knowledge;
2. Graphical user interface pedagogically evaluated;
3. Cases with formal reasoning;
4. Cases randomly generated;
5. Challenging content and generating competition among students using the game.

2.10 Competency

In terms of approach, there have been three main traditions in competence research since the middle of the last century: the behaviorist, the generic and the cognitive. (Mulder, Weigel, & Collins, 2007)

The behaviorist approach stresses the importance of observing successful and effective job performers and determining what differentiates them from their less successful counterparts. Competencies in this respect are acquired through training and development and competence is based on the description of observable behavior or performance in Situ. The definitive characteristics of the behavioral approach are demonstration, observation and assessment of behavior.

The generic approach is aimed more at identifying the common abilities that explain variations in performance. Again, in this approach, the most effective performers and their distinguishing characteristics are identified. Then, through statistical analysis, the main and generic characteristics of top performers are defined. Competence, in this sense, is more about framing an overall performance that is appropriate to a particular context. It is not about following simplistic recipes.

The definition of competence in the cognitive approach includes all of the mental resources of individuals that are used to master tasks, acquire knowledge and achieve a good performance. It is often used simultaneously with intelligence or intellectual abilities. The classical cognitive approaches focusing on general cognitive competencies include psychometric models of human intelligence, information processing models and the Piagetian model of cognitive development. Currently the competence-performance concept has been categorically expanded to encompass ‘social’ or ‘emotional’ competencies, in which ‘competence’ has replaced the original term, ‘intelligence’.

Although difficult to accept a definition of the term competency would recognize that is a combination of three elements: a) information, b) the development of a skill and, c) put into action in a unique situation. The best way to observe a competency is in the combination of these three aspects, which means that all competency requires mastery of specific information, while calls for the development of a skill or rather a set of skills derived from processes for information, but in a problem situation, that is, in a real unique situation, where competition can be generated. (Díaz Barriga, 2006)

The definition used for this document is as follows: “Competencies are all mental resources of individuals that are used to master tasks, acquire knowledge and achieve a good performance in some specified abilities with a certain skill level.”

Chapter 3

3 State of the Art

Developing serious games is a serious business in industry as well as in research, so this section introduces, in first place game types and then the point of view of industry and research center of serious game development processes and methods.

3.1 Game development processes in industry

There exist several methods and processes for developing games in the industry, such as Game Waterfall Process (GWP), eXtreme Game Development (XGD), Game-Scrum, and Game Unified Process (GUP).

3.1.1 Waterfall game development process

"*The waterfall development process is the one commonly used in game development.*" (Flood, 2003). As a traditional waterfall process it has distinct phases that need to be completed in a certain order before the process can go on onto next phase. Once a phase has been completed it must be ensured that all artifacts are flawless, because if defects propagate to further phases, fixing them will very costly.

The following figure (Fig. 6) shows the larger categories of levels found in game waterfall process.

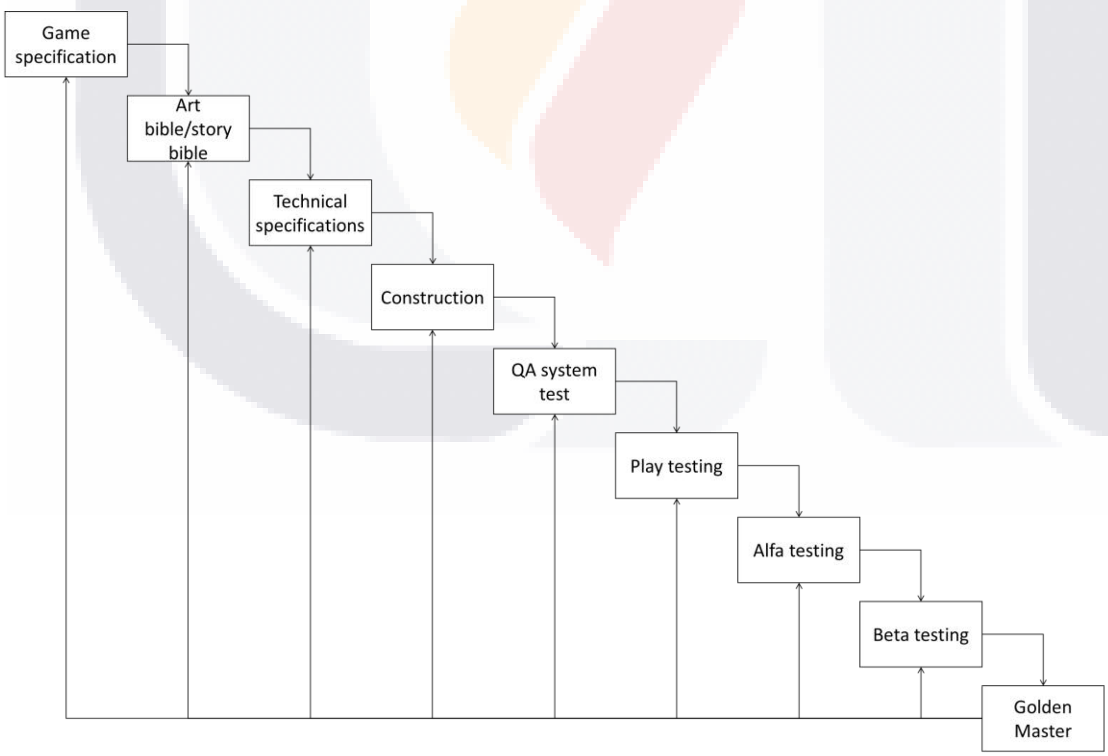


Fig. 6. Waterfall game development process. (Flood, 2003)

3.1.2 eXtreme Game Development

XGD is an agile game production method based on the Extreme Programming (XP) method. It is a way of adapting XP to the specificities of game development, especially: (Demachy, 2003)

1. How to adapt XP to game design and assets creation
2. How to automatically test game-specific elements, such as the "fun factor".

“*XGD is a new method for managing game projects to ensure that games are delivered on time. XGD was not invented from scratch. Rather, it is an adaptation of Extreme Programming (XP) to the game development process. As I said earlier, XGD is currently being rolled out at Titus Interactive Studio on two projects. I'll let you know in a few months how we fared using XGD -- which practices worked and which did not.*” (Demachy, 2003) [2]

3.1.3 Game-Scrum

According to Schwaber [Schwaber 2009], Scrum is a framework focused on project management - how to divide and coordinate the tasks so that everything can be done without impediments, under which you can use any other agile practices. In this view, XP would be more focused on the engineering of the project - which techniques are best to complete tasks efficiently.

Game-Scrum uses a combination of Scrum and XP methods, “*adapting them with the experience of professionals and focusing in people with little or no experience in game development*”, and is divided into three phases: Pre-production, Production and Post-production. Game-Scrum uses Scrum to divide and coordinate the tasks so that everything can be done without impediments, under which you can use any other agile practices, and XP to focus on the engineering of the project. (Godoy & Barbosa, 2010)

[2] At the time when this reference was accessed the Extreme Game Development Web Site http://www.extremegamedev.org was not available, but author encourages readers to read about Extreme practices in the Extreme programming Web Site http://www.extremeprogramming.org.

3.1.4 Game Unified Process

This methodology was the product of a project to develop games (casino games) and a complementary platform to support high-volume Internet game play. During this process, the project sponsor decided that changes should be made to the form of development so that the deadlines could be met, and so they decided to use a combination of two development methodologies commonly used in traditional software: RUP and XP. "*Each development group was given the latitude to adopt any of the interactive processes. Software engineering took a very RUP-like approach, creating use cases and following as best they could the dogma of RUP. The content group took more of an XP approach by working in small teams focusing on single games.*" (Flood, 2003)

3.2 Game development processes in research

3.2.1 Masuch approach

Masuch establishes that a typical game development process consists of the following steps (Masuch & Rueger, 2005):

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

3.2.2 Ibrahim approach

Ibrahim proposes an Educational Game Design Model (Fig. 7) 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. (Ibrahim & Jaafar, 2009)

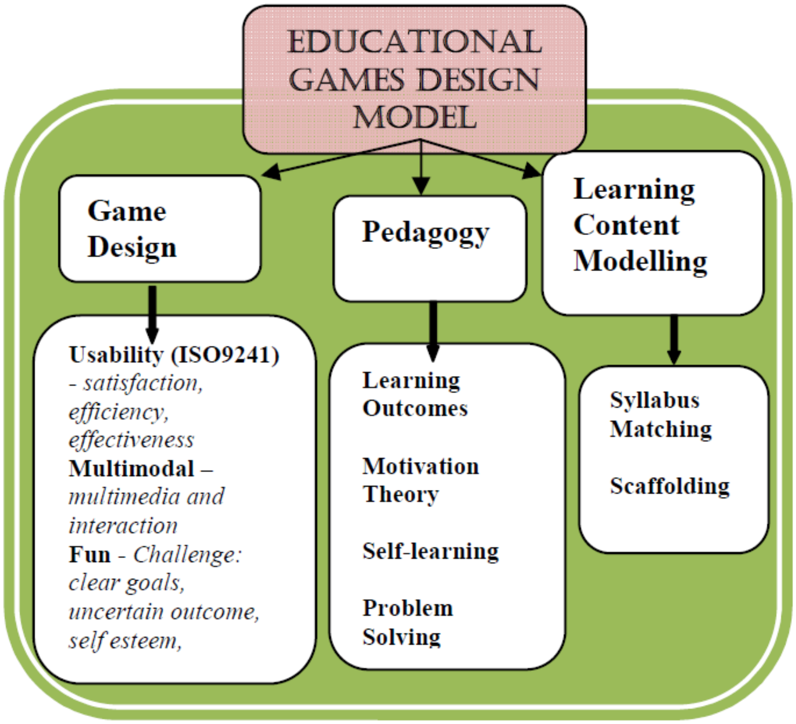


Fig. 7. Educational game design model proposed by (Ibrahim & Jaafar, 2009).

3.2.3 Zin approach

Zin proposes an Educational game design (Fig. 8) 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. (Zin & Yue, 2009)

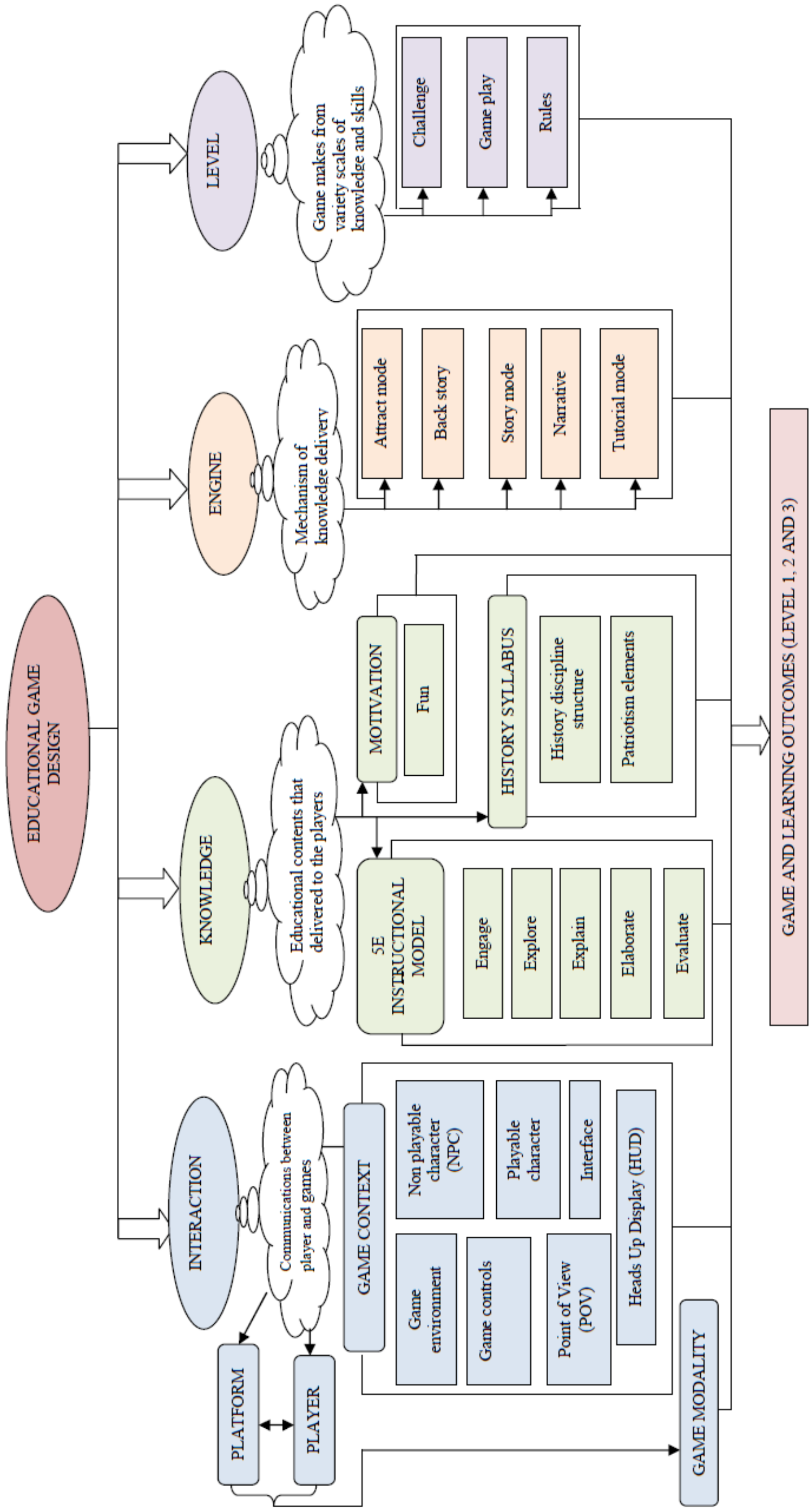


Fig. 8. Educational game design proposed by (Zin & Yue, 2009).

3.2.4 RETAIN model

In (FutureLab, 2010) 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 five areas the designer or teacher/trainer needs to consider once the learning goals have been defined (Table 2).

Table 2. Required aspects for appropriate serious games.

Aspect	Description
Relevance	1) presenting material in a way relevant to learners, their needs, and their learning styles, and 2) 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

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. (FutureLab, 2010)

"*Although a number of frameworks exist that are intended to guide and support the evaluation of educational software, few have been designed that consider explicitly the use of games or simulations in education. Similarly, research in game studies has generally focused upon approaches based upon playing leisure games, and therefore do not take enough account of factors including the context, learning theory and practice and the attributes of the learner and learner group*." (de Freitas & Oliver, 2006)

The four dimensions are shown in Fig. 9:

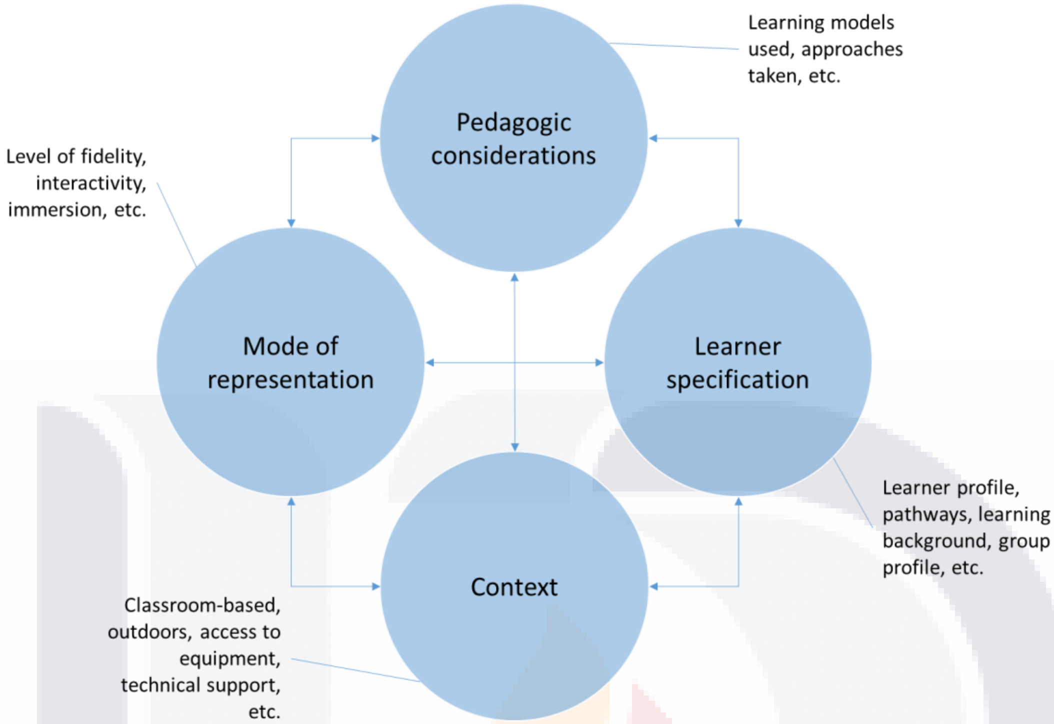


Fig. 9. deFreitas and Oliver's framework for learning considerations.

3.2.5 Álvaro Galvis method

The methodology given by Galvis provides quite robust mechanisms for analysis, education and communication design, and pilot/field testing, since it is based on proven valid principles of education, communication and educational technology. The graphical representation of this methodology can be seen on Fig. 10.

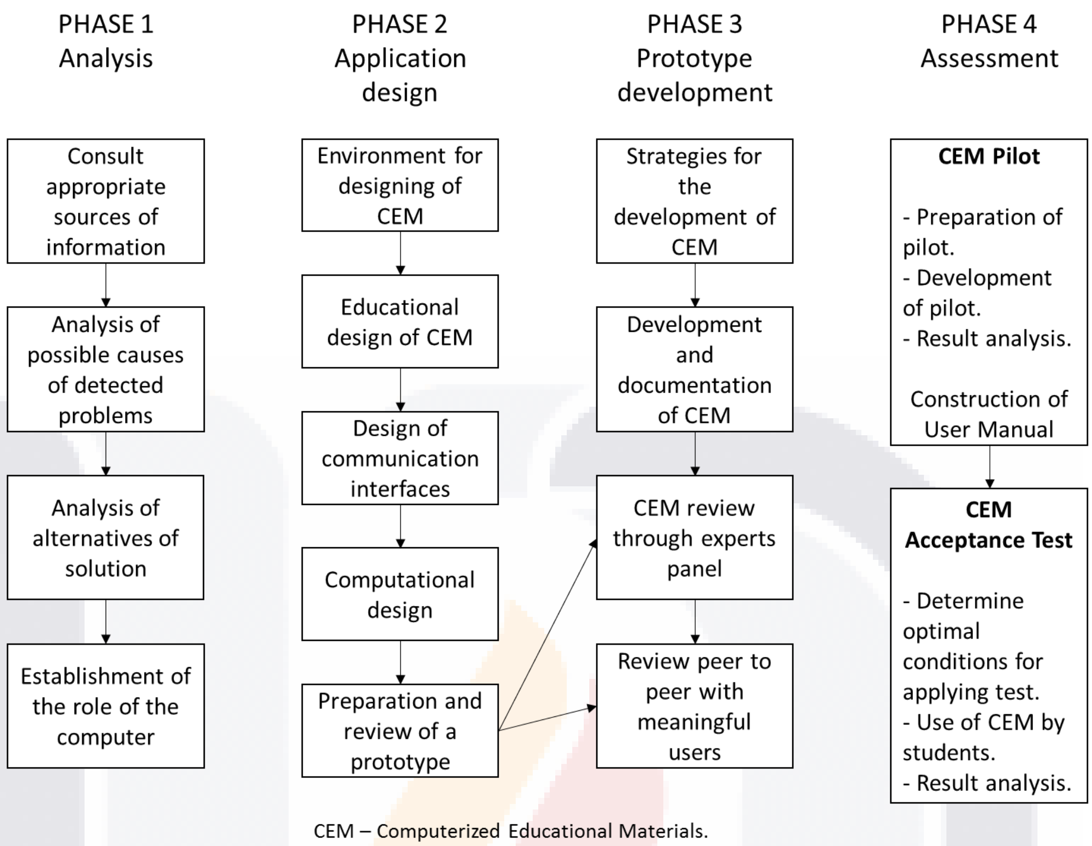


Fig. 10. Galvis methodology for developing computerized educational materials.

3.2.6 Pere Marqués method

Pere Marqués proposes a method for developing educational software, and the phases to develop such product are next. On Fig. 11 the graphical description of the method can be seen. (Gallardo, León, Martínez, Martínez, & Primera)

Step 1. Instructional analysis. Problem definition and necessities analysis.

Step 2. Idea genesis. Initial ideas for teaching/learning process. It takes into account the next aspects:

- a) Contents
- b) Learning activities
- c) Graphical user interface
- d) Documentation for supporting material
- e) Internet mediated pedagogic support

Step 3. Instructional design. In this phase all pedagogical fundamentals are established for the project. Some work products are:

- a) Design team integration

b) Instruments design
c) Functional design
d) Objectives
e) Contents
f) Interactive activities and teaching/learning strategies
g) Activities interaction and cognitive efforts
h) GUI – Metaphors and elements
i) Navigation systems
j) Curricular integration
k) Documentation of the materials

Step 4. Viability study and general framework of the project.
a) Viability study considers the next aspects: pedagogical, functional, technical, budget, and commercial.
b) Once the viability study has a positive result, then the general framework of the project is established considering the aspects analyzed on the previous study.

Step 5. Multimedia script. This script includes:
a) General aspects
b) Navigation map
c) Navigation system

Step 6. Content creation. This phase is in charge of creating all the contents and the documentation required by teachers to use the contents.

Step 7. Alfa Test prototype development.

Step 8. Internal evaluation. In this phase the Alfa test is driven.

Step 9. Beta Test prototype development.

Step 10. External evaluation. In this phase the Beta test is driven.

Step 11. Final version production.

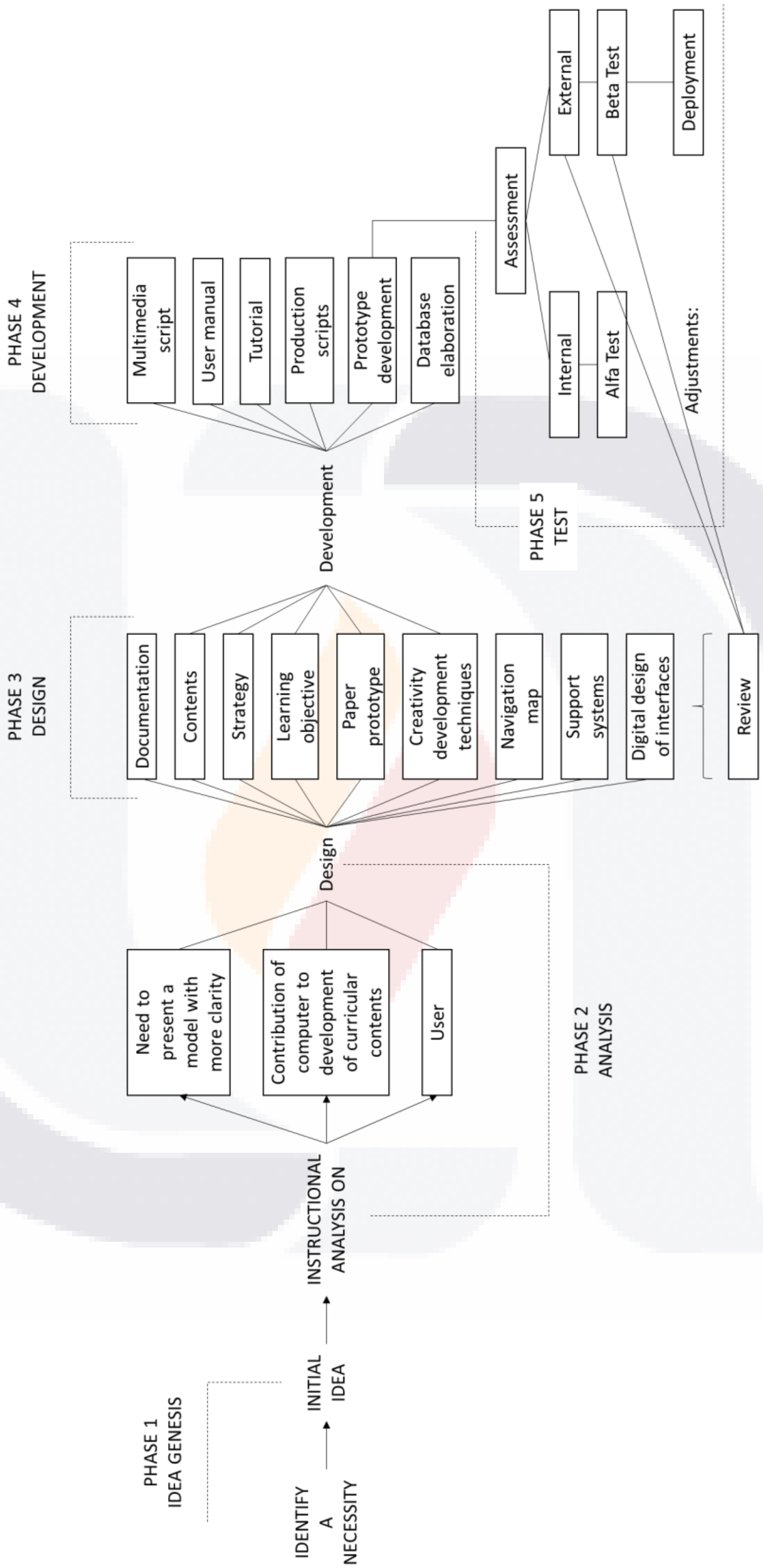


Fig. 11. Pere Marqués Method for developing educational software. (Jiménez A., Rico L., Méndez S., Ceron S., & Palechor Betancourt, 2010)

3.2.7 Luca Galli approach

Luca Galli (Galli, 2014) attempts to solve the design of the tasks and the choice of game mechanics shortcomings for novel designers by providing: 1) a development process to follow when designing new GWAPs (Games With A Purpose, a synonym of Serious Games), 2) the definition of the multimedia refinement tasks best suited to be solved with GWAPs and 3) the list of traditional game mechanics that best match these tasks.

In Fig. 12 Galli "*shows a possible representation of the game development process, obtained by modeling the guidelines and practices suggested by widely recognized designers, such as Chris Crawford and Stacy Fullerton*" (Galli, 2014).

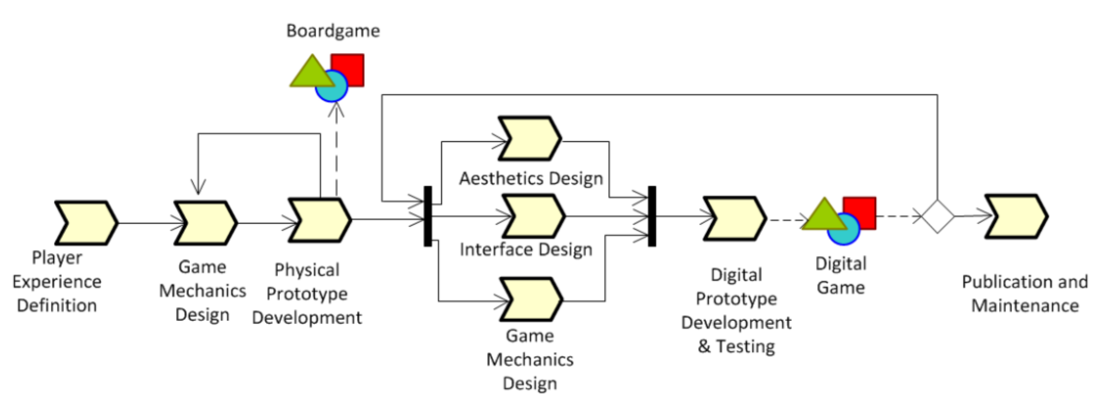


Fig. 12. Software Process Engineering Metamodel (SPEM) for game development. (Galli, 2014)

Galli establishes that a possible model (see Fig. 13) for "*the development process for a GWAP involves the definition of activities that have to be delegated to human performers and their integration within a game (existing or novel)*" (Galli, 2014).

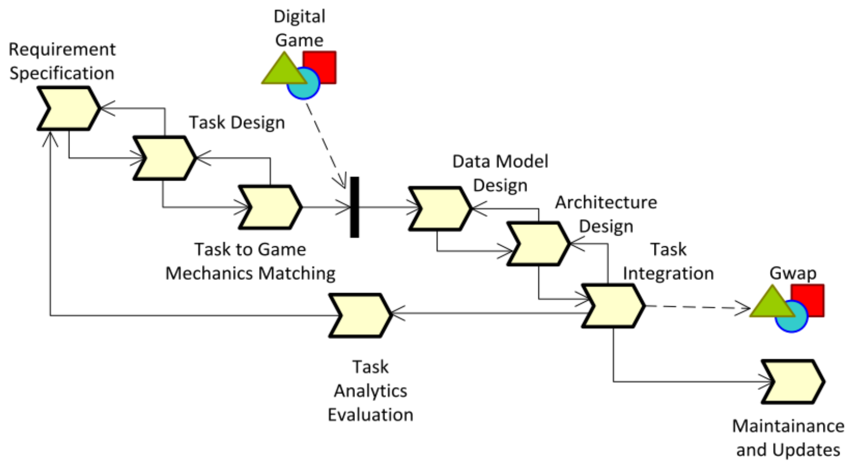


Fig. 13. Software Process Engineering Metamodel (SPEM) for GWAP Development. (Galli, 2014)

This model (Fig. 13) focuses on two main phases: Task Design and Task Matching, but emphasizes that the "*Requirement Specification involves the collection of information necessary for the definition of a task, a unit of work performed by human worker in the process of solving computational problems*" (Galli, 2014).

3.3 Method comparison

Next, in Table 3, there is a comparison among the different methods found in the industry and the literature. This table has been designed with two main sections:

1. Activities, which lists the activities identified in the different processes, models, methodologies and approaches (methods for short) described in the previous sections. Each of the identified activities are presented by the corresponding method as a task, activity or phase.
2. Methods, which lists the different methods analyzed in this research. Under this section is enlisted the column "Expected" that has been designed to show all the necessary elements of a method to consider it fully comprehensive and suitable for successful SSG developmet.

Table 3. Method comparison and expected activities for an ideal method.

Activities	*GWP*	*XGD*	*Game-Scrum*	*GUP*	*Masuch*	*Ibrahim*	*Zin*	*deFreitas*	*Galvis*	*Marqués*	*Galli*	*Expected*
Requirements specification											✓	✓
Task design											✓	
Task matching											✓	
Game specification	✓	✓	✓	✓		✓						✓
Pedagogical design						✓		✓	✓			✓
Interaction design							✓					✓
Instructional analysis										✓		✓
Instructional design						✓	✓		✓	✓		✓
Viability study										✓		✓
Game design												✓
Artwork	✓	✓	✓	✓	✓							✓
Storyboarding	✓	✓	✓	✓	✓							✓
Technical specifications	✓	✓	✓	✓				✓				✓
GUI design								✓	✓	✓		✓
Content design												✓
Level design							✓	✓				✓
Communicational design												
Documentation of materials												✓
Class integration										✓		✓
Engine design					✓		✓					
Programming the game engine					✓							
Development	✓	✓	✓	✓						✓		✓
Play testing	✓	✓	✓	✓	✓							✓
Alfa and Beta testing	✓	✓	✓	✓					✓	✓		✓
Golden master	✓	✓	✓	✓						✓		✓

Although there are a number of proposals that have been seen, none of these proposals has clarified how to produce a video game from the initial need for pedagogical considerations (de Freitas & Oliver, 2006), considerations of the game play and story (Zyda, 2005), the design of game-based training (Martens, Diener, & Steffen, 2008) or the implementation of HIVE's (Aldrich, 2009). Specifically, to the best of our knowledge, none of these methods shows how to perform requirements specification activities, transform the requirements into a game play and story (Game specification, pedagogical design, etc.) and finally produce a SSG, executing all the necessary activities.

In addition to this, it has not reached an agreement on the components that integrate a serious game. This is the main reason of the “Expected” column, to establish, based upon all the research done, the components necessary of a quality SSG.

Chapter 4

4 Process Overview

Although developing serious games is a serious business in many contexts, as you could see, there are no detailed processes that guide the development team through the hard task of creating a game. So in this chapter is presented the fundamentals of the SSG Development Process.

4.1 Process description

Given the problems posed in the previous chapters, this research proposes **A Software Engineering Process for Developing Short Serious Games based upon Competencies** (Álvarez Rodríguez, Barajas Saavedra, & Muñoz Arteaga, 2014) (Barajas Saavedra A. , Álvarez Rodríguez, Mendoza González, & Oviedo de Luna, 2015) (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, & Oviedo de Luna, Process for Modeling Competencies for Developing Serious Games, 2016). In Fig. 14 can be seen the Low-Detail Short 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, and specific skills on Mathematics.

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.

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 used 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 of the type of product to be developed.

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.
Besides, this process enables SSG Developers to correctly manage SSG Requirements with Software Engineering best practices. Also, this process provides a new technique called Competency-Based Decomposition that transforms a competency and its components (contents, expected learnings, and knowledge areas) into a manageable and measureable software requirement so developers can successfully implement or develop at large scale those requirements (competencies) in the SSG.

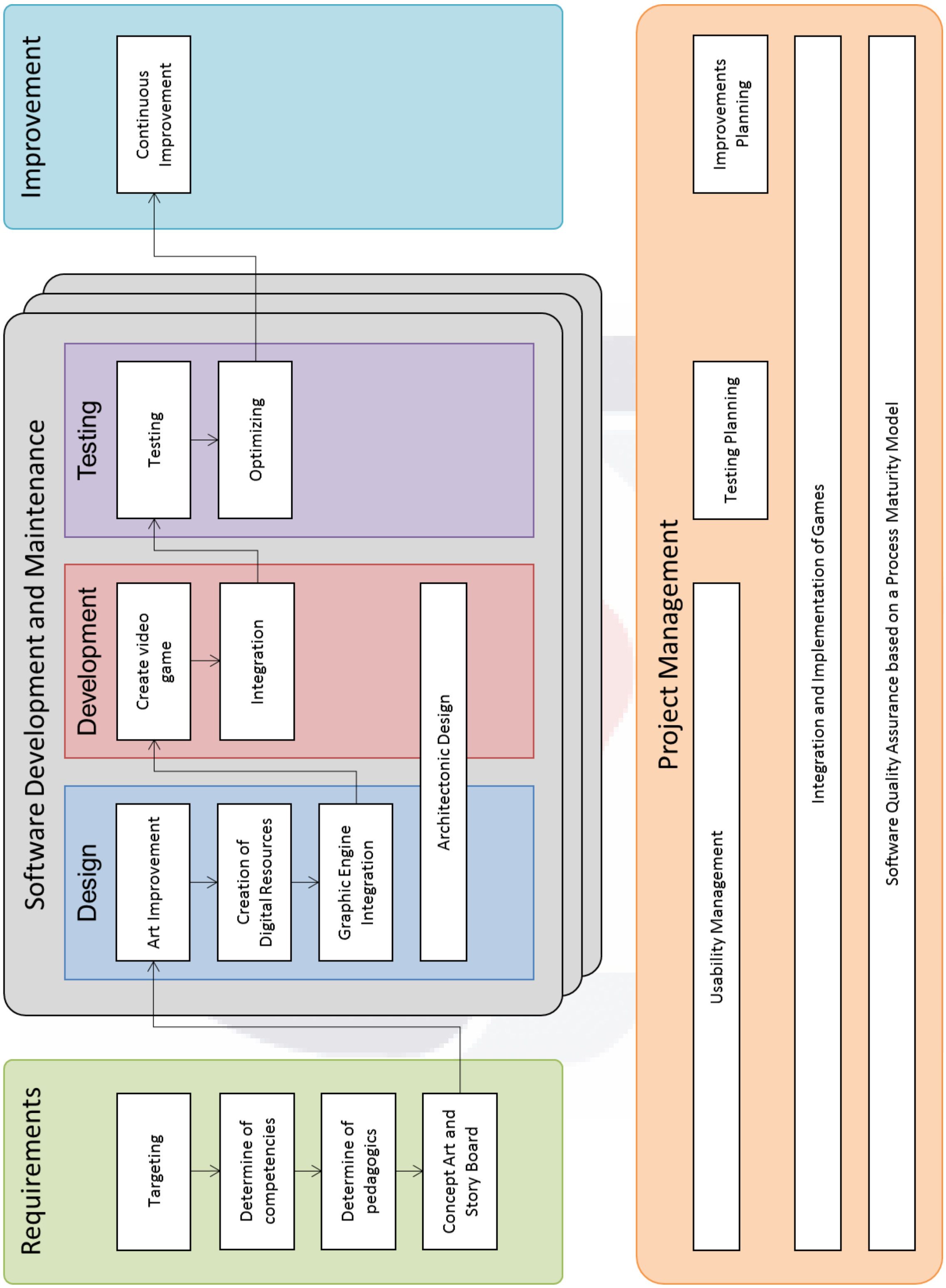


Fig. 14. Low-detail game development process graph. (Barajas Saavedra A. , Álvarez Rodríguez, Mendoza González, & Oviedo de Luna, 2015)

4.2 Process stages and activities

In this section are general descriptions of each of the phases of the SSG development process. (Álvarez Rodríguez, Barajas Saavedra, & Muñoz Arteaga, 2014) (Barajas Saavedra A. , Álvarez Rodríguez, Mendoza González, & Oviedo de Luna, 2015) (Barajas Saavedra A. , et al., Modelo de Verificación y Validación para la Producción de Videojuegos Serios Cortos, 2015)

In Chapter 5 are the detailed descriptions of each one of the phases.

4.2.1 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 (González Salazar, Mitre, Lemus Olalde, & González Sánchez, 2012)

4.2.2 Design stage

In this stage all digital resources required by the game engine are created. These digital resources includes: 2D illustrations, 3D models, Maps, Objects, Materials, surfaces, etc., Sounds and music; and to create game engine if needed. Input: Game Design Document. Outputs: Architecture Documentation, Digital resources meeting engine specifications.

4.2.3 Development stage

The objective of this stage is to create the game including: Layout, Events, Shader, and AI; to design game play; and to integrate all the above elements with menus, options, etc. Inputs: Architecture Documentation, Digital resources meeting engine specs. Outputs: Shot serious game.

4.2.4 Testing stage

In this stage the video games are tested. The testin includes the following aspects: Technical, Knowledge absorption, Usability, Usefulness; to obtain efficiency statistics; and to maintain game. Inputs: Serious game, testing plan. Outputs: Testing results, improvement plan, corrective actions plan.

4.2.5 Improvement stage

The objective is to analyze all process and product information collected during development process to improve the product and the future developments. Inputs: Testing results, improvement plan, corrective actions plan. Outputs: Improvement and corrective actions logs.

4.3 Quality aspects for educational digital resources

In the particular case of educational resources, Velazquez Amador et al. (Velázquez Amador, et al., 2011) mention that the quality of a digital educational resource covers various aspects of software development using an object-oriented paradigm, and issues related to pedagogy. Therefore, is identified the existence of technical and pedagogical aspects, and usability and content components, which are considered as aspects that determine the quality:

1. Technical aspects include reuse and adaptability, as well as those established by the software engineering as utility, reliability, among others.
2. Pedagogical aspects contemplate everything that facilitates the teaching-learning process, as we have examples, assessments, self-assessments, feedback, and a pedagogical objective expressed under any taxonomy, to mention some, Bloom's Taxonomy. The relationship between teaching methods and quality of the resource depends on the learning style of the user, so that John recommends that the modalities of digital resources include auditory, visual and kinesthetic recommendation that videogames cover perfectly. In the content items are those that give information about the complexity of the subject and the level of detail that addresses the content.

3. The aspects of usability of a digital resource concern the presentation of information (fonts, colors, sizes, etc.) and the disposition thereof (symmetrically, asymmetrically, using positive and negative space, etc.). From the point of view of software engineering usability it means ease of use and learning of an object created by humans.

The main aspect that determines the quality of the SSG is given in terms of the correct implementation of the specified software requirements. Therefore, the development process must have support for the timely and properly production of these resources (Pressman, 2006) (Sommerville, 2005). Then, based upon the product description presented in Section 2.9, the development process must meet the next characteristics: (Barajas Saavedra A. , et al., Modelo de Verificación y Validación para la Producción de Videojuegos Serios Cortos, 2015)

1. Efficient, for reducing the required rework in the requirements specification.
2. That ensures the products are small (short) and with a quick process.
3. That ensures the quality and the expected scope of the specified requirements through a 100% requirements implementation.

In order to achieve a quality production it is necessary to have a quality process (Sommerville, 2005) (Pressman, 2006), and that this one must be used appropriately. Then, the fulfilment of the requirements must be ensured in order to guarantee product quality. The compliance with requirements must be ensured from the views: pedagogical, educational and ludic.

Moreover besides the features inherent to the product (the game), we must take into account other aspects of quality. To ensure quality in the terms already mentioned, there are different strategies for quality management (Velázquez Amador, et al., 2011), which are:

1. Proactive strategies
    a. No automated tools
        i. Best practice guides

b. Automated tools
    i. Automated best practices guides
    ii. CASE tools
c. Patterns
2. Reactive strategies

So, in this research has been proposed two instruments based upon the Verification and Validation technics from Software Engineering that complement the previous process, and in that way, support the quality assurance process and the requirements traceability through all the construction of the SSG.

4.3.1 SSG Verification and Validation

When a software product is being developed and implemented it must be ensured that it will implement all the expected requirements and functionalities. For this purpose, some technics the Verification and Validation (V&V) must be used.

The V&V technics included in this process are the requirements and designs review, code inspections (Verification), and ends with the product testing by the user (Validation). (Sommerville, 2005)

The V&V process (Barajas Saavedra A. , et al., Modelo de Verificación y Validación para la Producción de Videojuegos Serios Cortos, 2015) can be graphically depicted in the next figure (Fig. 15):

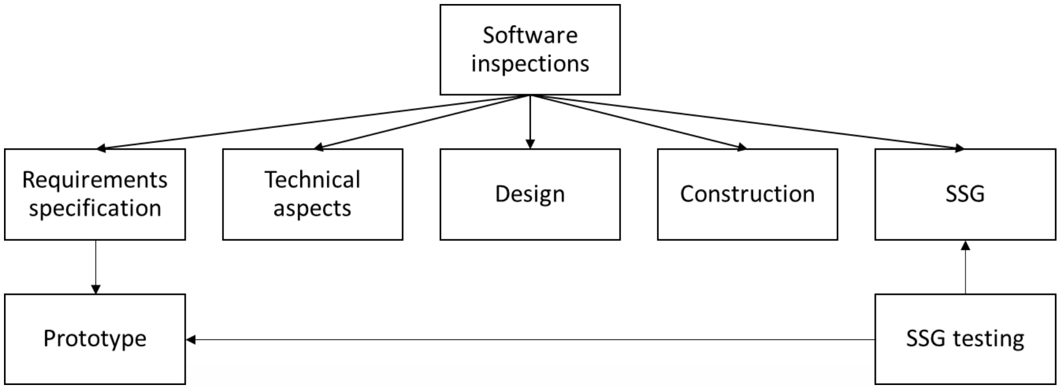


Fig. 15. SSG V&V process based upon the one proposed by Sommerville. *(Barajas Saavedra A. , et al., Modelo de Verificación y Validación para la Producción de Videojuegos Serios Cortos, 2015)*

As the reader can see in the previous figure, the V&V process is integrated by three technics: revision, inspections, and tests. Within the revisions and inspections scheme all the internal products of the software development process are reviewed, and in the tests the finished product is reviewed by the user taking into account the requirements traceability. (Sommerville, 2005)

In this research is proposed a hybrid scheme including the requirements traceability and the inspections based upon a checklist for inspecting the product and the process. This is the V&V process for the SSG production. The complete process can be found in the Appendix C – SSG Verification and Validation.

Chapter 5

5 Process Details

In this chapter, the reader can find the main aspects and details of the SSG Development Process.

5.1 Requirements stage

In this section you can find the detail of the implementation of the Requirements phase of the proposed process.

First, the workflow is presented. Then, the work breakdown structure is presented. Later, the team breakdown structure is presented. Finally, the work product breakdown structure is presented.

5.1.1 Workflow

In Fig. 16 is depicted the high-detail workflow for the Requirements phase.

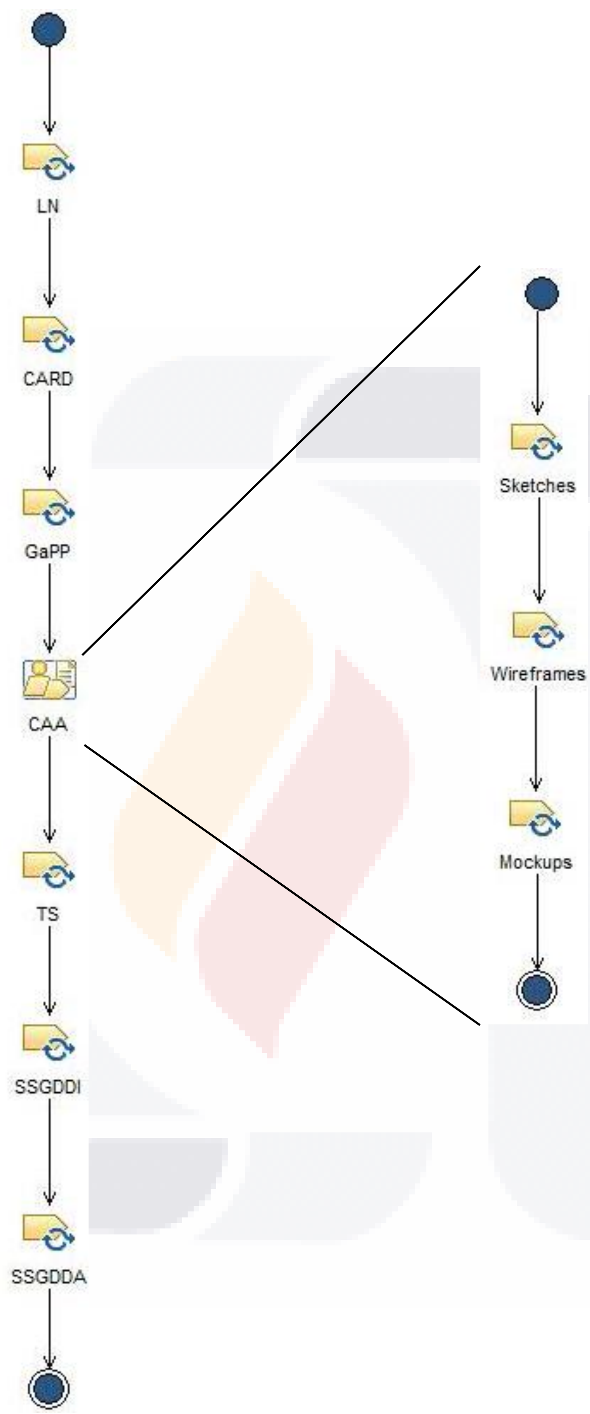


Fig. 16. High-detail requirements workflow graph.

In Fig. 17 is the mapping of each activity depicted in the low-detail game development process graph and the high-detail requirements phase workflow graph. This is for clarity of the reader.

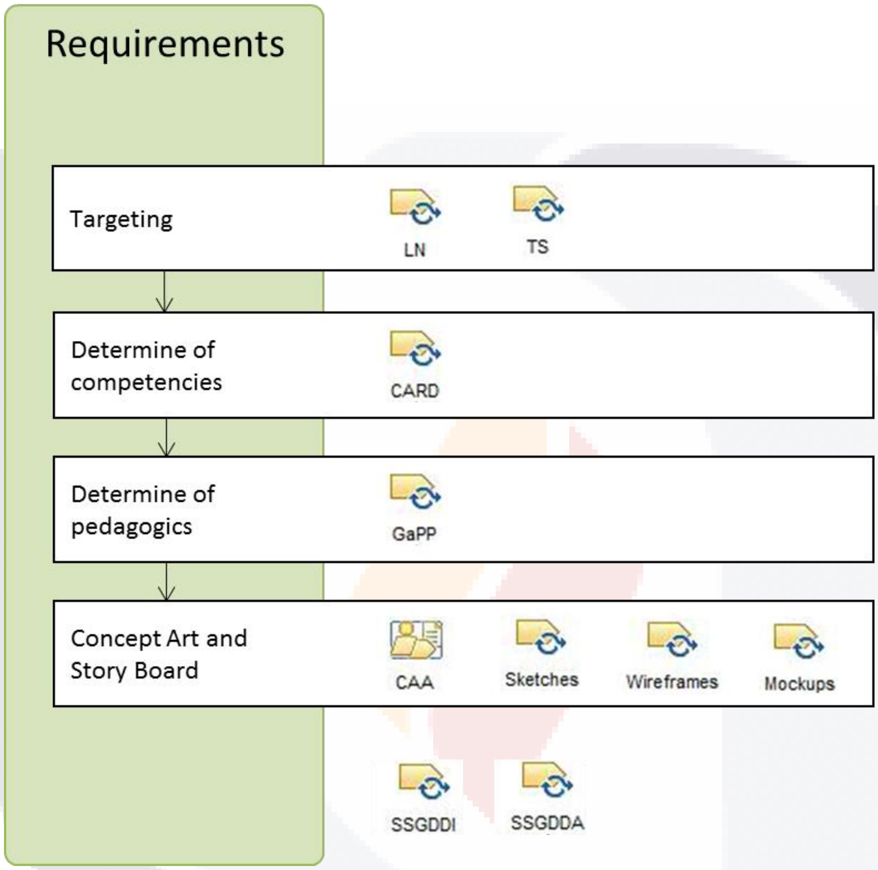


Fig. 17. Mapping of activities between the requirements phase workflow and the low-detail game development process.

5.1.2 Work breakdown structure

In Table 4 is shown the work breakdown structure for the Requirements stage.

Table 4. Requirements work breakdown structure.

Breakdown element	Steps	Index	Predecessors
LN	●●	4	
CARD	●●●●●●	5	4
GaPP	●●●●●●●●	6	5
CAA		7	6

Sketches	••••	8	
Wireframes	••••	9	8
Mockups	••••	10	9
TS	••••	11	10,7,7
SSGDDI	••	12	11
SSGDDA	•	13	12

5.1.3 Team breakdown

In Table 5 is shown the team breakdown structure for the Requirements stage.

Table 5. Requirements team breakdown structure.

Breakdown Element	Role	Model Info
CARD Product	Analyst	Responsible For
GaPP Product	Analyst	Responsible For
LN Product	Analyst	Responsible For
SSGDDA Product	Analyst	Responsible For
SSGDDI Product	Analyst	Responsible For
CARD Product	Analyst	Modifies
GaPP Product	Analyst	Modifies
LN Product	Analyst	Modifies
CARD	Analyst	Performs as Owner
GaPP	Analyst	Performs as Owner
LN	Analyst	Performs as Owner
SSGDDA	Analyst	Performs as Additional
SSGDDI	Analyst	Performs as Additional
CARD Product	Graphic Designer	Responsible For
Mockups Product	Graphic Designer	Responsible For
Sketches Product	Graphic Designer	Responsible For
SSGDDA Product	Graphic Designer	Responsible For
SSGDDI Product	Graphic Designer	Responsible For
Wireframes Product	Graphic Designer	Responsible For
CARD Product	Graphic Designer	Modifies
Mockups Product	Graphic Designer	Modifies
Sketches Product	Graphic Designer	Modifies
SSGDD Product	Graphic Designer	Modifies
SSGDDA Product	Graphic Designer	Modifies
SSGDDI Product	Graphic Designer	Modifies
TS Product	Graphic Designer	Modifies
Wireframes Product	Graphic Designer	Modifies
CARD	Graphic Designer	Performs as Owner
Mockups	Graphic Designer	Performs as Owner
Sketches	Graphic Designer	Performs as Owner
SSGDDA	Graphic Designer	Performs as Owner
SSGDDI	Graphic Designer	Performs as Owner
TS	Graphic Designer	Performs as Owner
Wireframes	Graphic Designer	Performs as Owner
CARD Product	GUI Designer	Responsible For
Mockups Product	GUI Designer	Responsible For

Sketches Product	GUI Designer	Responsible For
SSGDDA Product	GUI Designer	Responsible For
SSGDDI Product	GUI Designer	Responsible For
TS Product	GUI Designer	Responsible For
Wireframes Product	GUI Designer	Responsible For
CARD Product	GUI Designer	Modifies
Mockups Product	GUI Designer	Modifies
Sketches Product	GUI Designer	Modifies
SSGDD Product	GUI Designer	Modifies
SSGDDA Product	GUI Designer	Modifies
SSGDDI Product	GUI Designer	Modifies
TS Product	GUI Designer	Modifies
Wireframes Product	GUI Designer	Modifies
CARD	GUI Designer	Performs as Owner
Mockups	GUI Designer	Performs as Owner
Sketches	GUI Designer	Performs as Owner
SSGDDA	GUI Designer	Performs as Owner
SSGDDI	GUI Designer	Performs as Owner
TS	GUI Designer	Performs as Owner
Wireframes	GUI Designer	Performs as Owner
CARD Product	Instructional Designer	Responsible For
GaPP Product	Instructional Designer	Responsible For
Mockups Product	Instructional Designer	Responsible For
Sketches Product	Instructional Designer	Responsible For
SSGDDA Product	Instructional Designer	Responsible For
SSGDDI Product	Instructional Designer	Responsible For
Wireframes Product	Instructional Designer	Responsible For
CARD Product	Instructional Designer	Modifies
GaPP Product	Instructional Designer	Modifies
Mockups Product	Instructional Designer	Modifies
Sketches Product	Instructional Designer	Modifies
SSGDDA Product	Instructional Designer	Modifies
SSGDDI Product	Instructional Designer	Modifies
Wireframes Product	Instructional Designer	Modifies
CARD	Instructional Designer	Performs as Owner
GaPP	Instructional Designer	Performs as Owner
Mockups	Instructional Designer	Performs as Owner
Sketches	Instructional Designer	Performs as Owner
SSGDDA	Instructional Designer	Performs as Owner
SSGDDI	Instructional Designer	Performs as Owner
Wireframes	Instructional Designer	Performs as Owner
CARD Product	Teacher	Responsible For
LN Product	Teacher	Responsible For
SSGDDA Product	Teacher	Responsible For
SSGDDI Product	Teacher	Responsible For
CARD Product	Teacher	Modifies
LN Product	Teacher	Modifies
CARD	Teacher	Performs as Owner
LN	Teacher	Performs as Owner
GaPP	Teacher	Performs as Additional
Mockups	Teacher	Performs as Additional
Sketches	Teacher	Performs as Additional

SSGDDA	Teacher	Performs as Additional
SSGDDI	Teacher	Performs as Additional
Wireframes	Teacher	Performs as Additional
LN Product	User	Responsible For
Mockups Product	User	Responsible For
Sketches Product	User	Responsible For
SSGDDA Product	User	Responsible For
SSGDDI Product	User	Responsible For
LN	User	Performs as Additional
Mockups	User	Performs as Additional
Sketches	User	Performs as Additional
SSGDDA	User	Performs as Additional
SSGDDI	User	Performs as Additional
Wireframes	User	Performs as Additional

5.1.4 Work product breakdown

In Table 6 is shown the work product breakdown structure for the Requirements phase.

Table 6. Requirements work product breakdown structure.

Breakdown Element	Model Info
CARD Product	Optional Input, Mandatory Input, Output
GaPP Product	Mandatory Input, Optional Input, Output
LN Product	Mandatory Input, Output
Mockups Product	Output, Mandatory Input
Sketches Product	Mandatory Input, Output
SSGDD Product	Output
SSGDDA Product	Mandatory Input, Output
SSGDDI Product	Mandatory Input, Output
TS Product	Mandatory Input, Output
Wireframes Product	Mandatory Input, Output

5.2 Design stage

In this section you can find the detail of the implementation of the Design phase of the proposed process.

First, the workflow is presented. Then, the work breakdown structure is presented. Later, the team breakdown structure is presented. Finally, the work product breakdown structure is presented.

5.2.1 Workflow

In Fig. 18 is depicted the high-detail workflow for the Requirements phase.

Fig. 18. High-detail design workflow graph

In Fig. 19 is the mapping of each activity depicted in the low-detail game development process graph and the high-detail requirements phase workflow graph. This is for clarity of the reader.

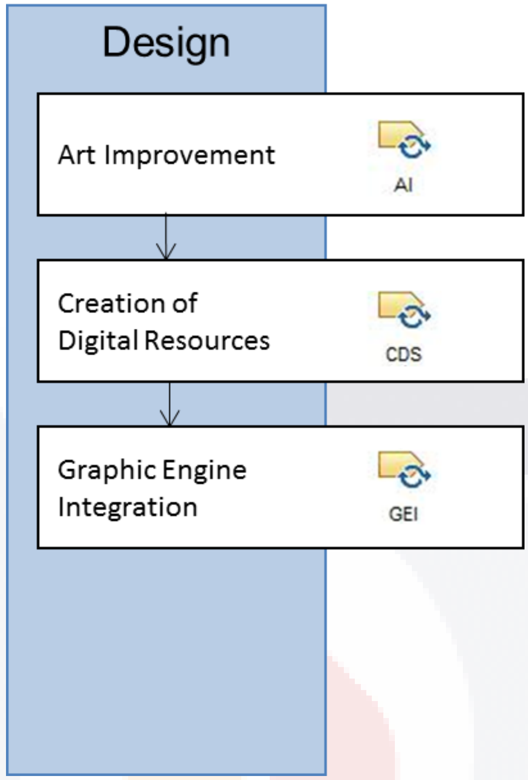


Fig. 19. Mapping of activities between the design phase workflow and the low-detail game development process

5.2.2 Work breakdown structure

In Table 7 is shown the work breakdown structure for the Design stage.

Table 7. Design work breakdown structure.

Breakdown element	Steps	Index	Predecessors
AI	●●●	17	
CDS	●●	18	17, 17
GEI	●●●	19	18, 18

5.2.3 Team breakdown

In Table 8 is shown the team breakdown structure for the Design stage.

Table 8. Design team breakdown structure.

Breakdown Element	Role	Model Info
GEI Product	Game Programmer	Responsible For
GEI Product	Game Programmer	Performs as Owner
GEI	Game Programmer	Performs as Owner
CDS	Game Programmer	Performs as Additional
CARD Product	Graphic Designer	Responsible For
Mockups Product	Graphic Designer	Responsible For
Sketches Product	Graphic Designer	Responsible For
SSGDDA Product	Graphic Designer	Responsible For
SSGDDI Product	Graphic Designer	Responsible For
Wireframes Product	Graphic Designer	Responsible For
AI Product	Graphic Designer	Responsible For
CDS Product	Graphic Designer	Modifies
AI	Graphic Designer	Performs as Owner
CDS	Graphic Designer	Performs as Owner
CARD Product	GUI Designer	Responsible For
Mockups Product	GUI Designer	Responsible For
Sketches Product	GUI Designer	Responsible For
SSGDDA Product	GUI Designer	Responsible For
SSGDDI Product	GUI Designer	Responsible For
Wireframes Product	GUI Designer	Responsible For
AI Product	GUI Designer	Responsible For
CDS Product	GUI Designer	Responsible For
CDS Product	GUI Designer	Modifies
CDS	GUI Designer	Performs as Owner

5.2.4 Work product breakdown

In Table 9 is shown the work product breakdown structure for the Design phase.

Table 9. Design work product breakdown structure.

Breakdown Element	Model Info
AI Product	Mandatory Input, Output
CDS Product	Mandatory Input, Output
GEI Product	Output
SSGDD Product	Mandatory Input, Optional Input

5.3 Development stage

In this section you can find the detail of the implementation of the Development phase of the proposed process.

First, the workflow is presented. Then, the work breakdown structure is presented. Later, the team breakdown structure is presented. Finally, the work product breakdown structure is presented.

5.3.1 Workflow

In Fig. 20 is depicted the high-detail workflow for the Development phase.

Fig. 20. High-detail development workflow graph

In Fig. 21 is the mapping of each activity depicted in the low-detail game development process graph and the high-detail requirements phase workflow graph. This is for clarity of the reader.

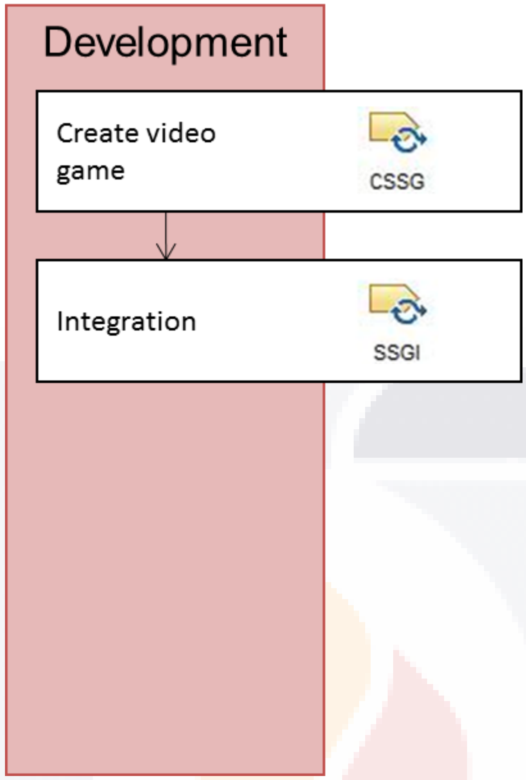


Fig. 21. Mapping of activities between the development phase workflow and the low-detail game development process

5.3.2 Work breakdown structure

In Table 10 is shown the work breakdown structure for the Development stage.

Table 10. Development work breakdown structure

Breakdown element	Steps	Index	Predecessors
CSSG	●●●	23	
SSGI	●●	24	23

5.3.3 Team breakdown

In Table 11 is shown the team breakdown structure for the Development stage.

Table 11. Development team breakdown structure.

Breakdown Element	Role	Model Info
GEI Product	Game Programmer	Responsible For
SSG Cinematics Product	Game Programmer	Modifies
SSG Integration Product	Game Programmer	Modifies
SSG Menus Product	Game Programmer	Modifies
SSG Scenes Product	Game Programmer	Modifies
CSSG	Game Programmer	Performs as Owner
SSGI	Game Programmer	Performs as Owner
CARD Product	Graphic Designer	Responsible For
Mockups Product	Graphic Designer	Responsible For
Sketches Product	Graphic Designer	Responsible For
SSGDDA Product	Graphic Designer	Responsible For
SSGDDI Product	Graphic Designer	Responsible For
Wireframes Product	Graphic Designer	Responsible For
CSSG	Graphic Designer	Performs as Additional
CARD Product	GUI Designer	Responsible For
Mockups Product	GUI Designer	Responsible For
Sketches Product	GUI Designer	Responsible For
SSGDDA Product	GUI Designer	Responsible For
SSGDDI Product	GUI Designer	Responsible For
TS Product	GUI Designer	Responsible For
Wireframes Product	GUI Designer	Responsible For
CSSG	GUI Designer	Performs as Additional

5.3.4 Work product breakdown

In Table 12 is shown the work product breakdown structure for the Development phase.

Table 12. Development work product breakdown structure

Breakdown Element	Model Info
GEI Product	Mandatory Input
SSG Cinematics Product	Mandatory Input, Output
SSG Integration Product	Output
SSG Menus Product	Mandatory Input, Output
SSG Scenes Product	Mandatory Input, Output

5.4 Testing stage

In this section you can find the detail of the implementation of the Testing phase of the proposed process.

First, the workflow is presented. Then, the work breakdown structure is presented. Later, the team breakdown structure is presented. Finally, the work product breakdown structure is presented.

5.4.1 Workflow

In Fig. 22 is depicted the high-detail workflow for the Testing phase.

Fig. 22. High-detail testing workflow graph

In Fig. 23 is the mapping of each activity depicted in the low-detail game development process graph and the high-detail requirements phase workflow graph. This is for clarity of the reader.

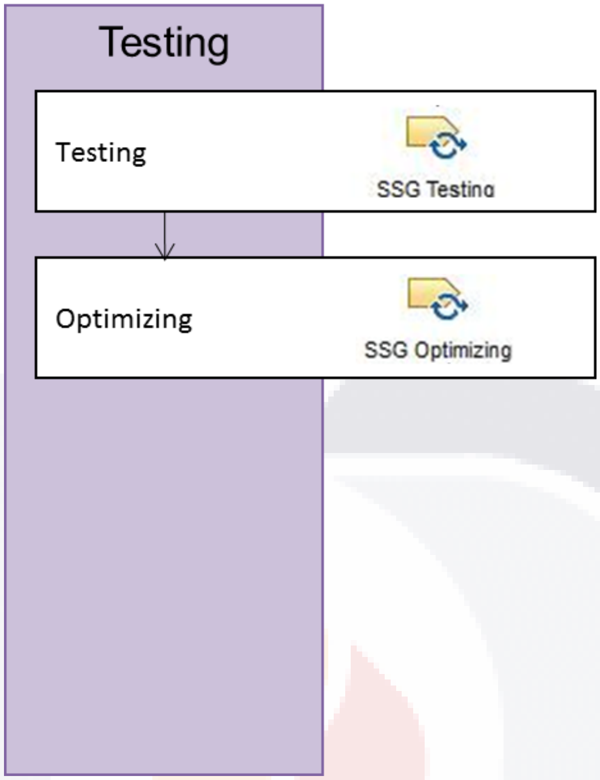


Fig. 23. Mapping of activities between the testing phase workflow and the low-detail game development process

5.4.2 Work breakdown structure

In Table 13 is shown the work breakdown structure for the Development stage.

Table 13. Testing work breakdown structure

Breakdown element	Steps	Index	Predecessors
SSG Testing	●●	27	
SSG Optimizing	●●	28	27

5.4.3 Team breakdown

In Table 14 is shown the team breakdown structure for the Development stage.

Table 14. Testing team breakdown structure.

Breakdown Element	Role	Model Info
GEI Product	Game Programmer	Responsible For
SSG Optimizing Product	Game Programmer	Modifies
SSG Optimizing	Game Programmer	Performs as Owner
SSG Optimizing Product	Game Tester	Modifies
SSG Testing Product	Game Tester	Modifies
SSG Optimizing	Game Tester	Performs as Owner
SSG Testing	Game Tester	Performs as Owner

5.4.4 Work product breakdown

In Table 15 is shown the work product breakdown structure for the Development phase.

Table 15. Testing work product breakdown structure

Breakdown Element	Model Info
SSG Product	Mandatory Input
SSG Optimizing Product	Output
SSG Testing Product	Mandatory Input, Output

5.5 Improvement stage

In this section you can find the detail of the implementation of the Optimizing phase of the proposed process.

First, the workflow is presented. Then, the work breakdown structure is presented. Later, the team breakdown structure is presented. Finally, the work product breakdown structure is presented.

5.5.1 Workflow

In Fig. 24 is depicted the high-detail workflow for the Optimizing phase.

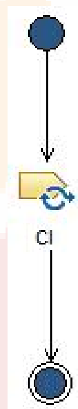


Fig. 24. High-detail optimizing workflow graph

In Fig. 25 is the mapping of each activity depicted in the low-detail game development process graph and the high-detail requirements phase workflow graph. This is for clarity of the reader.

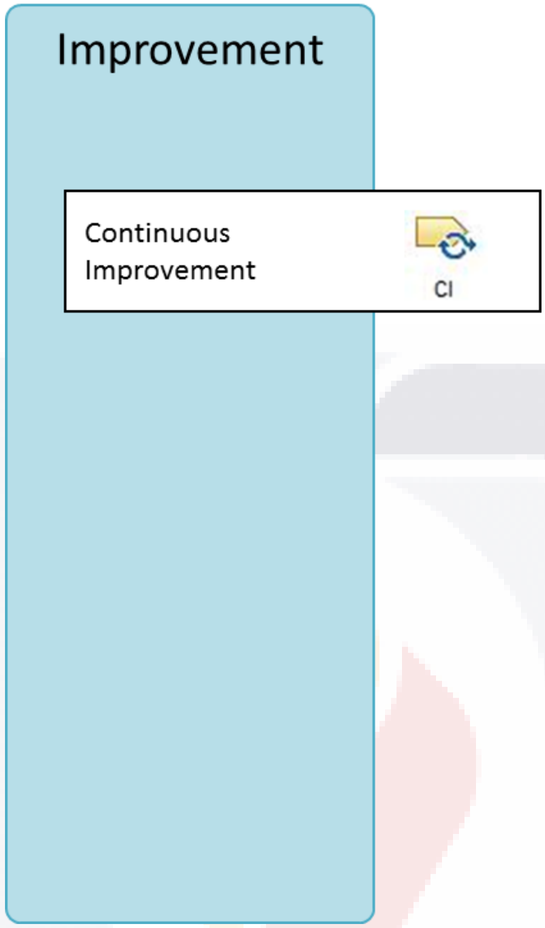


Fig. 25. Mapping of activities between the postmortem phase workflow and the low-detail game optimizing process

5.5.2 Work breakdown structure

In Table 16 is shown the work breakdown structure for the Optimizing stage.

Table 16. Optimizing work breakdown structure

Breakdown element	Steps	Index	Predecessors
CI	●●	32	

5.5.3 Team breakdown

In Table 17 is shown the team breakdown structure for the Optimizing stage.

Table 17. Optimizing team breakdown structure.

Breakdown Element	Role	Model Info
CI Product	Analyst	Responsible For
CI	Analyst	Performs as Owner
CI	Game Programmer	Performs as Additional
CI	Game Tester	Performs as Additional
CI	Graphic Designer	Performs as Additional
CI	GUI Designer	Performs as Additional
CI Product	Instructional Designer	Modifies
CI	Instructional Designer	Performs as Owner
CI Product	Teacher	Modifies
CI	Teacher	Performs as Owner
CI Product	User	Modifies
CI	User	Performs as Owner

5.5.4 Work product breakdown

In Table 18 is shown the work product breakdown structure for the Optimizing phase.

Table 18. Optimizing work product breakdown structure

Breakdown Element	Model Info
CI Product	Output
SSG Product	Mandatory Input, Output
SSG Maintenance Product	Optional Input
SSG Testing Product	Optional Input

Chapter 6

6 Developing Serious Games – Case Study Sixth Grade Math

In this chapter, the reader can find the implementation details of the SSG Development Process in a Case Study.

6.1 Developing SSG

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” (Álvarez Rodríguez, Barajas Saavedra, & Muñoz Arteaga, 2014) (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, Santaolaya Delgado, & Collazos Ordóñez, A serious games development process using competency approach. Case Study: Elementary School Math, 2014) (Barajas Saavedra A. , Álvarez Rodríguez, Mendoza González, & Oviedo de Luna, 2015) (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, & Oviedo de Luna, Process for Modeling Competencies for Developing Serious Games, 2016). An extract of the real documentation of the pilot projects can be found on Appendix E – Pilot projects.

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 (Appendix B – Competency-Based Decomposition) in order to establish the set of knowledge area, which should be covered by the developed serious games, see Table 19.

Table 19. Identified competencies and knowledge areas.

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

	Weight/mass	Application and comparison of the measurement units of weight/mass.
	Perimeters	Determining the shape of geometric figures from its dimensions.
	Areas	Determining the area of shapes based on its dimensions.
	Time	Application and comparison of the measurement units of time.
Information processing	Graphic representation of results	Creating tables and diagrams to interpret information and amounts from goals.
Processes of change	Patterns	Proportionalities equivalent.
	Values of unity	Find an objective from certain indications of a plane.
	Cross product	Application of operations using the cross product.
	Percentages	Use percentages for achieve goals.
The prediction and chance	Combinations	Resolution count problems and use the tree diagram.
	Odds	Application of operations through chance games.

Once competencies are identified the next step is to set objectives, pedagogical, content and learning activities that will be integrated into the serious games. 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 19 lead us to create 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 presented in Table 20.

Table 20. Extract of developed video games.

Competency	SSG
The numbers, relationships and operations	DS3A
	Fracciones
	MathChallenge
	MathFractions
	pokeMath
	SpaceMath
	Math Numbers
Geometry	CubeLand
	GeoBodies
	Marcianos
	Submarino
	Geometrix
Measures and Conversions	Áreas

Competency	SSG
	GolfMeter
	Jinete Solitario
	miHuerta
	Perimeters
	Time Champ
	Time Rider
	Alpinist
Processes of change	Kaxan
	Regla de Tres
	Ubicación
	Goats and Ghouls
The prediction and chance	Softy
	WWE
	CRacing

Screenshot for some video games can be seen in the next figures (Fig. 26, Fig. 27, Fig. 28, and Fig. 29).

Fig. 26. Space Math screenshots.

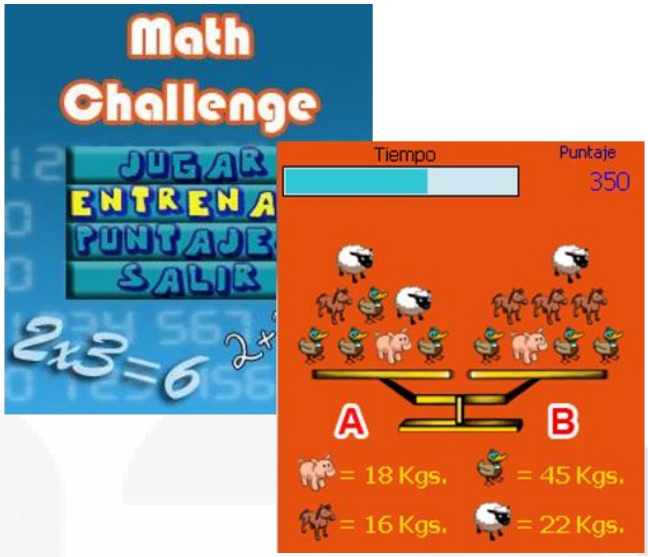


Fig. 27. Math Challenge screenshots.

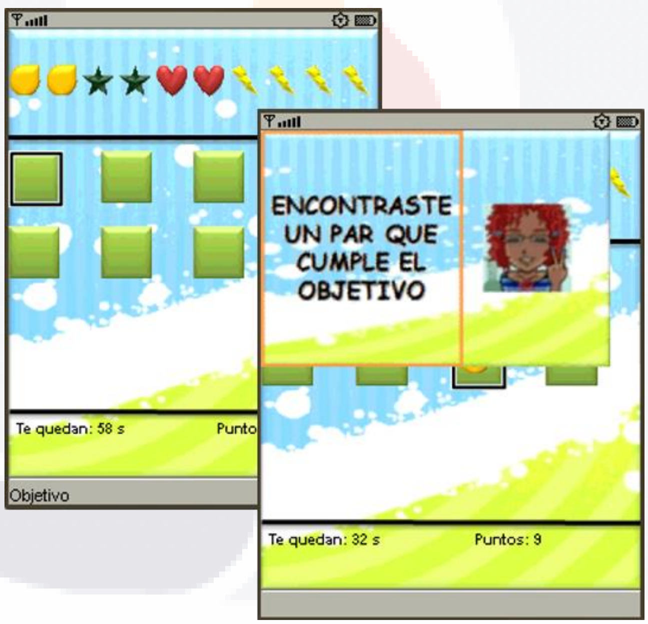


Fig. 28. Kaxan screenshots.

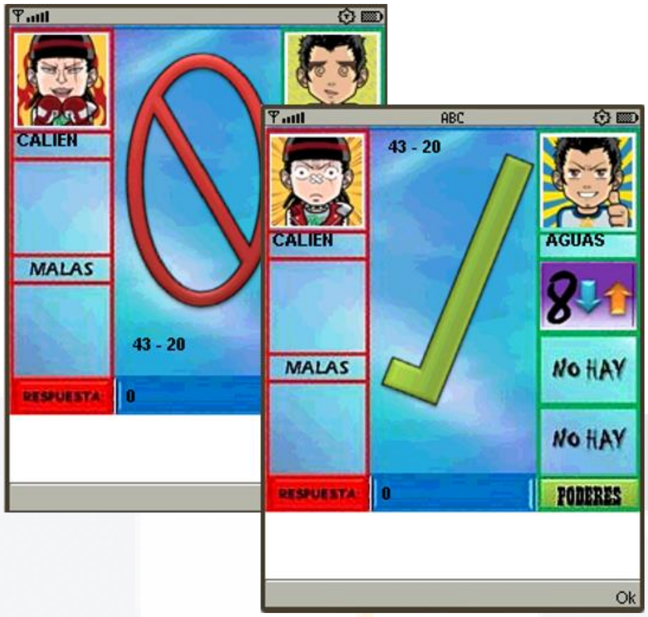


Fig. 29. DS3A screenshots.

6.2 V&V of the SSG

In order to perform the V&V of the process and products, the team filled the next formats in for each game (Barajas Saavedra A. , et al., Modelo de Verificación y Validación para la Producción de Videojuegos Serios Cortos, 2015):

1. Requirements traceability. This format was applied during all the development process.
2. Checklist. This format was applied every finished stage in order to continue with the next stage.

The general results of the application of the V&V process to six SSG are shown in the next table (Table 21).

Table 21. Analysis results for the application of the requirements traceability matrix and the checklist in six SSG.

Element	Geometrix	Alpinist	Serpientes y Escaleras	MathNumbers	CRacing	Goats and Ghouls
Implemented requirements	100%	100%	100%	100%	100%	100%
Process execution efficiency	100%	80%	100%	100%	100%	100%
Development time deviation	20%	20%	20%	20%	0%	20%
Checklist accomplishment	100%	100%	100%	100%	100%	100%

In Table 21 column one named "Element" describes each one of the characteristics to measure with the instruments, to know:

1. Implemented requirements indicates the percentage of the requirements that were implemented.
2. Process execution efficiency indicates the percentage of the required rework to correct defects in the requirements specification. A 100% means that the requirements specification was successful, an 80% means that the team must rework a 20% of the requirements specification.
3. Development time deviation indicates the percentage of additional required time to the planned to conclude the project. For example, if the time estimation indicates the project will take 8 weeks, and the execution of the project took 10 weeks, then the time deviation is of 25%.
4. Checklist accomplishment indicates the percentage of the checklist's elements that were achieved successfully during the process execution.

As can be seen from Table 21:

1. The whole of the projects implemented the 100% of the specified requirements.
2. Five of the projects did not required any rework for the requirements specification (learning activities, contents and the expected learning), which indicates that the

requirements were specified successfully in the first iteration of the process. The project which efficiency is 80% was due to a mistake in the identification of the learning activities of the SSG, so they have to be redesigned.

3. A single project finished in time. The rest of the projects ended with a schedule overrun of 20% according with the planned finish time.
4. All the projects have a 100% checklist accomplishment, because, alike a Test Driven Development, the teams know all the items in the checklist since the beginning of each project.

6.3 Testing the SSG

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” (Fig. 30) 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.

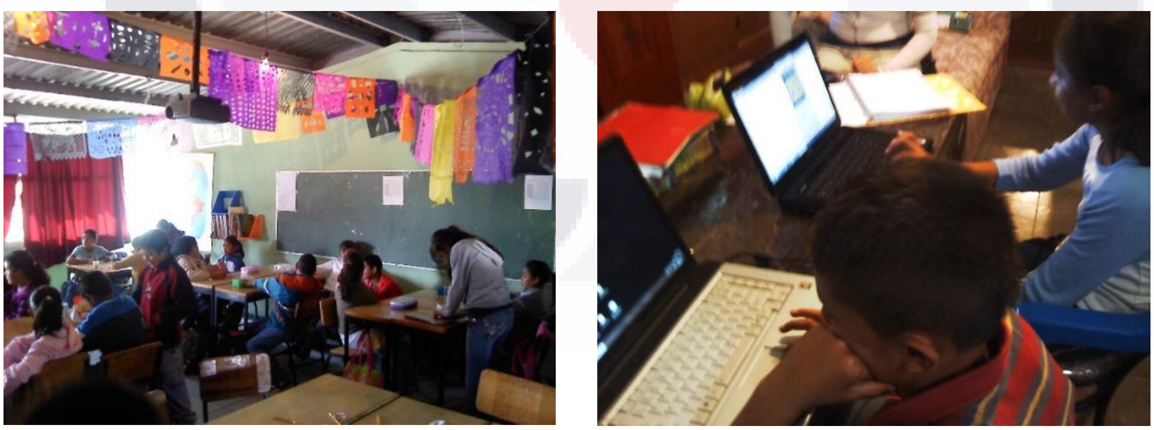


Fig. 30. Kids in their classroom and kids playing with the games.

The process performed for the test was as follows (Hernández Sampieri, Fernández Collado, & Baptista Lucio, 2010):

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 collected data allow to determine trends in student's scores before and after use short serious games. The overall findings are graphically depicted in Fig. 31 where dotted-line displays the results obtained during initial examination. Solid-line displays the results of the evaluation performed after short serious games use.

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 are graphically depicted in Fig. 31 where dotted-line displays the results obtained during initial examination. Solid-line displays the results of the evaluation performed after short serious games use.

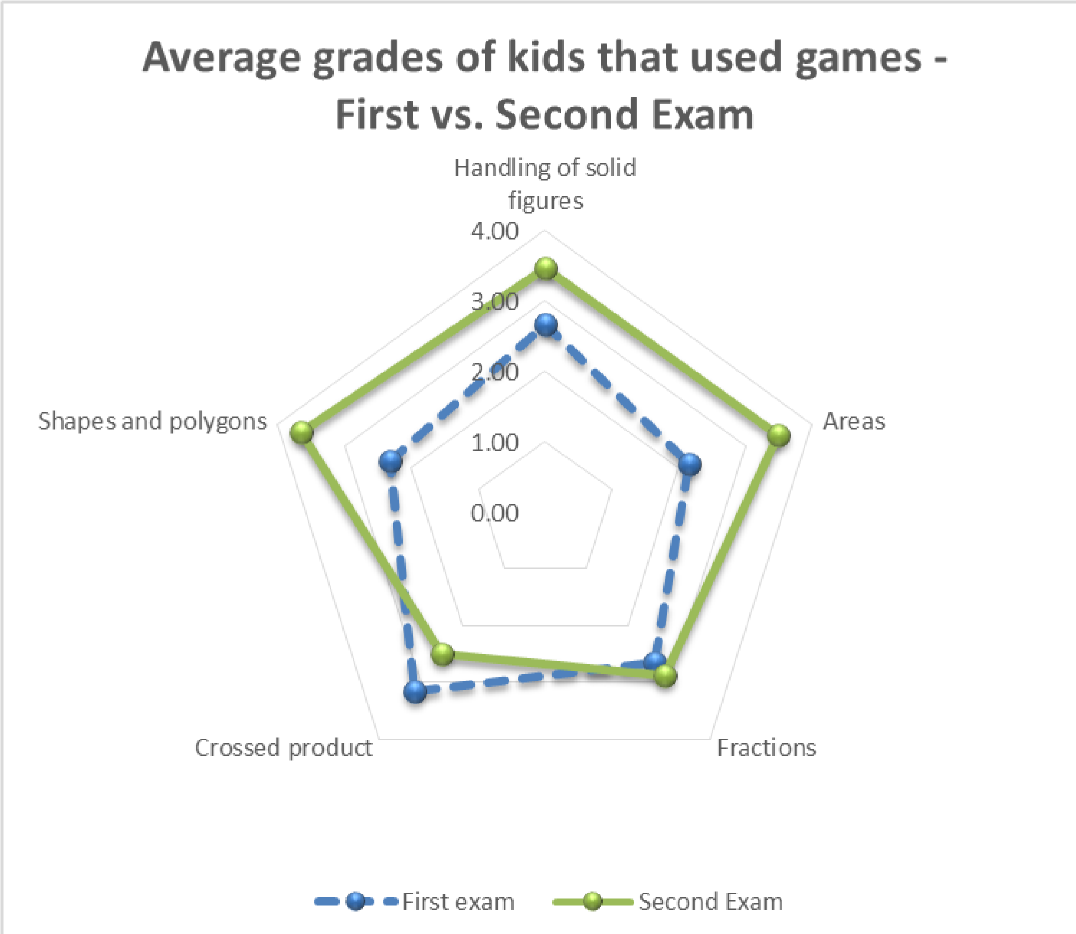


Fig. 31. Overall result of the students in different areas of knowledge tested.

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.

As the reader can see, there are improvements in four knowledge areas, this is due to the students achieved a higher level of adoption of the competencies implemented in the short serious games they used.

The "Crossed Product" game, which shows a decrease in the adoption of the competency, was developed with a question bank instead of randomly-generated problems, so the students memorized such question bank and did not achieve the intended adoption of the competency.

Chapter 7

7 Discussion and Analysis

In this chapter is presented all the discussion topics derived from the research, including all the issues identified along the course of the Doctorate, the results obtained of the SSG production, and the results obtained when the kids use the SSG.

7.1 Discussion

The correct implementation of the competencies and the characteristics of the short serious games is extremely important because this is the only way to guarantee that the students or users will achieve a higher level of adoption of the competencies implemented in the games. (Álvarez Rodríguez, Barajas Saavedra, & Muñoz Arteaga, 2014) (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, Santaolaya Delgado, & Collazos Ordóñez, A serious games development process using competency approach. Case Study: Elementary School Math, 2014) (Barajas Saavedra A. , Álvarez Rodríguez, Mendoza González, & Oviedo de Luna, 2015) (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, & Oviedo de Luna, Process for Modeling Competencies for Developing Serious Games, 2016)

Accordingly with the results shown in Table 21 (Barajas Saavedra A. , et al., Modelo de Verificación y Validación para la Producción de Videojuegos Serios Cortos, 2015):

1. Implemented requirements reached a 100% implementation because the developed games only focused on a single area of knowledge as it was established as a basic feature in Section 2.9. Short serious games.
2. The process execution efficiency refers to the percentage of work done that needed to be corrected, so if you have to correct 15% of the work, then the efficiency is 85%. For the game Alpinist, the team corrected a 20% of the done work for the requirements specification (particularly, section 3.9 Planned activities of the format 3. Game Pedagogical Planning), so their efficiency reached the 80%. The rest of the SSG there was no work to be corrected.
3. Development time deviation refers to how many extra time it took to finish the SSG. If planning established that the project should finish in 10 weeks, and it took 2 more weeks, then the project has a 20% development time deviation. CRacing finished in time according to the plan. The rest of the games took 20% more time to finish according to the plan.
4. Checklist accomplishment refers to how many items of the Checklist are covered in the development. In this case all developments covered a 100% of the elements in the checklist, so it is ensured a stable development. The percentages indicate that a 100%

requirements implementation has been achieved, due to the SSG requirements are very clear.

Added to this, the process execution efficiency reached a 100% in five out of six projects because the developers achieved, in one iteration, a successful requirements specification, indicating that the proposed process is usable. A team did not reach a 100% process execution efficiency due to the developers focused on the development of the game and left aside the requirements specification, analysis and design, and initial documentation at the beginning of the project.

The deadline of the projects overran because the most of the developers were not familiarized with videogame development. Nevertheless, a 20% deviation is acceptable because "*A project is considered successful if a solution has been delivered and it met the success criteria within a range acceptable to your organization*" (Ambysoft, 2014).

The checklist was filled in completely, i.e., every aspect was fulfilled, since, on not having fulfilled anyone of them, it is not possible to continue with the development.

Finally, as the reader can see, the "Crossed Product" game did not achieve its purpose: transfer the competency into the students due to a deviation in its development.

Chapter 8

In this chapter are presented the conclusions and future work of this research.

8.1 Conclusions

Quality assurance of a software product is a very important issue, so much so many institutions have developed models and guidelines as SWEBOK (IEEE Computer Society, 2014), PMBOK (Guía de los Fundamentos para la Dirección de Proyectos (Guía del PMBOK), 2008), BABOK (International Institute Of Business Analysis, 2015), CMMi (Carnegie Mellon University, 2014), MoProSoft (Normalización Y Certificación Electrónica A.C., 2014), among others, to support development and ensure a quality production.

This research proposes a **Short Serious Game Development Process** that includes an explicit requirements management which allows the identification and modeling of the software requirements from a set of implicit educative competencies of an official syllabus, showing 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. In addition to this, this research also proposes a **Verification and Validation Model** in order to ensure that all developed products have a good grade of quality in terms of the requirements implementation.

This process makes available to research or (independent) development groups, universities and companies a clear guide to the development of a short serious game. It also eases the implementation of the process itself because it has a documental support that guides the team through the development of the products. This process also allows managing the product quality through checkpoints in the provided documentation, achieving in this way develop a high quality product with a high level of fulfilment of the competencies (requirements).

The CBD process allows clearly identify the competencies to implement in the short serious games, since in many cases this aspect is not taken into account during the development process (if a development process exists). The CBD process takes as inputs common elements in the syllabus and turns them into short serious game programmable and measurable competencies (learning needs).

Once identified the competencies, the short serious game development process is capable of building software products, from those requirements (which include learning activities and learning contents), with a high quality level and meeting the correct implementation of the competencies.

This research has created and tested (with real world students) a big set of Verified and Validated Short Serious Games through the proposed process, CBD process and V&V model, achieving an improvement in the competency adoption due to the correct implementation of requirements (competencies, learning activities and learning contents) into the games and ensuring their quality.

The research also reflected the importance of ensuring well-designed short 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. This was identified from the tests performed with end users.

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 established objectives of the research were:

1. To create a process that ease teacher and pedagogues the task of transforming a syllabus into competencies and areas of knowledge to develop all materials and

resources needed to teach. See Chapter 4. Process Overview and Chapter 5. Process Details.

2. To test the process in a real subject and from the identified competencies and areas of knowledge develop a set of short serious games. See Chapter 6. Developing Serious Games – Case Study Sixth Grade Math.
3. To test the developed short serious games with real students to identify if there is any improvement. See Chapter 6. Developing Serious Games – Case Study Sixth Grade Math.

8.2 Future work

The research lines to develop in a short term are next:

1. Design patterns for SSG. Design patterns for the main elements of the SSG.
2. Maturity model for SSG development process. A maturity model to ensure the continuous improvement of the development process of SSG.
3. Extend the process to support the development of other types of games.
4. Include multicultural support to SSG, in order to automatically adapt their contents to the cultural context.
5. Design and execute more study cases.

Chapter 9

In this chapter all the processes, models, articles, and conferences that emerged from the research are listed.

9.1 Products

1. The complete SSG Development Process modeled on SPEM 2.0 can be found in the CD attached to this document and in the Web site www.catrinaproject.com
2. Link to download all developed SSG: www.catrinaproject.com
3. During the course of this research seven articles were published in the next forums (Appendix A – Publications):
    a. (Oviedo de Luna, Álvarez Rodríguez, Barajas Saavedra, & Muñoz Arteaga, 2014) – 2014 CONTE
    b. (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, Santaolaya Delgado, & Collazos Ordóñez, A serious games development process using competency approach. Case Study: Elementary School Math, 2014) – 2014 INTERACCION
    c. (Álvarez Rodríguez, Barajas Saavedra, & Muñoz Arteaga, 2014) – VLE
    d. (Barajas Saavedra A. , Álvarez Rodríguez, Mendoza González, & Oviedo de Luna, 2015) – 2015 TOJET
    e. REDIE (in editorial process) (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, & Oviedo de Luna, Process for Modeling Competencies for Developing Serious Games, 2016)
    f. IEEE Latin-American (submitted) (Barajas Saavedra A. , et al., Modelo de Verificación y Validación para la Producción de Videojuegos Serios Cortos, 2015)
4. During the course of this research the author participated in the next congresses:
    a. 2014 CIIP UAA
    b. 2014 CONTE
    c. 2014 INTERACCION
5. An example of the application of the CBD to one subject of sixth grade and a program of Engineering degree (the complete version can be found on the attached CD) is in Appendix B – Competency-Based Decomposition.
6. The details of the process of V&V can be found in Appendix C – SSG Verification and Validation.

7. All formats needed to execute the process can be found in Appendix D – Formats.
8. The evidence of the projects used for the V&V process can be found on Appendix E – Pilot projects.
9. The methodology implemented for this research can be found in Appendix F – Methodology.
10. The work plan of this research can be found in Appendix G – Work plan.
11. The reviews made to this work can be found in Appendix H – Work reviews.

Chapter 10

10 Bibliography

10.1 Bibliography

Aghabeigi, B., Calvert, T., El-Nasr, M., & Riedewa, M. (2012, September 7-9|). Assistive design and production in computer games: Parametric systems, data mining, visual analytics. *2012 IEEE International Games Innovation Conference (IGIC)*, 1-4. doi:10.1109/IGIC.2012.6329860

Aldrich, C. (2009). Virtual Worlds, Simulations, and Games for Education: A Unifying View. *Innovate: Journal of Online Education, 5*(5).

Almiron, M. E., & Porro, S. (2014). ICT in Teaching: An Analysis of Cases. *Revista Electrónica de Investigación Educativa, 16*(2). Retrieved January 2015, from http://redie.uabc.mx/vol16no2/contenido-almiron-porro.html

Álvarez Rodríguez, F., Barajas Saavedra, A., & Muñoz Arteaga, J. (2014, May 16). Serious Game Design Process, Study Case: Sixth Grade Math. *Creative Education, 05*(09), 647-656. doi:doi:10.4236/ce.2014.59077

Ambysoft. (2014). *2013 IT Project Success Rates Survey Results*. Retrieved 6 3, 2015, from http://www.ambysoft.com/surveys/success2013.html

Ariel. (2015, January 13). *App Stores Growth Accelerates in 2014*. (appfigures) Retrieved April 8, 2015, from http://blog.appfigures.com/app-stores-growth-accelerates-in-2014/

Barajas Saavedra, A., & Álvarez Rodríguez, F. J. (2009). Enseñanza de Matemáticas a través de objetos de aprendizaje móviles. *CcITA 2009* (pp. 51-60). Mérida: Yucatán.

Barajas Saavedra, A., & Álvarez Rodríguez, F. J. (2012). Mathematics Game e-Library for Elementary School, Study Case: Mexico. *Proceedings of the SPDECE-2012. Ninth nultidisciplinary symposium on the design and evaluation of digital content for education*, 123-134.

Barajas Saavedra, A., Álvarez Rodríguez, F. J., & Muñoz Arteaga, J. (2007, Mayo). Póster Interpretación del Área de Proceso de Administración de Requerimientos de CMMI. *Octavo Seminario de Investigación del Noveno Verano de la Ciencia*. Aguascalientes, Aguascalientes, México.

Barajas Saavedra, A., Álvarez Rodríguez, F. J., Mendoza González, R., & Oviedo de Luna, A. C. (2015, April 1). Short Serious Games Creation under the Paradigm of Software Process and Competencies as Software Requirements. Case Study: Elementary Math

Competencies. (A. İşman, Ed.) *Turkish Online Journal of Educational Technology, 14*(2), 155-166. Retrieved April 1, 2015, from http://tojet.net/articles/v14i2/14219.pdf

Barajas Saavedra, A., Álvarez Rodríguez, F. J., Muños Arteaga, J., & Muñoz López, J. (2008). RADIP: A Software Development Process for Mexican PyMEs. (G. Sidorov, B. Cruz, M. A. Martínez, & S. Torres, Eds.) *Advances in Computer Science and Engineering, 34*.

Barajas Saavedra, A., Álvarez Rodríguez, F. J., Muñoz Arteaga, J., & Bautista Villalpando, L. E. (2011). Uso de objetos de aprendizaje en dispositivos móviles. In F. J. Álvarez Rodríguez, & J. Muñoz Arteaga (Eds.), *Avances en Objetos de Aprendizaje - Experiencias de redes decolaboración en México* (pp. 131-157). Aguascalientes, Aguascalientes, México: Universidad Autónoma de Aguascalienes.

Barajas Saavedra, A., Álvarez Rodríguez, F. J., Muñoz Arteaga, J., & Oviedo de Luna, A. (2016). Process for Modeling Competencies for Developing Serious Games. *Revista Electrónica de Investigación Educativa*.

Barajas Saavedra, A., Álvarez Rodríguez, F. J., Muñoz Artega, J., & Muñoz López, J. (2008, Mayo). RADIP: A Software Development Process for Mexican PyMEs. *Advances in Computer Science and Engineering, 34*, 311-322.

Barajas Saavedra, A., Álvarez Rodríguez, F. J., Muñoz Artega, J., Santaolaya Salgado, R., Collazos, C. A., & Hurtado Alegría, J. A. (2015). Modelo de Verificación y Validación para la Producción de Videojuegos Serios Cortos. *Revista IEEE América Latina*.

Barajas Saavedra, A., Álvarez Rodríguez, F., Muñoz Arteaga, J., & Bautista Villalpando, L. (2009, Agosto 25). Redes internacionales de OVAs: Proyecto Videojuegos para Matemáticas.

Barajas Saavedra, A., Álvarez Rodríguez, F., Muñoz Arteaga, J., Santaolaya Delgado, R., & Collazos Ordóñez, C. (2014). A serious games development process using competency approach. Case Study: Elementary School Math. In A. I.-O. (AIPO) (Ed.), *XV International Conference on Human Computer Interaction* (pp. 572-579). Puerto de la Cruz, Tenerife, España: AIPO. Retrieved September 30, 2014

Barajas Saavedra, A., Muñoz Arteaga, J., Álvarez Rodríguez, F. J., & Bautista Villalpando, L. E. (2010). Educational Videogame e-Library. *Design and Engineering of Game-like Virtual and Multimodal Environments (DEnG-VE).* Berlín.

Barajas Saavedra, A., Muñoz Arteaga, J., Álvarez Rodríguez, F., & García Gaona, M. (2009). Developing Large Scale Learning Objects for Software Engineering Process Model. *2009 Mexican International Conference on Computer Science*, 203-208. doi:DOI 10.1109/ENC.2009.46

Cai, L., Liu, F., & Liang, Z. (2010, December 10-12). The research and application of education game design model in teaching Chinese as a Foreign Language. *2010 IEEE International Conference on Progress in Informatics and Computing (PIC), 2*, 1241-1245. doi:10.1109/PIC.2010.5687919

Carnegie Mellon University. (2014). *CMMI*. Retrieved November 2014, from Software Engineering Institute: http://www.sei.cmu.edu/cmmi/

Carnegie Mellon University. (2014). *SEI Work Areas*. Retrieved November 2014, from Software Engineering Institute: http://www.sei.cmu.edu/

Carnegie Mellon University. (2014). *Team Software Process (TSP) Body of Knowledge (BOK).* Retrieved November 2014, from Digital Libray | SEI | CMU: http://resources.sei.cmu.edu/asset_files/TechnicalReport/2010_005_001_15254.pdf

Carnegie Mellon University. (2014). *The Personal Software Process (PSP) Body of Knowledge, Version 2.0.* Retrieved November 2014, from Digital Libray | SEI | CMU: http://resources.sei.cmu.edu/asset_files/SpecialReport/2009_003_001_15029.pdf

Chatzoglou, P. D. (1997). Use of Methodologies: an Empirical Analysis of their Impact on the Economics of the Development Process. *European Journal of Information Systems, 6*, 256-270.

Chen, C.-M., & Hsu, S.-H. (2008). Personalized Intelligent Mobile Learning System for Supporting Effective English Learning. *Journal of Educational Technology & Society*, *11*(3), 153-180.

Cheng, Z., Hao, F., JianYou, Z., & Yun, S. (2010, November 17-19). Research on Design of Serious Game Based on GIS. *2010 IEEE 11th International Conference on Computer-Aided Industrial Design & Conceptual Design (CAIDCD), 1*, 231-233. doi:10.1109/CAIDCD.2010.5681365

Chroust, G. (1996). What is a software process? *Journal of Systems Architecture*.

Chuang, T. Y., You, J. H., & Duo, A. (2010, August 4-6). Digital game design principles for spatial ability enhancement. *2010 IET International Conference on Frontier Computing. Theory, Technologies and Applications*, 122-127. doi:10.1049/cp.2010.0548

Cooper, K. M., & Longstreet, C. S. (2012, July-August 30-1). Towards model-driven game engineering for serious educational games: Tailored use cases for game requirements. *2012 17th International Conference on Computer Games (CGAMES)*, 208-212. doi:10.1109/CGames.2012.6314577

Critelli, M., Schwartz, D. I., & Gold, S. (2012, September 7-9). Serious social games: Designing a business simulation game. *2012 IEEE International Games Innovation Conference (IGIC)*, 1-4. doi:10.1109/IGIC.2012.6329843

Dávila Balcarce, G., & Velásquez Contreras, Á. (2007). Evaluation of the Aplication of Shared Games: "Devorón" and "Temporal". *Revista Electrónica de Investigación Educativa, 9*(2). Retrieved January 2015, from http://redie.uabc.mx/vol9no2/contenido-davila.html

de Freitas, S., & Jarvis, S. (2006). A framework for developing serious games to meet learner needs. *I/ITSEC '06: Proceedings of the International Conference on Interservice/Industry Training, Simulation and Education*.

de Freitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers & education, 46*(3), 249-264.

Demachy, T. (2003, July 16). *Extreme Game Development: Right on Time, Every Time*. Retrieved July 1, 2014, from Gamasutra: http://www.gamasutra.com/view/feature/131236/extreme_game_development_right_on_.php

Díaz Barriga, Á. (2006). El enfoque de compentecias en la educación. ¿Una alternativa o un disfraz de cambio? *Revista Perfiles Educativos*(111), 7-36. Retrieved September 2013, from http://www.iisue.unam.mx/perfiles/perfiles_articulo.php?clave=2006-111-7-36&url=2006/n111a2006/mx.peredu.2006.n111.p7-36.pdf

Dondlinger, M. J. (2007). Educational video game design: A review of the literature. *4*. (J. W. Rice, Ed.) Denton, Texas. Retrieved February 2013, from http://www.eduquery.com/jaet/

Emam, A., & Mostafa, M. G. (2012, July - August 30-1). Using game level design as an applied method for Software Engineering education. *2012 17th International Conference on Computer Games (CGAMES)*, 248-252. doi:10.1109/CGames.2012.6314583

Flood, K. (2003, May 14). *Game Unified Process*. Retrieved July 1, 2014, from GameDev.net: http://www.gamedev.net/page/resources/_/technical/general-programming/game-unified-process-r1940

Froschauer, J., Seidel, I., Gärtner, M., Berger, H., & Merkl, D. (2010, October). Design and evaluation of a Serious Game for immersive cultural training. *16th International Conference on Virtual Systems and Multimedia (VSMM)*, 253-260. doi:10.1109/VSMM.2010.5665978

Fuggetta, A. (1995). Il Processo Software, Aspetti strategici e organizzativi.

FutureLab. (2010, june). Games in Education: Serious Games - A FutereLb Literature Review. Harbourside, Bristol, United Kingdom. Retrieved January 1, 2014, from www.futurelab.org.uk

Gallardo, J., León, M., Martínez, A., Martínez, K., & Primera, D. (n.d.). Metodología para el Desarrollo de Software Educativo por el Dr. Pere Marqués. *Revista Digital UPEL*. Retrieved July 1, 2014, from http://issuu.com/katherine1909/docs/revista_digital_final_metod._per__marqu_s_2_

Galli, L. (2014, November 3-7). Matching Game Mechanics and Human Computation Tasks in Games with a Purpose. *Proceedings of the 2014 ACM International Workshop on Serious Games*, 9-14. doi:10.1145/2656719.2656727

Garrido Miranda, J. M. (2013). Strategy Video Games: Some Principles for Teaching. *Revista Electrónica de Investigación Educativa*, *15*(1). Retrieved January 2015, from http://redie.uabc.mx/vol15no1/contenido-garridojm.html

Godoy, A., & Barbosa, E. (2010). IX Brazilian Symposium on Computer Games and Digital Entertainment. *Game-Scrum: An Approach to Agile Game Development*, (pp. 292-

295). Florianópolis. Retrieved July 1, 2014, from http://sbgames.org/sbgames2010/proceedings/proceedingsEN.html

González Salazar, M., Mitre, H. A., Lemus Olalde, C., & González Sánchez, J. (2012, July 30-1). Proposal of Game Design Document from software engineering requirements perspective. *2012 17th International Conference on Computer Games (CGAMES)*, 81-85. doi:10.1109/CGames.2012.6314556

Guía de los Fundamentos para la Dirección de Proyectos (Guía del PMBOK) (Cuarta ed.). (2008). Newtown Square, Pennsylvania, EE.UU.: Project Management Institute, Inc.

Hernández Sampieri, R., Fernández Collado, C., & Baptista Lucio, M. d. (2010). *Metodología de la Investigación* (Quinta ed.). México D.F., D.F., México: McGrawHill. Retrieved February 2013

Horridge, M. (2009). *A Practical Guide To Building OWL Ontologies Using Protege 4 and CO-ODE Tools Edition 1.2.* The University of Manchester.

Huang, Y., Dong, Y., & Liu, D.-H. (2011, December 27-29). Research on educational game design of the blank trial procedure. *2011 International Conference on e-Education, Entertainment and e-Management (ICEEE)*, 249-252. doi:10.1109/ICeEEM.2011.6137798

Hwang, J.-P., Wu, T.-T., Huang, Y.-M., & Huang, Y.-M. (2012, July 4-6). Development and Evaluation of Peer Feedback in the English Quiz Game Design in Social Network. *2012 IEEE 12th International Conference on Advanced Learning Technologies (ICALT)*, 235-239. doi:10.1109/ICALT.2012.136

IBM. (2014). *What is the Rational Unified Process?* Retrieved November 2014, from IBM Search: http://www.ibm.com/developerworks/rational/library/content/RationalEdge/jan01/WhatIstheRationalUnifiedProcessJan01.pdf

Ibrahim, R., & Jaafar, A. (2009, August 5-7). Educational Games (EG) Design Framework: Combination of Game Design, Pedagogy and Content Modeling. *2009 International Conference on Electrical Engineering and Informatics ICEEI '09, 1*, 293-298. doi:10.1109/ICEEI.2009.5254771

IEEE Computer Society. (2014). *SWEBOK v3.0 Guide to the Software Engineering Body of Knowledge*. IEEE.

INEGI. (2009, Diciembre 7). *Enciclomedia ¿Qué es?* Retrieved Diciembre 7, 2009, from Enciclomedia Una forma diferente de aprender y enseñar: http://www.inegi.gob.mx/inegi/contenidos/espanol/ciberhabitat/escuela/enciclomedia/

International Institute Of Business Analysis. (2015). *A Guide to the Business Analysis Body of Knowledge (BABOK Guide)* (3 ed.). IIBA.

International Organization for Standardization. (2014). *ISO/IEC 15504-1:2004*. Retrieved November 2014, from International Organization for Standardization: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=38932

International Organization for Standardization. (2014). *ISO/IEC TR 29110-1:2011*. Retrieved November 2014, from International Organization for Standardization: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=51150

International Standardization Organization. (2014). *ISO Standards*. Retrieved from International Standardization Organization: http://www.iso.org/iso/home/standards.htm

Jiménez A., Á. I., Rico L., D. P., Méndez S., C. M., Ceron S., S., & Palechor Betancourt, S. (2010, December). Procesos y técnicas de ingeniería de Software para la Modelación de Videojuegos. *Inventum*(9), 54-66. Retrieved July 1, 2014, from http://biblioteca.uniminuto.edu/ojs/index.php/Inventum

Jovanovic, M., Starcevic, D., Minovic, M., & Stavlja, V. (2011, July). Motivation and Multimodal Interaction in Model-Driven Educational Game Design. *IEEE Transactions on Systems, Man and Cybernetics, Part A: Systems and Humans, 41*(4), 817-824. doi:10.1109/TSMCA.2011.2132711

Kalles, D., & Ntoutsi, E. (2002). Interactive verification of game design and playing strategies. *2002. (ICTAI 2002). Proceedings. 14th IEEE International Conference on Tools with Artificial Intelligence*, 425-430. doi:10.1109/TAI.2002.1180834

Klopfer, E., Osterweil, S., & Salen, K. (2009). *Moving Learning Games Forward: Obstacles, Opportunities and Openness.* Retrieved August 30, 2013, from education.mit.edu: http://education.mit.edu/papers/MovingLearningGamesForward_EdArcade.pdf

Kulpa, M. K., & Johnson, K. A. (2003). *Interpreting the CMMI: A Process Improvement Approach*. Boca Raton, Florida, Estados Unidos: Auerbach Publications CRC Press LLC.

Madeira, R. N., Silva, B., & Palma, J. (2012, April 17-20). Helping math learning, A Moodle-based tool to facilitate the implementation of assessment tests. *2012 IEEE Global Engineering Education Conference (EDUCON)*, 1-7. doi:10.1109/EDUCON.2012.6201176

Mao, C., Yi, Z., JianGang, O., & Guo-tao, H. (2010, December 17-19). Game Design and Development Based on Logical Animation Platform. *2010 International Conference on Computational and Information Sciences (ICCIS)*, 573-576. doi:10.1109/ICCIS.2010.146

Margain Fuentes, M. d., & Durón Rosales, B. (2002, Octubre). Tesis de Maestría Diseño de una herramienta para la interpretación y evaluación de los procesos de ingeniería del modelo CMMI y su aplicación en el diagnóstico de la industria de software. México.

Martens, A., Diener, H., & Steffen, M. (2008). Game-based Learning with Computers - Learning, Simulations, and Games. *Transactions on Edutainment*, 172-190.

Martinón, A., & Riera, T. (1999, marzo 3). *Importancia de las Matemáticas*. Retrieved marzo 19, 2009, from DivulgaMAT: http://divulgamat.ehu.es/weborriak/publicacionesdiv/medios/elpaisNDet.asp?Id=218

Masuch, M., & Rueger, M. (2005, January 28-29). Challenges in collaborative game design developing learning environments for creating games. *Third International Conference on Creating, Connecting and Collaborating through Computing*, 67-74. doi:10.1109/C5.2005.7

McBride, B., & Dollin, C. (2009, Febrero 9). *An Introduction to RDF and the Jena API*. Retrieved Febrero 2009, from http://jena.sourceforge.net/tutorial/RDF_API/index.html

McGinnis, T., Bustard, D. W., Black, M., & Charles, D. (2008, February). Enhancing E-Learning Engagement Using Design Patterns from Computer Games. *2008 First International Conference on Advances in Computer-Human Interaction*, 124-130. doi:10.1109/ACHI.2008.43

McIlraith, S. A., Son, T. C., & Zeng, H. (2001). Semantic Web Services. In S. University, *IEEE Intelligent Systems 2001* (pp. 46-53).

Mulder, M., Weigel, T., & Collins, K. (2007, March). The concept of competence in the development of vocational education and training in selected EU member states: a critical analysis. *Journal of Vocational Education & Training, 59*(1), 67-88. doi:10.1080/13636820601145630

Murray, J., Bogost, I., Mateas, M., & Nitsche, M. (2006, June). Game Design Education: Integrating Computation and Culture. *IEEE Computer Society, 39*(6), 43-51. doi:10.1109/MC.2006.195

Normalización Y Certificación Electrónica A.C. (2014). *Autoevalúe su implantación de la Norma NMX-I-059-NYCE (MoProSoft)*. Retrieved November 2014, from MoProSoft: http://www.moprosoft.com.mx/

Oktaba, H., & Ibargüengoitia González, G. (1998). Software Process Modeled with Objects: Static View. *Computación y Sistemas, 1*(4).

Oviedo de Luna, A. C., Álvarez Rodríguez, F. J., Barajas Saavedra, A., & Muñoz Arteaga, J. (2014, 09 24-26). Instrumento de Evaluación del Grado de Apropiación Asistido por TIC de Competencias en Preescolar – DiDAC-TIC. Puebla. doi:10.13140/2.1.1323.0080

Pankin, J., Roberts, J., & Savio, M. (2012, July). *Blended Learning at MIT*. Retrieved August 30, 2013, from web.mit.edu: http://web.mit.edu/training/trainers/resources/blended_learning_at_mit.pdf

Parker, J. R., & Becker, K. (2011, November 2-3). Serious Game Design I: The Bicameral Sketch. *2011 IEEE International Games Innovation Conference (IGIC)*, 137-138. doi:10.1109/IGIC.2011.6115119

Pinelle, D., Wong, N., & Stach, T. (2008, April 5-10). Heuristic Evaluation for Games: Usability Principles for Video Game Design. *CHI '08 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1453-1462. doi:10.1145/1357054.1357282

Plat, N. v., & J. Toetenel, H. (1992, Septiembre). Application and benefits of formal methods in software development. *Software Engineering Journal, 7*(5), 335-346.

Pressman, R. S. (2006). *Software engineering: a practitioner's approach* (Sexta ed.). McGraw-Hill.

Procuradía Federal del Consumidor. (2009, Febrero 16). *PROFECO - Resultados de encuestas y sondeos.* Retrieved Marzo 20, 2009, from Resultados del sondeo sobre consolas y videojuegos: http://www.profeco.gob.mx/encuesta/mirador/Consolas%20de%20videojuegos.zip

Rational. (1998). *Rational Unified Process Best Practices for Software Development Teams.* Retrieved from IBM.com: https://www.ibm.com/developerworks/rational/library/content/03July/1000/1251/1251_bestpractices_TP026B.pdf

Reyes Delgado, P. Y. (2005). Tesis de Maestría Diseño de un Instrumento de Auto-evaluación para Diagnosticar el Estatus de las Organizaciones en México con Respecto al Modelo ProSoft: Proceso de Gestión de Procesos de la Categoría de Gestión. México.

Secretaría de Educación Pública. (2011). *Programas de estudio 2011 - Guía para el maestro - Educación básica - Primaria - Sexto grado* (First Electronic Edition ed.). Cuauhtémoc, México, D.F., México: Gobierno Federal SEP. Retrieved September 15, 2014, from http://www.curriculobasica.sep.gob.mx/images/PDF/prog_primaria/PRIM_6to2011.pdf

Secretaría de Educación Pública. (2013). *Estadísticas ENLACE 2012.* Retrieved Octubre 25, 2012, from Evaluación Nacional del Logro Académico en Centros Escolares Educación Básica: http://www.enlace.sep.gob.mx/ba/

Sheshagiri, M., Sadeh, N. M., & Gandon, F. (2004). Using Semantic Web Services for Context-Aware Applications.

Shih, J.-L., Chuang, C.-W., Tseng, J.-J., & Shih, B.-J. (2010, April 12-16). Designing a Role-play Game for Learning Taiwan History and Geography. *2010 Third IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL),* 54-60. doi:10.1109/DIGITEL.2010.27

Silva Alarcón, A. (2004). Modelos de calidad: La industria del software en México. México.

Software Engineering Institute. (1992, September). *Software Process Development and Enactment: Concepts and Definitions.* Retrieved from Software Engineering Institute | Carnegie Mellon University: http://resources.sei.cmu.edu/library/asset-view.cfm?assetid=11591

Sommerville, I. (2005). *Software enginnering* (Septima ed.). Pearson Education.

SPICE. (1998). *The theory and Practice of Software Process Improvement and Capability Determination.* (K. El Emam, & J.-N. Drouin, Eds.) IEEE Computer Society Press.

Standford Center for Biomedical Informatics Research. (2009). *The Protégé Ontology Editor and Knowledge Acquisition System*. Retrieved 2009, from Stanford Center for Biomedical Informatics Research: http://protege.stanford.edu/

Statista. (2015). *Most popular Apple App Store categories in March 2015, by share of available apps*. (Statista) Retrieved April 8, 2015, from http://www.statista.com/statistics/270291/popular-categories-in-the-app-store/

Statista. (2015). *Most popular Google Play app store categories in 4th quarter 2012, by share of listed apps*. (Statista) Retrieved April 8, 2015, from http://www.statista.com/statistics/256772/most-popular-app-categories-in-the-google-play-store/

Tejada Fernández, J. (2005). Competencies-Based Work in the Practicum: How to Organize and Evaluate It. *Revista Electrónica de Investigación Educativa, 7*(5). Retrieved January 2015, from http://redie.uabc.mx/vo7no2/contenido-tejada.html

Toca Boca. (2015, 4 19). *Apps for play*. Retrieved Junio 2015, from http://tocaboca.com/

Toca Boca. (2015, 4 19). *For Parents*. Retrieved 6 2015, from http://tocaboca.com/for-parents/

Tsarkov, D., & Horrocks, I. (2009). *FaCT++*. Retrieved 2009, from School of Computer Science - University of Manchester.

Umetsu, T., Hirashima, T., & Takeuchi, A. (2002, December 3-6). Fusion Method for Designing Computer-Based Learning Game. *Proceedings of the International Conference on Computers in Education (lCCE'02), 1*, 124-128. doi:10.1109/CIE.2002.1185882

UNESCO. (n.d.). *Non-Formal Education*. Retrieved Mayo 2015, from ICT in Education: http://www.unescobkk.org/education/ict/ict-in-education-projects/non-formal-education/

Vázquez Alonso, Á., & Manassero Mas, M. A. (2007, Febrero 7). *Las actividades extraescolares relacionadas con la ciencia y la tecnología.* Retrieved Marzo 2009, 20, from http://redie.uabc.mx/vol9no1/contenido-vazquez3.html

Velázquez Amador, C. E., Álvarez Rodríguez, F. J., Garza González, L., Sicilia, M. Á., Mora Tavarez, J. M., & Muñoz Arteaga, J. (2011, Noviembre). Una Experiencias en el Desarrollo Masivo de Objetos de Aprendizaje Empleando Parámetros de Calidad y un Proceso de Gestión Bien Definido. *IEEE - Revista Iberoamericana de Tecnologías del Aprendizaje, 6*(4), 155-163.

Vidani, A. C., & Chittaro, L. (2009, March 23-24). Using a Task Modeling Formalism in the Design of Serious Games for Emergency Medical Procedures. *2009. VS-GAMES '09. Conference in Games and Virtual Worlds for Serious Applications*, 95-102. doi:10.1109/VS-GAMES.2009.24

Virvou, M., Katsionis, G., & Manos, K. (2005). Combining Software Games with Education: Evaluation of its Educational Effectiveness. *Educational Technology & Society, 8*(2), 54-65.

W3C. (2004, Febrero 10). *OWL Web Ontology Language Overview*. Retrieved Febrero 2008, 2009, from W3C Recommendation 10 February 2004: http://www.w3.org/TR/owl-features/

Wechselberger, U. (2008, September 22-24). The Eduventure II. An Approach to Educational Game Design. *2008 International Conference on Cyberworlds*, 397-404. doi:10.1109/CW.2008.40

Zin, N. A., & Yue, W. S. (2009, August 5-7). History educational games design. *ICEEI '09. International Conference on Electrical Engineering and Informatics, 2009., 1*, 269-275. doi:10.1109/ICEEI.2009.5254775

Zyda, M. (2005, September). From visual simulation to virtual reality to games. *Computer, 38*(9), 25-32. doi:10.1109/MC.2005.297

Appendixes

Appendixes

Appendix A – Publications

CONTE 2014

Oviedo de Luna, A. C., Álvarez Rodríguez, F. J., Barajas Saavedra, A., & Muñoz Arteaga, J. (2014, 09 24-26). Instrumento de Evaluación del Grado de Apropiación Asistido por TIC de Competencias en Preescolar – DiDAC-TIC. Puebla.


Investigación en Ciencia, Tecnología y Educación
Aportaciones de Redes Innovadoras en Tecnología Educativa
Editores:
Etelvina Archundia Sierra
Miguel Ángel León Chávez
Juan Manuel González Calleros
Josefina Guerrero García
Carmen Cerón Garnica
Rocío Boone Rojas
Puebla, Pue. México. 2014
ISBN: 978-607-487-778-6

CAPÍTULO VEINTE

Instrumento de Evaluación del Grado de Apropiación Asistido por TIC de Competencias en Preescolar – DiDAC-TIC

Ana Oviedo de L.[1], Francisco Álvarez R.[2], Arturo Barajas S.[2], Jaime Muñoz A.[2]

[1,2] Dpto. de Ciencias de la Computación, Universidad Autónoma de Aguascalientes,
Av. Universidad 940. 20131 Aguascalientes, México
[1]`oviedo.ana@gmail.com`, [2]`{fjalvar, abarajas, jmunozar}@correo.uaa.mx`

Resumen. El uso de TIC para apoyar la educación en México se está volviendo un tema común entre los educadores, principalmente del sector privado. Las TIC se consideran un complemento exitoso que promueve competencias adicionales a las propuestas por el Ministerio de Educación en México. Sin embargo, no existen instrumentos que indiquen de forma precisa si realmente se promueven dichas competencias. En esta investigación se propone un instrumento para la evaluación cualitativa del desarrollo de competencias en estudiantes de preescolar apoyado en el uso de TIC a través de tabletas en sus clases formales.

Palabras Clave: Educación basada en competencia, evaluación educativa, instrumentos de evaluación.

1 Introducción

Hoy en día el acceso a diferentes dispositivos móviles es creciente, los niños tienen un acercamiento a tabletas desde edades tempranas. Mayormente, estos dispositivos son usados con fines de ocio por parte de los niños por lo cual los fabricantes y desarrolladores de software ofertan un sin número de aplicaciones y juegos altamente atractivos a los usuarios. De ahí la oportunidad de ofrecer a los educandos de edad preescolar una serie de herramientas que permitan presentar de manera atractiva y novedosa los contenidos a cubrir durante su paso por la educación preescolar.

El uso de las Tecnologías de la Información y la Comunicación (TIC) en la educación es cada vez una práctica más común. Su inserción en los diferentes niveles educativos va creciendo cada vez más, abarcando diferentes áreas de conocimiento y, siendo éstas, herramientas auxiliares para el desarrollo de las competencias que señalan los planes y programas de cada nivel educativo.

Aportaciones de Redes Innovadoras en Tecnología Educativa. 2014, pp. 263 - 273.

Es aquí donde radica la importancia de contar con instrumentos que ayuden a evaluar el impacto generado por el uso de tabletas en la adquisición de competencias, dándonos un panorama de cuáles son los beneficios obtenidos por el uso de estos dispositivos y observar si efectivamente son instrumentos que promuevan el desarrollo de competencias y no que sean meramente distractores.

2 Problemática

El nivel preescolar ha comenzado a incluir estas tecnologías en sus actividades cotidianas con el fin de favorecer las competencias establecidas por el Programa de Educación Preescolar (PEP) [1]. Sin embargo, no existen herramientas que evalúen el nivel de logro alcanzado en el desarrollo de competencias por los educandos que interactúan con las TIC. La evaluación del uso de las TIC está generalmente centrada en la habilidad para utilizar dichas herramientas y no en los conocimientos derivados por su uso.

La incorporación de las TIC en preescolar es una temática importante con diferentes experiencias y percepciones. En Venezuela se han realizado investigaciones para medir los beneficios producidos por el uso de las TIC en la etapa inicial de la educación formal. Dicha investigación se encuentra publicada en el documento "*Experiencias de uso de las TIC en la Educación Preescolar en Venezuela*" y ahonda en la importancia de un uso moderado y guiado por los educadores para la construcción de aprendizajes propios en el nivel preescolar, a través de una investigación exploratoria con los diferentes actores de la educación (directivos, maestros, la sociedad y los niños).

Dicho lo anterior, es de gran importancia incluir las TIC en la educación preescolar como parte de las actividades cotidianas buscando favorecer las competencias que el PEP propone. Para que esta práctica sea exitosa es conveniente considerar un instrumento de evaluación que nos permita verificar el desarrollo de competencias a través del uso de tabletas.

En México, el Ministerio de Educación ha establecido los lineamientos o competencias esperadas para los alumnos de educación básica en términos de su habilidad para el manejo de las TIC, en un documento denominado "*Habilidades Digítales para todos*" [2]. Por lo anterior, en esta investigación se presenta una propuesta de un instrumento centrado en evaluar la apropiación de conocimientos y competencias a través del uso de TIC y no solamente las destrezas desarrolladas en el uso de las herramientas como proponen otros instrumentos

Algunos de los aspectos que se deben considerar en la evaluación son los niveles de acoplamiento entre las diferentes herramientas digitales que existen y los contenidos establecidos para el desarrollo de competencias de los niños de preescolar. Es decir, ¿es posible incorporar en las planeaciones diarias el uso de herramientas tecnológicas como tabletas? Además de los niveles de logro obtenidos al incorporar dichas herramientas ¿es posible lograr la aceptación (la interacción fácil e intuitiva entre el software y el niño) en el uso de las nuevas tecnologías como herramientas para construir su propio aprendizaje?

3 Antecedentes

3.1 Evolución de las TIC (tabletas) en la educación preescolar

De acuerdo a la revisión de tabletas realizada por la Fundación Down España, publicada en su documento "*Proyecto Haz TIC*" [3], el iPad es el dispositivo más amigable con los niños debido a su interfaz intuitiva y de fácil manejo. Por otro lado, Android ha realizado adaptaciones en su sistema operativo en algunos países europeos incorporando iconos más grandes, llamativos o incluso con personajes de series de televisión que se han sumado a la creación de estos dispositivos para ampliar su mercado con la finalidad de tener una mejor aceptación con el público infantil. En el continente americano se ha sumado a esta modalidad de productos la compañía Disney, con la Disney tablet que únicamente ofrece fondos de pantalla e imágenes de sus personajes.

En la siguiente tabla (Tabla 1) se muestran las principales características de algunos modelos de tabletas diseñadas especialmente para niños.

Tabla 5. Características de las principales tabletas para niños en el mercado europeo.

Tableta	SO	Procesador y Almacenamiento	Observaciones
Samsung Galaxy Tab 3 Kids		Dual-core a 1,2GHz 8GB	Tenemos una batería de 4000mAh que nos asegura que se podrá utilizar a lo largo del día, de 6 a 8h. Viene con un lápiz digital para que nuestro crío pueda dibujar en las aplicaciones de dibujo. Una especie de S-pen infantil que será compatible con las aplicaciones que nos descarguemos de una Kid Store que Samsung nos proporciona además de Google Play
Meep X2	Android 4.2	1 GB de RAM y procesador de doble núcleo	Diseño colorido bastante atractivo y que se enfoca a niños a partir de los 6 años de edad. La tablet es a prueba de salpicaduras y golpes
Fnac junior	Android 4.1	Dual core a 1,6GHz	La Tablet Fnac Junior incluye más de 20 aplicaciones y libros interactivos infantiles. Una tableta pensada para mejorar la capacidad lectora y que se sincroniza con Fnac Books

Tableta	SO	Procesador y Almacenamiento	Observaciones
RTVE Tablet	Android 4.0	4GB interno, MicroSD externo	En cuanto al software tendremos hasta 8 perfiles de usuario distintos. También tendremos un cuidado control parental con un sistema exclusivo de filtrado de contenidos. Tenemos como en la mayoría de estas tablets para niños aplicaciones para colorear, jugar con la cámara para hacerse fotos con los personajes animados
Super Paquito Tablet	MagicOS 2.0	16GB	Fue una de las primeras marcas en construir una tablet diseñada para niños. Hay varios modelos, pero todos cuentan con Magic OS, una interfaz con iconos de gran tamaño, aplicaciones específicas de dibujo y retoque e incluso correo para los pequeños. También han acompañado a esta experiencia de una tienda de aplicaciones propia, PaquitoLand, donde podremos aumentar aún más el vendaval de opciones disponible, incluyendo muchos juegos especiales

En México algunas editoriales se han dedicado a diseñar aplicaciones para el iPad que permiten manejar los contenidos que señalan los planes y programas establecidos por el Ministerio de Educación para cada nivel educativo. Tal es el caso de la editorial Santillana y su programa UNO [4] que ha creado una plataforma en la que docentes pueden encontrar recursos didácticos para el desarrollo de sus clases, así como actividades interactivas a través del iPad para los alumnos.

Al igual que la editorial Santillana otras editoriales han creado materiales y programas que vinculan la experiencia del aprendizaje a la interacción con los medios digitales ya sea a través de portales web, o de dispositivos móviles.

En México, las competencias en TIC no han sido consideradas formalmente en los planes de estudio del Ministerio de Educación. La inclusión de las TIC se ha visto favorecida principalmente en la educación privada como complemento a su oferta educativa para atraer más estudiantes, utilizando recursos multimedia y Web.

El objetivo de evaluar la inclusión de las TIC en la educación preescolar es favorecer su papel en la educación pública abordando los diferentes campos formativos o competencias propuestos por el Ministerio de Educación a través de actividades que favorezcan el trabajo colaborativo, el pensamiento matemático, la lectoescritura y el acercamiento a las ciencias, coadyuvando al logro del perfil de egreso esperado al concluir la etapa de educación inicial.

4 Competencias curriculares en la educación preescolar

En México la educación básica se ha dividido en cuatro periodos, clasificando los niveles de logro que el estudiante debe adquirir al concluir cada periodo. El primer periodo concluye al término de la educación preescolar entre los 5 y 6 años de edad. El alumno debe cubrir los campos formativos que el PEP establece generando un mapa curricular que construya un vínculo formativo en los diferentes niveles educativos que se han establecido por el Ministerio de Educación. (Fig. 1, cabe resaltar que en la figura no se muestra el cuarto período por no estar estandarizada la articulación de este.) [5]

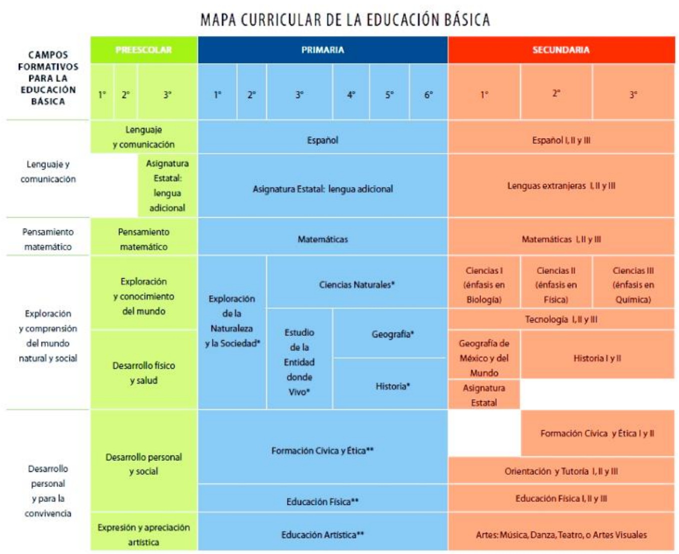


Fig. 12. Mapa curricular de la educación básica en México para articular los diferentes niveles educativos en la educación basada en competencias.

Las competencias que se establecen en la educación preescolar constituyen el principal componente de la articulación de los tres niveles de educación básica y están relacionados con el perfil de egreso, es decir, siendo la educación preescolar el primer acercamiento a la educación formal es de vital importancia se adquieran las competencias esperadas para tener un paso exitoso por el resto de la educación básica.

En la siguiente tabla (Tabla 2) se presentan los campos formativos y los aspectos a organizar en cada uno de ellos [1].

Tabla 6. Campos Formativos de la Educación Preescolar en México.

Campo formativo	Aspectos que se organizan
Lenguaje y Comunicación	Adquieren confianza para expresarse, dialogar y conversar, mejoran su capacidad de escucha, y enriquezcan el lenguaje oral para comunicarse en diversas situaciones. Desarrollen interés por la lectura, usen diversos tipos de texto y sepan para que se usan, se inicien en la práctica de la escritura para expresar gráficamente las ideas que quieren comunicar y reconozcan algunas propiedades del sistema de escritura.
Pensamiento Matemático	Usen el pensamiento matemático en situaciones que demanden establecer relaciones de correspondencia, cantidad y ubicación entre objetos al contar, estimar, reconocer atributos, comparar y medir; comprendan las relaciones entre los datos de un problema y usen estrategias o procedimientos propios para resolverlos.
Exploración y Conocimiento del Mundo	Se interesen en la observación de fenómenos naturales y las características de los seres vivos; participen en situaciones de experimentación que los lleven a describir, preguntar, predecir, comparar, registrar, elaborar explicaciones e intercambiar opiniones sobre procesos de transformación del mundo natural y social inmediato, y adquieran actitudes favorables hacia el cuidado del medio.
Desarrollo Físico y Salud	Mejoren sus habilidades de coordinación, control, manipulación y desplazamiento; practiquen acciones de salud individual y colectiva para preservar y promover una vida saludable, y comprendan que medidas y actitudes que pongan en riesgo su integridad personal.
Desarrollo Personal y Social	Se apropien de los valores y principios necesarios para la vida en comunidad, reconociendo que las personas tenemos rasgos culturales distintos, y actúen con base en el respeto a las características y los derechos de los demás, el ejercicio de responsabilidades, la justicia y la tolerancia, el reconocimiento y aprecio a la diversidad lingüística, cultural, étnica y de género.
Expresión y Apreciación Artística	Usen la imaginación y la fantasía, la iniciativa y la creatividad para expresarse por medio de los lenguajes artísticos (música, artes visuales, danza, teatro) y apreciar manifestaciones artísticas y culturales de su entorno y de otros contextos.

5 Propuesta de Instrumento de Evaluación DiDAC-TIC

La evaluación establecida por el Ministerio de Educación en México para el nivel preescolar es en gran medida cualitativa, y se basa principalmente en la observación del educador frente al grupo apoyándose en instrumentos como guías de observación, listas de cotejo, portafolios de evidencia, entre otros, por lo que los niveles alcanzados en el desarrollo de competencias están sujetos al criterio del educador tomando en cuenta la movilización de los conocimientos y habilidades que se mencionan en la sección anterior.

Los parámetros utilizados en la educación preescolar en México son de carácter cualitativo y están clasificados en **Excelente** (E): se considera que un alumno tiene este nivel de desempeño cuando ha logrado adquirir la competencia de manera que pueda aplicarla en diferentes situaciones, **Muy Bien** (MB): se considera que un alumno tiene este nivel de desempeño cuando ha logrado adquirir la competencia más no es capaz de siempre aplicarla en las situaciones que enfrenta cotidianamente, **Bien** (B): se considera que un alumno tiene este nivel de desempeño cuando ha logrado adquirir la competencia mas no logra aplicarla y **En Proceso** (EP): se considera que una competencia está en proceso cuando el niño aun no es comprende o aplica las conceptos y competencias.

Se han realizado esfuerzos previos para la elaboración de instrumentos de evaluación de las TIC en la implementación del programa piloto E-Blocks de la empresa brasileña Positivo en el Estado de Aguascalientes. Esta prueba consistió en el uso de la tecnología por seis preescolares públicos cuyos resultados están plasmados en el artículo "*Método de evaluación para TIC aplicadas en la educación preescolar, caso: sistema del Estado de Aguascalientes*" [6].

El instrumento propuesto es una herramienta que ayuda en la evaluación de la adquisición de competencias asistidas por las TIC (en el caso particular del uso de tabletas) ofreciendo indicadores que facilitan a la educadora, durante la sesión de trabajo, observar si las actividades desarrolladas con las tabletas están contribuyendo a la construcción de aprendizajes propios del educando.

A continuación en la Tabla 3 se muestra el instrumento propuesto en esta investigación, el cual contempla los aspectos del PEP en términos de competencias y forma de evaluación. El equipo ha bautizado al instrumento y su proceso de evaluación como DiDAC-TIC (**Di**agnóstico, **D**esarrollo de **A**ctividades, **C**ierre, con el uso de **TIC**),

En la sección 1 se busca medir si el uso de las tabletas ha logrado potenciar en el alumno la interacción entre pares, adaptación al entorno y comunidad respetando las reglas que los diferentes entornos representan.

En la sección 2 se evalúa si la tableta ha mejorado el uso correcto del lenguaje, permitiéndole al alumno expresarse en diferentes entornos y situaciones.

En la sección 3 se mide que los alumnos sean capaces de interactuar de manera natural con los números y las diferentes relaciones, es decir, puedan resolver situaciones que involucren asociaciones, sumas, restas, etc.

En la sección 4 se pretende ver cómo a través del uso de los dispositivos puede relacionar las actividades que realiza en sus dispositivos con su entorno más cercano promoviendo el cuidado del ambiente desde su papel como miembro de una comunidad.

En la sección 5 se busca medir si se moviliza en el alumno la apreciación de las bellas artes así como encontrar en ellas una manera de expresar y comunicar sus emociones.

En la sección 6 se mide la capacidad de desarrollar actividades que promuevan su salud integral del alumno y su comunidad.

Para llevar a cabo el llenado del instrumento, el educador debe palomear el grado de cumplimiento de cada uno de los aspectos considerados, contabilizando cuantos E, MB, B o EP hay y así poder reforzar cada una las áreas con oportunidad de un mayor desarrollo.

Tabla 7. Formato del Instrumento de Evaluación de Campos Formativos DiDaC-TIC.

Indicadores	E	MB	B	EP
1 Desarrollo Personal y Social				
Los niños respetan las normas de uso de los dispositivos electrónicos.				
Los niños cumplen con roles o comisiones, permitiendo que cada uno realice una tarea o función.				
Los líderes de equipo asignan tareas durante la sesión para organizar el trabajo				
El líder recuerda las tareas a realizar para que se cumplan los objetivos.				
Los niños reconocen y respetan sus tareas asignadas				
Los niños respetan las normas de uso de los dispositivos electrónicos.				
2 Lenguaje y Comunicación				
Los niños dialogan para repartir las tareas a realizar				
Los niños expresan sus dudas con los miembros de su equipo, y maestro				
Todos los miembros de equipo expresan su opinión para lograr la solución de un problema o tarea.				
Los niños identifican los símbolos o iconos de su tableta o dispositivo.				
3 Pensamiento Matemático				
Resolución de problemas que impliquen reunir, quitar, igualar, comparar, y repartir objetos.				
Manejo de números en situaciones variadas.				
Reconoce y nombra características de objetos, figuras y cuerpos geométricos.				
Ubicación espacial.				
4 Exploración y Conocimiento del Mundo				
Puede tener una conexión con la naturaleza a través de videos y actividades multimedia.				
Elabora inferencias y predicciones a partir de lo que sabe y supone del medio natural				
Respeta los turnos y tareas asignadas en el uso de las tabletas				
Relaciona la información que obtiene de la tableta con su entorno cercano (familia, escuela, colonia)				
5 Expresión y Apreciación Artística				

Escucha , interpreta, y comunica las canciones a través de la tableta				
Expresión corporal con acompañamiento del canto y de la música				
Es capaz de buscar y visualizar lo que son las artes plásticas				
Puede realizar creaciones propias a través de software educativo.				
6 Desarrollo Físico y Salud				
Imita acciones planteadas por programas para el desarrollo de equilibrio y motricidad				
Respeta las medidas preventivas de seguridad.				
Imita acciones planteadas por programas para el desarrollo de equilibrio y motricidad				
Respeta las medidas preventivas de seguridad.				

En la siguiente figura se muestra el plan de trabajo para desarrollar la parte de experimentación del instrumento que se propone.

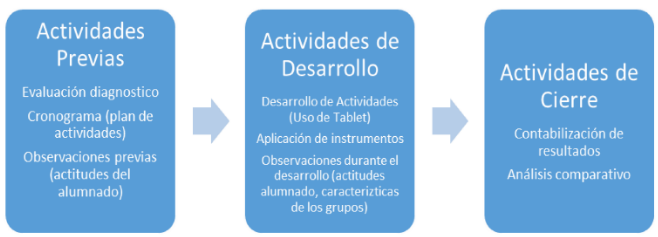


Fig. 2. Proceso de Evaluación "DiDAC-TIC" propuesto.

A continuación se detallan las actividades mencionadas en la figura anterior para su mejor comprensión.

La evaluación diagnostica, se realiza por parte de los profesores al frente del grupo en el cual observaremos cuales son los conocimientos previos de los alumnos como parámetros de comparación al inicio y final de la experimentación. El cronograma nos describirá la relación entre las competencias que se busca desarrollar con cada aplicación. Las observaciones previas se refieren a la percepción de las actitudes de los niños antes de la realización de la experimentación.

El segundo momento importante para recaudar datos consiste en poner en práctica el uso de las herramientas que previamente se ha establecido, para que las maestras o aplicadores a través del instrumento puedan evaluar el desempeño, tomando nota de las diferentes actitudes como la disposición al trabajo en equipo y organización.

Finalmente tomaremos los resultados de los diferentes momentos de evaluación para realizar un análisis comparativo que nos permita realizar una comparación importante sobre el impacto del uso de tabletas.

272 *Oviedo-de Luna A. C., et al.*

6 Conclusiones

En este trabajo se ha presentado un análisis de la situación actual en México del desarrollo de competencias de preescolar a través de la TIC, observando que su implementación es pobre y se realiza principalmente en el sector privado como un complemento para atraer más alumnos.

Debido a la falta de formalización de instrumentos de evaluación de la apropiación competencias cuando los estudiantes usan TIC, no existen mecanismos para medir el impacto real del uso de las TIC en la educación formal a nivel preescolar en México, lo cual es de suma importancia para discernir si el uso de estos recursos apoya al desarrollo de las competencias en los estudiantes.

En este trabajo se presenta una propuesta para un instrumento de medición del impacto de uso de las TIC en la educación preescolar, el cual puede aclarar si el uso de tabletas ayuda a la mejor adquisición de competencias.

Se plantea realizar la experimentación con muestras en preescolares con acceso a estos dispositivos, realizando actividades comunes que permitan a las educadoras observar cual es el resultado reflejado por el uso de dichos dispositivos. El objetivo de este estudio será contrastar si a través de la inclusión de tabletas se logra obtener resultados satisfactorios en el desarrollo de las competencias establecidas por el Ministerio de Educación de México para tener conclusiones más acertadas respecto al impacto que tienen estas, si son una herramienta efectiva en esta tarea de la adquisición de competencias para aplicar en la vida.

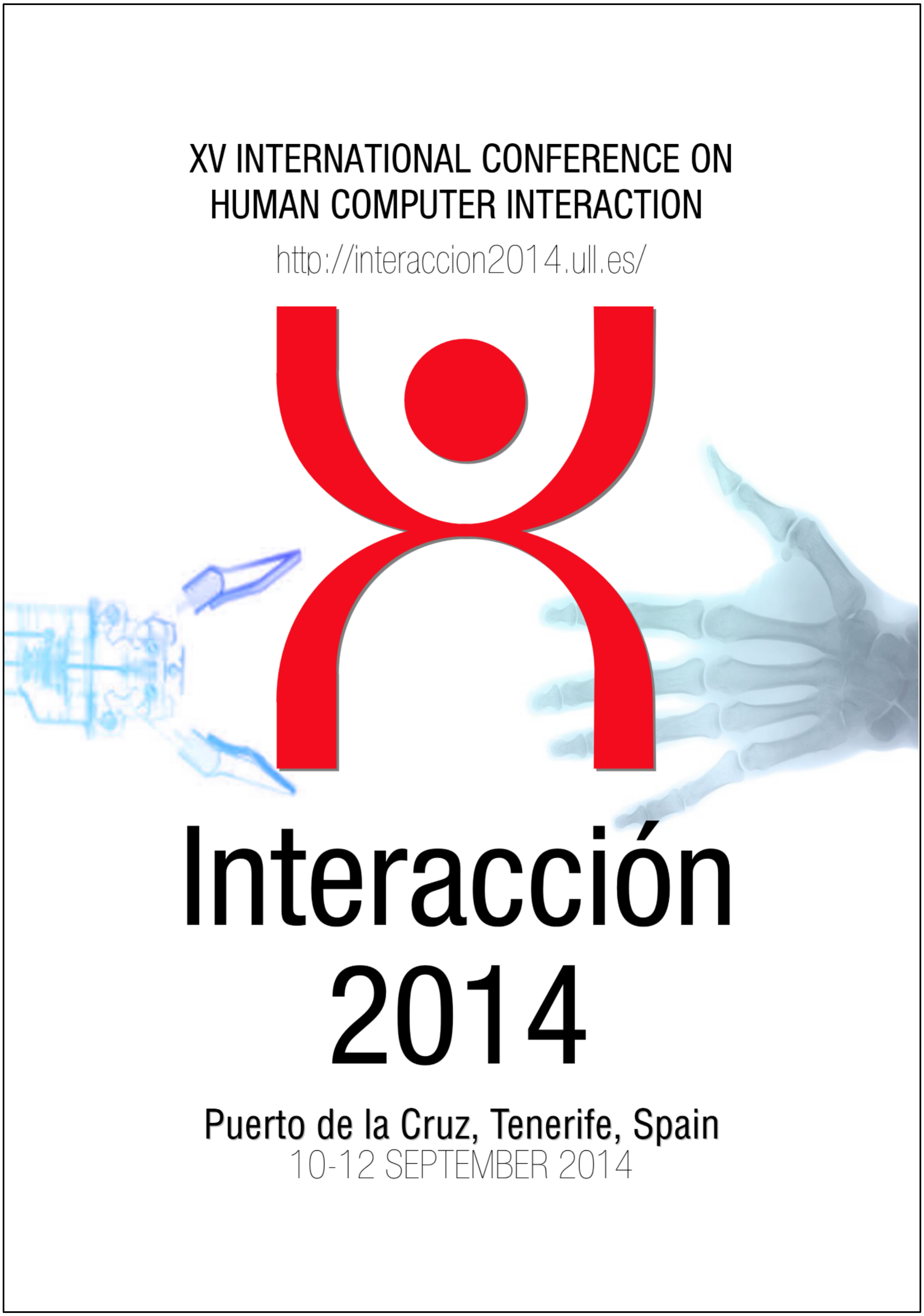
Referencias

1. Secretaria de Educación Pública, «Programa de estudios 2011/ guia para la educadora-básica,» 2011. [En línea]. Available: www.reformapreescolar.sep.gob.mx/actualizacion/programa/Preescolar2011.pdf. [Último acceso: 10 03 2014].
2. Secretaria de Educación Pública, «Habilidades Digítales para Todos,» [En línea]. Available: http://www.hdt.gob.mx/hdt/acerca-de-hdt/que-es-hdt/.
3. F. E. d. S. d. Down, «Down España,» [En línea]. Available: http://www.sindromedown.net/index.php?idMenu=12&int1=1171. [Último acceso: 04 2014].
4. Editorial Santillana, «UNO Internacional,» [En línea]. Available: http://www.sistemauno.com/web/index.html. [Último acceso: 12 05 2014].
5. Secretaria de Educación Básica, «Acuerdo 592 Por el que se establece la Articulación de la Educación Básica,» México, 2011.
6. P. Quezada y F. Alvarez, «Método de evaluación para TIC's aplicadas en la educación preescolar, caso:,» de Tecnologías y Aprendizaje. Avances en Iberoamérica Vol. 2, vol. 2, Cancún, Quintana Roo: Universidad Tecnológica de Cancún, 2013, pp. 405-412.
7. Organización de Estados Iberoamericanos para la Educación, la Ciencia y la Cultura (OEI), 2010. [En línea]. Available: http://www.educativo.utalca.cl/medios/educativo/profesores/basica/integracion.pdf.

8. Secretería de Educación Pública, «Evluación Universal,» 2013. [En línea]. Available: http://www.evaluacionuniversal.sep.gob.mx.
9. D. G. d. I. Educativa, «Reforma Preescolar,» Octubre 2003. [En línea]. Available: http://www.reformapreescolar.sep.gob.mx/ACTUALIZACION/PROGRAMA/FUNDAMENTOS.PDF.
10. G. M. Elena, «Incorporación de la Informática en la Educación Inicial,» Acción Pedagógica, nº 14, pp. 82-94, 2005.
11. M. Herdoiza, «Evaluación de los Aprendizajes: Fundamentos,» Strengthening Achievement in Basic Education (SABE) project.

INTERACCION 2014

Barajas Saavedra, A., Álvarez Rodríguez, F., Muñoz Arteaga, J., Santaolaya Delgado, R., & Collazos Ordóñez, C. (2014). A serious games development process using competency approach. Case Study: Elementary School Math. In A. I.-O. (AIPO) (Ed.), *XV International Conference on Human Computer Interaction* (pp. 572-579). Puerto de la Cruz, Tenerife, España: AIPO. Retrieved September 30, 2014


XV INTERNATIONAL CONFERENCE ON
HUMAN COMPUTER INTERACTION
http://interaccion2014.ull.es/
Interacción
2014
Puerto de la Cruz, Tenerife, Spain
10-12 SEPTEMBER 2014

Interacción 2014

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

Arturo Barajas Saavedra
Universidad Autónoma de Aguascalientes
Av. Universidad 940
Aguascalientes, México
+52 449 9107400 ext. 358
abarajas@correo.uaa.mx

Francisco J. Álvarez Rodríguez
Universidad Autónoma de Aguascalientes
Av. Universidad 940
Aguascalientes, México
+52 449 9107400 ext. 362
fjalvar@correo.uaa.mx

Jaime Muñoz Arteaga
Universidad Autónoma de Aguascalientes
Av. Universidad 940
Aguascalientes, México
+52 449 9108417
jmunoza@correo.uaa.mx

René Santaolaya Salgado
Centro Nacional de Investigación y Desarrollo Tecnológico CENIDET
Interior Internado Palmira S/N
Morelos, México
+52 777 3627770
rene@cenidet.edu.mx

César A. Collazos Ordoñez
Universidad Autónoma de Aguascalientes
Av. Universidad 940
Aguascalientes, México
(+57-2) 8209800
ccollazo@unicauca.edu.co

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 HIVE's (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.

Interacción 2014

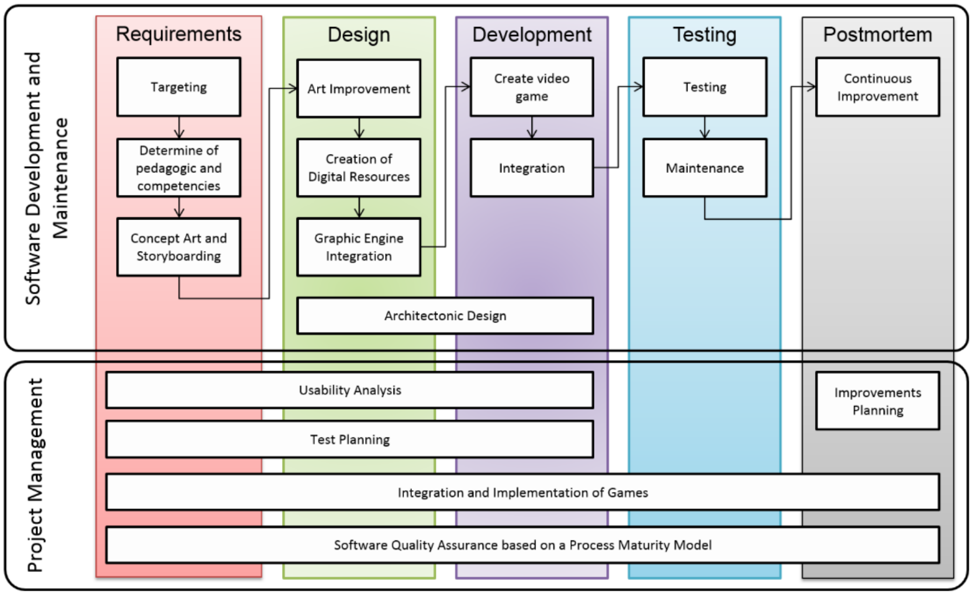


Figure 1. Proposed Serious Game Development Process.

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. And **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]

574

4.1.2 *Design Stage*

Its objectives are to create all digital resources needed by the game engine for the creation of the video game. These digital resources includes: 2D illustrations, 3D models, Maps, Objects, Materials, surfaces, etc., Sounds and music; and to create game engine if needed. Input: Game Design Document. Outputs: Architecture Documentation, Digital resources meeting engine specs.

4.1.3 *Development Stage*

The objective of this stage is to create the game including: Layout, Events, Shader, and AI; to design game play; and to integrate all the above elements with menus, options, etc. Inputs: Architecture Documentation, Digital resources meeting engine specs. Outputs: Serious game.

4.1.4 *Testing Stage*

Its objectives are to test the videogame in the next aspects: Technical, Knowledge absorption, Usability, Usefulness; to obtain efficiency statistics; and to maintain game. Inputs: Serious game, testing plan. Outputs: Testing results, improvement plan, corrective actions plan.

4.1.5 *Postmortem Stage*

The objective is to analyze all process and product information collected during development process to improve future developments. Inputs: Testing results, improvement plan, corrective actions plan. Outputs: Improvement and corrective actions logs.

4.2 Serious Games Quality

Velázquez in [1] mentions that the quality of a digital educational resource covers various aspects of software development using an object-oriented paradigm, and issues related to pedagogy. Therefore, is identified the existence of pedagogical and technical aspects, and usability and content components, which are considered as aspects that determine the quality.

Pedagogical aspects contemplate everything that facilitates the teaching-learning process, as are examples, assessments, self-assessments, feedback, and a pedagogical objective expressed under any taxonomy, to mention some, Bloom's Taxonomy.

The relationship between teaching methods and quality of the resource depends on the learning style of the user, so that it is recommended that the modalities of digital resources include auditory, visual and kinesthetic, recommendation that videogames cover perfectly.

In the content items are those that give information about the complexity of the subject and the level of detail that addresses the content.

Technical aspects include reuse and adaptability, as well as those established by the Software Engineering and utility, reliability, among others.

The aspects of usability (established in Software Engineering) of a digital resource concern the presentation of information (fonts, colors, sizes, etc.) and the disposition thereof (symmetrically, asymmetrically, using positive and negative space, etc.). From the point of view of software engineering usability is ease of use and learning of an object created by humans.

Bearing in mind the quality aspects for serious games, and the analyzed literature on video games and learning objects, a non-exhaustive set of basic features that represent a good starting point to achieve a usable product with a good grade of quality were identified:

1. Short and focused on a single knowledge area to guarantee portability of the video game. In case of a Game Scenario can implement all the knowledge areas of a competency through a set of mini-games or in a single game.
2. Graphical user interface with aesthetic and minimalist design, friendly, and pedagogically evaluated;
3. Cases with formal reasoning;
4. Cases randomly generated to prevent the student memorize the answers to problems;
5. Challenging content and generating competition among students using the game, i.e., cases with different levels of difficulty.

Then, the fulfilment of the requirements must be ensured in order to guarantee product quality. The compliance with requirements must be ensured from the views: pedagogical, educational and ludic.

This "Serious Game Requirements Management" was not found in the literature review done, so in the next section is presented a process to match a formal competency with a non-formal content, identifying the aspects and factors that should be implemented in the production of the game so that satisfactorily cover the expectation of the competency within a scholar grade and guarantee the quality of the serious game through the fulfilment of the requirements. This process is called Competency-based decomposition, and it is a proven successful way to accomplish the production of a digital educational resource [1].

4.3 Competency-Based Decomposition

To carry out the production of video games, the Competency-based decomposition has to be implemented as shown in the following figure (see Figure 2). Based upon the review of the work in [13] and [14] the definition used in this research for competency is as follows: "Competencies are all mental resources of individuals that are used to master tasks, acquire knowledge and achieve a good performance in some specified abilities with a certain skill level."

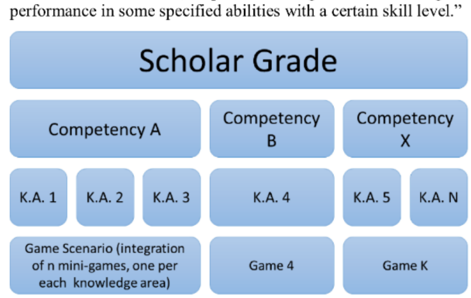


Figure 2. Competency-based decomposition process.

To achieve portability of video games and be able to integrate independently in formal classes, it seeks to be focused on a knowledge area. In turn, a scenario (which integrates different games under a common graphical standard) is created to cover a competency. Even a scenario could integrate various or just a fraction of different competencies, depending on the particular need.

575

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".

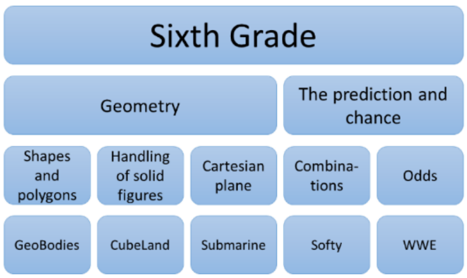


Figure 3. Competency-based decomposition example.

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 2. Identified competencies and knowledge areas

Competency	Knowledge area	Description
The numbers, relationships and operations	Operations	Use basic operations to reach a particular goal.
		Resolve operations mentally and prioritize them.
	Decimal system	Operations and use the decimal point.
	Fractions	In relation to a unit, determine what fraction corresponds to certain questions.
Geometry	Shapes and polygons	Relate the figure appearing under his name respectively.
	Handling of solid figures	Creation of new figures from points or other basic shapes
	Cartesian plane	Find an objective from the motion within a plane.
Measures and Conversions	Lengths	Application and comparison of the measurement units of length.
	Volume	Application and comparison of volume measurement units.
	Weight/mass	Application and comparison of the measurement units of weight/mass.
	Perimeters	Determining the shape of geometric figures from its dimensions.
	Areas	Determining the area of shapes based on its dimensions.
	Time	Application and comparison of the measurement units of time.
Information processing	Graphic representation of results	Creating tables and diagrams to interpret information and amounts from goals.
Processes of change	Patterns	Equivalent proportionalities.
	Values of unity	Find an objective from certain indications of a plane.
	Cross product	Application of operations using the cross product.
	Percentages	Use percentages for achieve goals.
The prediction and chance	Combinations	Resolution count problems and use the tree diagram.
	Odds	Application of operations through chance games.

Once competencies are identified the next step is to set objectives, pedagogical, content and learning activities that will be integrated into the serious games. 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 3. Extract of developed video games

Video game	Compentency	Knowledge area
pokeMath	The numbers, relationships and operations	Operations
Math Challenge	The numbers, relationships and operations	Operations
	Measures and Conversions	Weight/mass
DS3A	The numbers, relationships and operations	Operations
SpaceMath	The numbers, relationships and operations	Operations

Fracciones	The numbers, relationships and operations	Fractions
GeoBodies	Geometry	Shapes and polygons
CubeLand	Geometry	Handling of solid figures
Submarino	Geometry	Cartesian plane
GolfMeter	Measures and Conversions	Lengths
miHuerta	Measures and Conversions	Volume
Áreas	Measures and Conversions	Areas
Ubicación	Processes of change	Values of unity
Regla de Tres	Processes of change	Cross product
Kaxan	Processes of change	Percentages
WWE	The prediction and chance	Odds
Marcianos	Geometry	Shapes and polygons
Time Rider	Measures and Conversions	Time
Time Champ	Measures and Conversions	Time
Jinete Solitario	Measures and Conversions	Lengths
Perimeters	Measures and Conversions	Perimeters
Softy	The prediction and chance	Combinations
Math Fractions	The numbers, relationships and operations	Fractions

Screenshot for some video games can be seen in the next figures (Figure 4, Figure 5, Figure 6, and Figure 7).

Figure 4. Kaxan screenshots.

Figure 5. Space Math screenshots.

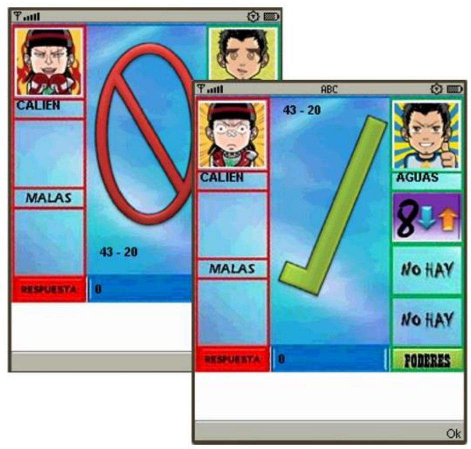


Figure 6. DS3A screenshots.

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.

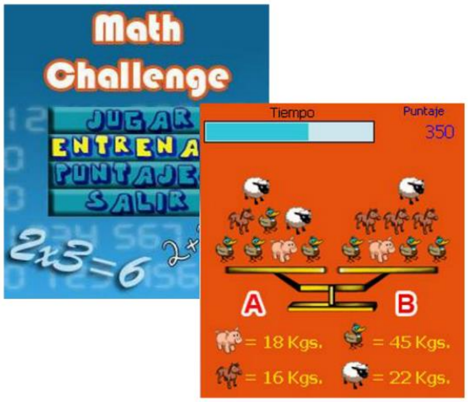


Figure 7. Math Challenge screenshots.

Figure 8. Kids in their classroom and kids playing with the games.

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.

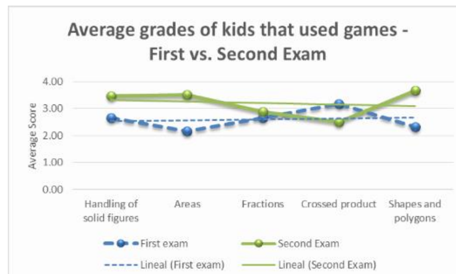


Figure 9. Overall result of the students in different areas of knowledge tested.

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

[1] C. E. Velázquez Amador, F. J. Álvarez Rodríguez, L. Garza González, M. Á. Sicilia, J. M. Mora Tavarez and J. Muñoz Arteaga, "Una Experiencias en el Desarrollo Masivo de Objetos de Aprendizaje Empleando Parámetros de Calidad y un Proceso de Gestión Bien Definido," IEEE - Revista Iberoamericana de Tecnologías del Aprendizaje, vol. 6, no. 4, pp. 155-163, Noviembre 2011.

[2] A. Barajas Saavedra, J. Muñoz Arteaga, F. J. Álvarez Rodríguez and M. E. García Gaona, "Developing Large Scale Learning Objects for Software Engineering Process Model," 2009 Mexican International Conference on Computer Science, pp. 203-208, 2009.

[3] A. C. Vidani and L. Chittaro, "Using a Task Modeling Formalism in the Design of Serious Games for Emergency Medical Procedures," 2009. VS-GAMES '09. Conference in Games and Virtual Worlds for Serious Applications, pp. 95-102, 23-24 March 2009.

[4] M. Masuch and M. Rueger, "Challenges in collaborative game design developing learning environments for creating games," Third International Conference on Creating, Connecting and Collaborating through Computing, pp. 67-74, 28-29 January 2005.

[5] H. Oktaba y G. Ibargüengoitia González, «Software Process Modeled with Objects: Static View,» Computación y Sistemas, vol. 1, nº 4, 1998.

[6] R. S. Pressman, Software engineering: a practitioner's approach, Sexta ed., McGraw-Hill, 2006.

[7] I. Sommerville, Software enginnering, Septima ed., Pearson Education, 2005.

[8] C. Aldrich, «Virtual Worlds, Simulations, and Games for Education: A Unifying View,» Innovate: Journal of Online Education, vol. 5, nº 5, 2009.

[9] FutureLab, "Games in Education: Serious Games - A FutereLb Literature Review," Harbourside, 2010.

[10] R. Ibrahim and A. Jaafar, "Educational Games (EG) Design Framework: Combination of Game Design, Pedagogy and Content Modeling," 2009 International Conference on Electrical Engineering and Informatics ICEEI '09, vol. 1, pp. 293-298, 5-7 August 2009.

[11] N. A. M. Zin and W. S. Yue, "History educational games design," ICEEI '09. International Conference on Electrical Engineering and Informatics, 2009., vol. 1, pp. 269-275, 5-7 August 2009.

[12] M. González Salazar, H. A. Mitre, C. Lemus Olalde and J. L. González Sánchez, "Proposal of Game Design Document from software engineering requirements perspective," 2012 17th International Conference on Computer Games (CGAMES), pp. 81-85, 30-1 July 2012.

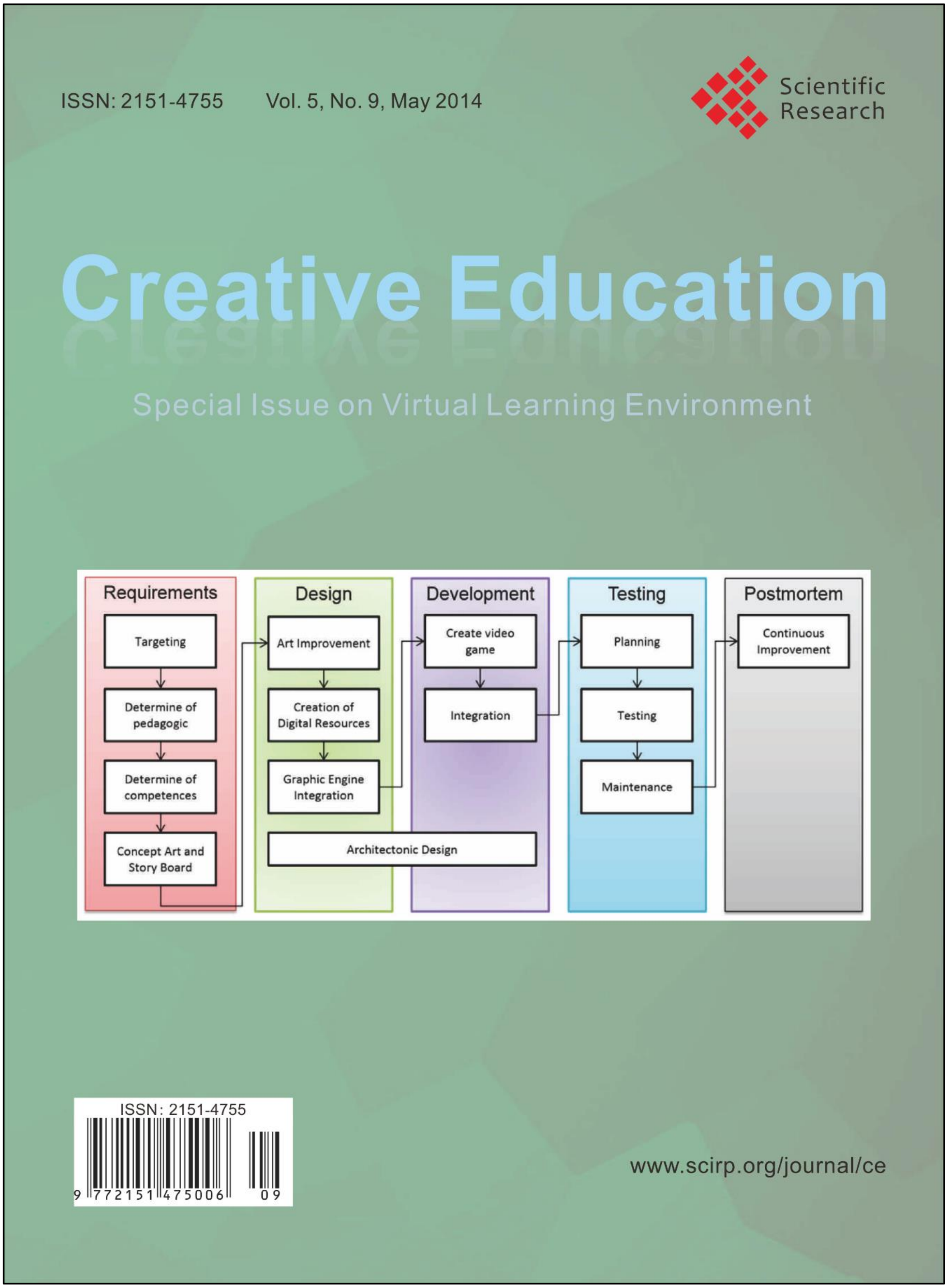
[13] M. Mulder, T. Weigel and K. Collins, "The concept of competence in the development of vocational education and training in selected EU member states: a critical analysis," Journal of Vocational Education & Training, vol. 59, no. 1, pp. 67-88, March 2007.

[14] Á. Díaz Barriga, "El enfoque de compentecias en la educación. ¿Una alternativa o un disfraz de cambio?," Revista Perfiles Educativos, no. 111, pp. 7-36, 2006.

[15] R. Hernández Sampieri, C. Fernández Collado and M. d. P. Baptista Lucio, Metodología de la Investigación, Quinta ed., México D.F., D.F.: McGrawHill, 2010, p. 613.

Creative Education 2014

Álvarez Rodríguez, F., Barajas Saavedra, A., & Muñoz Arteaga, J. (2014, May 16). Serious Game Design Process, Study Case: Sixth Grade Math. *Creative Education*, *05*(09), 647-656. doi:doi:10.4236/ce.2014.59077


ISSN: 2151-4755
Vol. 5, No. 9, May 2014
Scientific Research
Creative Education
Special Issue on Virtual Learning Environment
Requirements
Targeting
Determine of pedagogic
Determine of competences
Concept Art and Story Board
Design
Art Improvement
Creation of Digital Resources
Graphic Engine Integration
Architectonic Design
Development
Create video game
Integration
Testing
Planning
Testing
Maintenance
Postmortem
Continuous Improvement
ISSN: 2151-4755
9 772151 475006 09
www.scirp.org/journal/ce

Creative Education, 2014, 5, 647-656
Published Online May 2014 in SciRes. http://www.scirp.org/journal/ce
http://dx.doi.org/10.4236/ce.2014.59077

Serious Game Design Process, Study Case: Sixth Grade Math

Francisco J. Álvarez-Rodríguez, Arturo Barajas-Saavedra, Jaime Muñoz-Arteaga

Centro de Ciencias Básicas, Universidad Autónoma de Aguascalientes, Aguascalientes, México
Email: fjalvar@correo.uaa.mx

Received 4 March 2014; revised 4 April 2014; accepted 11 April 2014

Abstract

The way in which students are being educated is evolving; the traditional teaching paradigm, where formal and non-formal education are treated as a mutually exclusive, must be changed and turned into a new learning paradigm where formal and non-formal education are treated as one in order to achieve a meaningful and relevant learning. In Mexico, it is clear that educational level of students is barely improving in elementary school students, considering basic topics on Math, Science, and Spanish. There is a need to integrate more efficient mechanisms, like serious video games, in non-formal environment for students and increase learning opportunities beyond the classroom. Therefore, it is envisaged as a possibility, the large scale production of video games to address this problematic. But, a reason why it is not often carried out the large scale development of digital resources is the lack of well-defined development processes and documented experiences. This research will provide solution to the lack of well-defined development processes for large scale production of serious video games, presenting a proposal for a development process with fundamentals in software engineering. The overall findings of the research show that there is an improvement in the knowledge acquisition of the students.

Keywords

Game Design Process, Serious Video Games, Electronic Learning

1. Introduction

The way in which students are being educated is evolving; modern individuals require an ongoing learning due to the technological changes (UNESCO, 2009). The profile of the modern student has changed with the "information age". Individuals evolve in an environment strongly influenced by the presence of diverse artificial and technological elements (McGinnis, Bustard, Black, & Charles, 2008).

How to cite this paper: Álvarez-Rodríguez, F. J., Barajas-Saavedra, A., & Muñoz-Arteaga, J. (2014). Serious Game Design Process, Study Case: Sixth Grade Math. *Creative Education, 5,* 647-656. http://dx.doi.org/10.4236/ce.2014.59077

The traditional teaching paradigm, where formal and non-formal education are treated as a mutually exclusive, must be changed and turned into a new learning paradigm where formal and non-formal education are treated as one in order to achieve a meaningful and relevant learning.

In Mexico, general basic education is oriented to contribute in achieving better levels of intelligence, feelings and personality in students. Aimed to complement these efforts, several strategies have been implemented to incorporate technology (equipment, educational software, Web 2.0 tools, among others) within both, public and private schools from elementary to higher education (SEP BCS, 2009).

However, and despite the efforts, it is clear—based on the ENLACE (by its acronym in Spanish, National Assessment of Academic Achievement in Schools) assessment results—that educational level of students is barely improving in elementary school students, considering basic topics on Math, Science, and Spanish (Secretaría de Educación Pública, 2012).

There is a need to integrate more efficient mechanisms in non-formal environment for students and increase learning opportunities beyond the classroom. Mechanisms with great potential are video games. One of the aspects that have to be solved is to produce content that "*provide immersion*, *motivation*, *fun and high level of engagement*" (Ibrahim & Jaafar, 2009).

Therefore, it is envisaged as a possibility, the large scale production of video games to address both production and mix of strategies (Barajas Saavedra, 2009).

This research is focused on large-scale production of games, the resolution of problems related to such production and presents a solution to the lack of production processes for large-scale games. Then, in Section 2, the problematic production of games is presented. Later, in Section 3, a state of the art studio for the characterization of the games (which establishes the foundation for the design of the process) is presented. In Section 4 some processes proposed by other authors are reviewed. Finally, in Sections 5 and 6, the process proposed in this research, its implementation and the results obtained of the case study are shown.

2. Is There Any Process?

"*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.*" (Velázquez Amador et al., 2011). Some of the reasons why it is not often carried out 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 documented experiences (Barajas Saavedra, 2009; Velázquez Amador et al., 2011). Lack of standard methodologies to guide and organize game design 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 serious games that makes their development more difficult (Vidani & Chittaro, 2009). Game design in an educational environment has to face some severe restrictions in the development process compared to professional game development (Masuch & Rueger, 2005).

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.

Quality Aspects for Educational Digital Resources

In the particular case of educational resources studied in this research (Velázquez Amador et al., 2011), mentions that the quality of a digital educational resource covers various aspects of software development using an object-oriented paradigm, and issues related to pedagogy. Therefore, is identified the existence of technical and pedagogical aspects, and usability and content components, which are considered as aspects that determine the quality.

Technical aspects include reuse and adaptability, as well as those established by the software engineering and utility, reliability, among others.

Pedagogical aspects consider everything that facilitates the teaching-learning process, as are examples, assessments, self-assessments, feedback, and a pedagogical objective expressed under any taxonomy, to mention some, Bloom's Taxonomy.

The relationship between teaching methods and quality of the resource depends on the learning style of the user, so that, it is recommended that the modalities of digital resources include auditory, visual and kinesthetic; video games cover this recommendation perfectly.

The aspects of usability of a digital resource concern the presentation of information (fonts, colors, sizes, etc.) and the disposition thereof (symmetrically, asymmetrically, using positive and negative space, etc.). From the point of view of software engineering usability is ease of use and learning of an object created by humans.

This research will provide solution to the lack of well-defined development processes for large scale production of serious video games, presenting a proposal for a development process with fundamentals in software engineering practices, the results of using this process for the production of various video games, and the results of usability testing of video games with students. Solving, in this way, the problems identified within this subject of investigation (Barajas Saavedra, 2009), that is to say: 1) the experts in contents have not been provided with simple and intuitive tools that automate the large scale production; 2) the game producers do not have the rationale that supports the structuring or design of the serious game, or the experience in the competencies in which the videogame applies; 3) for the production of a serious game neither a structured nor based on software engineering process exists that guarantees the consistency and standardization of the production to increase and to guarantee the quality of products.

3. Video Game Specification or State of the Art

3.1. Blended Learning (B-Learning)

Jeff Pankin et al. (Pankin, Roberts, & Savio, 2012) define b-Learning as structured opportunities to learn, which use more than one learning or training method, inside or outside the classroom. This definition includes different learning or instructional methods (lecture, discussion, guided practice, reading, games, case study, simulation), different delivery methods (live classroom or computer mediated), different scheduling (synchronous or asynchronous) and different levels of guidance (individual, instructor or expert led, or group/social learning).

Blended approaches reflect a combination of the following factors (Pankin, Roberts, & Savio, 2012) (**Figure 1**).

Some strategies have emerged such as the proposed in (Madeira, Silva, & Palma, 2012), which suggests combining traditional classroom learning with modern computer-mediated activities. The authors establish that "the use of Learning Management System (LMS) in a b-Learning setting facilitates the student-teacher interaction outside the classroom in a virtual classroom environment" available 24 × 7. They report an improvement in the engagement and failure, among others success aspects.

In other researches like in (McGinnis, Bustard, Black, & Charles, 2008) is mentioned that e-learning systems, despite their potential, "do not yet have the impact that many believe is possible". Moreover, the gap seems to be increasing because of the greater expectations of the current generation who have grown up with modern technology. Some of the main problems of e-learning are (McGinnis, Bustard, Black, & Charles, 2008): lack of engagement in the learning material, lack of compelling content, lack of interaction with user, unchallenging learning material, finally, lack of contextualization in the e-Learning design.

One of the aspects that have to be solved is to produce content that "provide immersion, motivation, fun and high level of engagement" (Ibrahim & Jaafar, 2009). The e-Learning by itself does not achieve these objectives, making it clear that it requires a blended strategy to achieve the expected learning objectives.

3.2. Serous Video Games

Many authors (e.g. Aghabeigi, Calvert, El-Nasr, & Riedewa, 2012; Critelli, Schwartz, & Gold, 2012; Emam & Mostafa, 2012; Huang, Dong, & Liu, 2011; Hwang, Wu, Huang, & Huang, 2012; Jovanovic, Starcevic,

Schedule:	synchronous	⟷	asynchronous
Guidance:	instructor-led	⟷	self-paced
Technology:	online	⟷	offline
Participation:	individual	⟷	group

Figure 1. Blended approaches reflect a combination of these factors.

Minovic, & Stavlja, 2011; Mao, Yi, JianGang, & Guo-tao, 2010; Cai, Liu, & Liang, 2010; Chuang, You, & Duo, 2010), establish that video games are effective learning mechanisms that provide "*immersion*, *motivation*, *fun and high level of engagement*" (Ibrahim & Jaafar, 2009).

"*Computer games are very effective in the just-in-time delivery of new competencies and knowledge*". Engagement and immersion is kept by the game system continually delivering optional, achievable, new challenges and/or experiences to the player (McGinnis, Bustard, Black, & Charles, 2008).

"Playing" is a close activity with "learning". During "playing", one can often learn many things to improve his/her "playing" with high motivation. However, the "playing" is usually excluded from "learning" from the educational point of view, because of the following two difficulties, the one is the difficulty in grasping individual learner's playing and the other is the difficulty in providing adequate feedback for each playing. Such adaptive interaction is impossible to realize in usual classroom (Umetsu, Hirashima, & Takeuchi, 2002).

Several authors consider Serious games as the next generation of e-Learning tools because games stress visual and experiential learning; they require active involvement, strategizing, hypothesis testing, or problem-solving by student players while providing almost instantaneous feedback (Dondlinger, 2007; Cooper & Longstreet, 2012).

3.3. Serious Games for Learning

It is important to produce content that eliminate the border between formal and non-formal education. To accomplish this, it must be established, in concrete terms, how these games will be produced to successfully meet the desired competencies at each grade level for each subject. A proven successful way to accomplish this production is the decomposition of each subject into generic and specific competencies (Competency-based decomposition), such as that proposed in (Barajas Saavedra, 2009) and later carried out in the massive development of learning objects project "Business-Academia-Government Linkage Model for the Development of IT Capabilities of Human Resources". All these contents are stored in the CAPACINET platform, available at http://capacinet.gob.mx/modpara/ (Velázquez Amador, et al., 2011). This approach allows to match a formal competency with a non-formal content, identifying the aspects and factors that should be implemented in the production of the game so that satisfactorily cover the expectation of the competency within a scholar grade.

Bearing in mind this approach, and the analyzed literature on video games and learning objects, a non-exhaustive set of basic features that represent a good starting point to achieve a usable and effective transfer of knowledge through serious games were identified: 1) Short and focused on a single competency, to enable the student to focus on a particular topic at a time; 2) Graphical user interface with aesthetic and minimalist design, friendly, and pedagogically evaluated; 3) Cases with formal reasoning; 4) Cases randomly generated to prevent the student memorize the answers to problems; 5) Challenging content and generating competition among students using the game, i.e., cases with different levels of difficulty.

4. Previous Approaches

Masuch establishes that a typical game design process consists of the following steps (Masuch & Rueger, 2005): 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; and 7) Balancing and bug fixing

Ibrahim 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 (Ibrahim & Jaafar, 2009).

Zin 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 (Zin & Yue, 2009).

5. Game Design Process

In **Figure 2** can be seen the Game Design Process proposed by this research, which one is described in the next paragraphs. As the reader can see, the designed process has five stages, which are intended to capture all the elements of the game from the targeting and pedagogical requirements establishment, through design and development up to technical testing, usability testing and testing for absorption of knowledge, with a final step of continuous improvement.

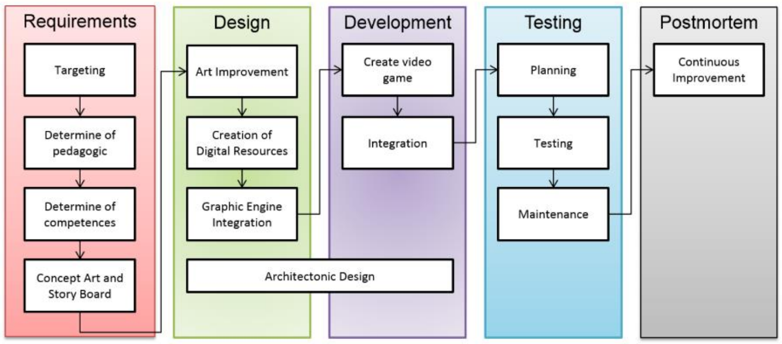


Figure 2. Game design process proposed.

This Game Design Process is founded in the traditional Software Engineering paradigms and complemented by previous efforts on large scale development of digital learning resources (Barajas Saavedra, 2009), and specific skills on Mathematics. Next, a brief description of each stage of the process is explained.

- 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.
- Design Stage. Its objectives are to create all digital resources needed by the game engine for the creation of the video game. These digital resources includes: 2D illustrations, 3D models, Maps, Objects, Materials, surfaces, etc., Sounds and music; and to create game engine if needed.
- Development Stage. The objective of this stage is to create the game including: Layout, Events, Shader, and AI; to design game play; and to integrate all the above elements with menus, options, etc.
- Testing Stage. Its objectives are to test the videogame in the next aspects: Technical, Knowledge absorption, Usability, Usefulness; to obtain efficiency statistics; and to maintain game.
- Postmortem Stage. The objective is to analyze all process and product information collected during development process to improve future developments.

Advantages of the Proposed Process

The game development process proposed provides developers and game designers with a process that will lead them clearly through the production of an serious 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 a serious video game, such as graphic designers, programmers, instructional designers, content developers, educators, project managers , project leaders, to name a few.

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 integrate efficiently the pedagogics and competencies to the video game requirement, so, developers are able to design video games that meet the need in the classroom (formal education) and the team is able to create products that tell teachers how to integrate the game within their classes, creating a bridge between formal and informal education.

6. Study Case

As a proof of concept of our approach the research team conduct a study case using as scenario "the development of serious games to cover all the official competencies for sixth grade for elementary school in Mexico".

At first, the team identify 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 1.

Competencies shown in Table 1 lead us to create a collection of 50 serious video games oriented to increase learning encouraging appropriation of specific math-competencies. An extract of this list is shown in Table 2.

After the initial production phase of serious 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" 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 (Hernández Sampieri, Fernández Collado, & Baptista Lucio, 2010): 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 evalua-

Table 1. Identified generic and specific competencies.

Generic competencies	Specific competencies
The numbers, relationships and operations	Operations
	Decimal system
	Fractions
Geometry	Shapes and polygons
	Handling of solid figures
	Cartesian plane
Measures and Conversions	Lengths
	Volume
	Weight/mass
	Perimeters
	Areas
	Time
Information processing	Graphic representation of results
Processes of change	Patterns
	Values of unity
	Cross product
	Percentages
The prediction and chance	Combinations
	Odds

Table 2. Extract of developed video games.

Video game	Generic competency	Specific competency
Math Challenge	The numbers, relationships and operations	Operations
Math Challenge	Measures and Conversions	Weight/mass
Space Math	The numbers, relationships and operations	Operations
Fracciones	The numbers, relationships and operations	Fractions
Geo Bodies	Geometry	Shapes and polygons
Cube Land	Geometry	Handling of solid figures
Submarino	Geometry	Cartesian plane
Golf Meter	Measures and Conversions	Lengths
miHuerta	Measures and Conversions	Volume
Áreas	Measures and Conversions	Areas
Ubicación	Processes of change	Values of unity
Regla de Tres	Processes of change	Cross product
Kaxan	Processes of change	Percentages
WWE	The prediction and chance	Odds
Marcianos	Geometry	Shapes and polygons
Time Rider	Measures and Conversions	Time
Perimeters	Measures and Conversions	Perimeters
Softy	The prediction and chance	Combinations

tion 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 second test was applied to identify the impact of video games use. 8) The collected data were analyzed with SPSS software.

6.1. Results

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

The overall findings of our study are graphically depicted in **Figure 3** where diamonds-line displays the results obtained during initial examination. Squares-line displays the results of the evaluation performed after serious video 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 video 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.

6.2. Discussion

It is important to mention that the characteristics of the games used in this study were implemented in each of the produced resources, facilitating production and assured learning outcomes.

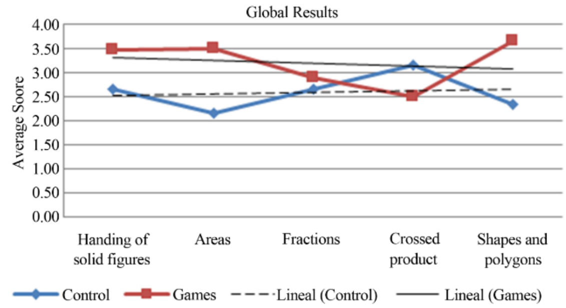


Figure 3. Overall result of the students in different areas of knowledge tested.

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" (**Figure 4**), 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.

On the other hand, the game related to the knowledge area "Crossed Product" (**Figure 5**) 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.

7. Conclusions

This research work is focused on creating a process to successfully develop serious games for learning math and to determine the impact of using serious video games to convey specific Basic-Math competencies in elementary school. The proposed process enabled a team of developers to create a collection of 50 video games, explicitly defining its pedagogical characteristics and its implementation in the finished product. The developed serious video games are based on a competency-based approach oriented to improve appropriation of Math competencies by students.

We conducted a four-week study to determine the impact of using the developed serious video games to ensure that design guaranties the knowledge absorption. This study was performed at a public-rural elementary school participating 29 sixth-grade kids. The results obtained show that serious video games represent suitable resources for teaching Math in elementary schools, since children are very interested in their use. Similarly, we could observe that the use of video 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 these strategies were applied in a continuous way by teachers and along the scholar year.

The results obtained of the application of the questionnaire of the System Usability Scale reflected the importance of ensuring well-designed serious video 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.

There are several aspects to consider as future work. One of them is to improve the current set of serious video games and increase the items of the list, improve and formalize the development process of serious video games bearing in mind the competency-based approach followed in this research.

Another important aspect to do is to conduct a study along the scholar-year period to evaluate the enhanced

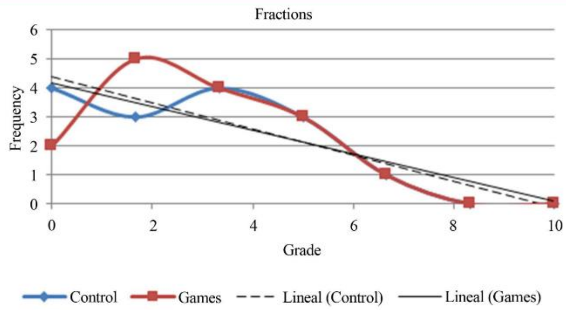


Figure 4. Test results for knowledge area of "Fractions".

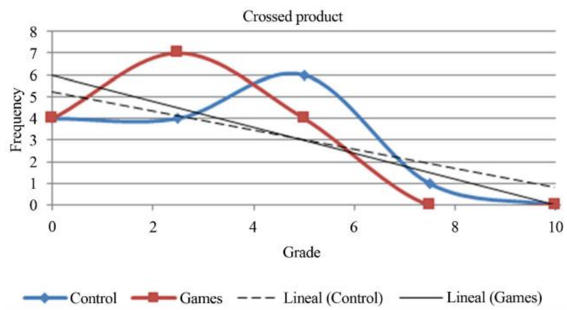


Figure 5. Test results for knowledge area of "Fractions".

set of serious video games. We also are working in identifying and analyzing usability aspects and user interface design in serious video games.

References

Aghabeigi, B., Calvert, T., El-Nasr, M., & Riedewa, M. (2012). Assistive Design and Production in Computer Games: Parametric Systems, Data Mining, Visual Analytics. *2012 IEEE International Games Innovation Conference (IGIC)*, 1-4. http://dx.doi.org/10.1109/IGIC.2012.6329860

Barajas Saavedra, A. (2009). Developing Large Scale Learning Objects for Software Engineering Process Model. *2009 Mexican International Conference on Computer Science*, 203-208. http://dx.doi.org/10.1109/ENC.2009.46

Cai, L., Liu, F., & Liang, Z. (2010). The Research and Application of Education Game Design Model in Teaching Chinese as a Foreign Language. *2010 IEEE International Conference on Progress in Informatics and Computing (PIC), 2,* 1241-1245. http://dx.doi.org/10.1109/PIC.2010.5687919

Chuang, T. Y., You, J. H., & Duo, A. (2010). Digital Game Design Principles for Spatial Ability Enhancement. *2010 IET International Conference on Frontier Computing. Theory, Technologies and Applications,* 122-127.

Cooper, K. M., & Longstreet, C. S. (2012). Towards Model-Driven Game Engineering for Serious Educational Games: Tailored Use Cases for Game Requirements. *2012 17th International Conference on Computer Games (CGAMES)*, 208-212. http://dx.doi.org/10.1109/CGames.2012.6314577

Critelli, M., Schwartz, D. I., & Gold, S. (2012). Serious Social Games: Designing a Business Simulation Game. *2012 IEEE International Games Innovation Conference (IGIC)*, 1-4.

Dondlinger, M. J. (2007). Educational Video Game Design: A Review of the Literature. 4. In J. W. Rice (Ed.), Denton, Texas. http://www.eduquery.com/jaet/

Emam, A., & Mostafa, M. G. (2012). Using Game Level Design as an Applied Method for Software Engineering Education.

2012 17th International Conference on Computer Games (CGAMES), 248-252. http://dx.doi.org/10.1109/CGames.2012.6314583

Hernández Sampieri, R., Fernández Collado, C., & Baptista Lucio, M. D. (2010). Metodología de la Investigación (Quinta ed.). México D.F., D.F., México: McGrawHill.

Huang, Y., Dong, Y., & Liu, D.-H. (2011). Research on Educational Game Design of the Blank Trial Procedure. *2011 International Conference on E-Education, Entertainment and E-Management (ICEEE)*, 249-252. http://dx.doi.org/10.1109/ICeEEM.2011.6137798

Hwang, J.-P., Wu, T.-T., Huang, Y.-M., & Huang, Y.-M. (2012). Development and Evaluation of Peer Feedback in the English Quiz Game Design in Social Network. *2012 IEEE 12th International Conference on Advanced Learning Technologies (ICALT),* 235-239. http://dx.doi.org/10.1109/ICALT.2012.136

Ibrahim, R., & Jaafar, A. (2009). Educational Games (EG) Design Framework: Combination of Game Design, Pedagogy and Content Modeling. *2009 International Conference on Electrical Engineering and Informatics ICEEI '09, 1,* 293-298. http://dx.doi.org/10.1109/ICEEI.2009.5254771

SEP BCS (2009). *Enciclomedia*. Retrieved Diciembre 7, 2009, from Enciclomedia: http://www.sepbcs.gob.mx/tics/enciclomedia.htm

Jovanovic, M., Starcevic, D., Minovic, M., & Stavlja, V. (2011). Motivation and Multimodal Interaction in Model-Driven Educational Game Design. *IEEE Transactions on Systems, Man and Cybernetics, Part A: Systems and Humans, 41,* 817-824. http://dx.doi.org/10.1109/TSMCA.2011.2132711

Madeira, R. N., Silva, B., & Palma, J. (2012). Helping Math Learning, a Moodle-Based Tool to Facilitate the Implementation of Assessment Tests. *2012 IEEE Global Engineering Education Conference (EDUCON),* 1-7. http://dx.doi.org/10.1109/EDUCON.2012.6201176

Mao, C., Yi, Z., JianGang, O., & Guo-tao, H. (2010). Game Design and Development Based on Logical Animation Platform. *2010 International Conference on Computational and Information Sciences (ICCIS),* 573-576. http://dx.doi.org/10.1109/ICCIS.2010.146

Masuch, M., & Rueger, M. (2005). Challenges in Collaborative Game Design Developing Learning Environments for Creating Games. *Third International Conference on Creating, Connecting and Collaborating through Computing*, 67-74. http://dx.doi.org/10.1109/C5.2005.7

McGinnis, T., Bustard, D. W., Black, M., & Charles, D. (2008). Enhancing E-Learning Engagement Using Design Patterns from Computer Games. *2008 First International Conference on Advances in Computer-Human Interaction,* 124-130. http://dx.doi.org/10.1109/ACHI.2008.43

Pankin, J., Roberts, J., & Savio, M. (2012). Blended Learning at MIT. http://web.mit.edu/training/trainers/resources/blended_learning_at_mit.pdf

Secretaría de Educación Pública (2012). Estadísticas ENLACE 2012. From Evaluación Nacional del Logro Académico en Centros Escolares Educación Básica: http://www.enlace.sep.gob.mx/ba/

Umetsu, T., Hirashima, T., & Takeuchi, A. (2002). Fusion Method for Designing Computer-Based Learning Game. *Proceedings of the International Conference on Computers in Education (ICCE'02), 1,* 124-128. http://dx.doi.org/10.1109/CIE.2002.1185882

UNESCO (2009). Non-Formal Education. http://www.unescobkk.org/education/ict/themes/non-formal-education/

Velázquez Amador, C. E., Álvarez Rodríguez, F. J., Garza González, L., Sicilia, M. Á., Mora Tavarez, J. M., & Muñoz Arteaga, J. (2011). Una Experiencias en el Desarrollo Masivo de Objetos de Aprendizaje Empleando Parámetros de Calidad y un Proceso de Gestión Bien Definido. *IEEE - Revista Iberoamericana de Tecnologías del Aprendizaje, 6,* 155-163.

Vidani, A. C., & Chittaro, L. (2009). Using a Task Modeling Formalism in the Design of Serious Games for Emergency Medical Procedures. 2009. VS-GAMES '09. *Conference in Games and Virtual Worlds for Serious Applications,* 95-102. http://dx.doi.org/10.1109/VS-GAMES.2009.24

Zin, N. A., & Yue, W. S. (2009). History educational games design. ICEEI '09. *International Conference on Electrical Engineering and Informatics, 1,* 269-275. http://dx.doi.org/10.1109/ICEEI.2009.5254775

TOJET 2015

Barajas Saavedra, A., Álvarez Rodríguez, F. J., Mendoza González, R., & Oviedo de Luna, A. C. (2015, April 1). Short Serious Games Creation under the Paradigm of Software Process and Competencies as Software Requirements. Case Study: Elementary Math Competencies. (A. İşman, Ed.) *Turkish Online Journal of Educational Technology*, *14*(2), 155-166. Retrieved April 1, 2015, from http://tojet.net/articles/v14i2/14219.pdf

ISSN 2146-7242

Turkish Online Journal of Educational Technology

Volume 14, Issue 2
April 2015

TOJET
01.04.2015

TOJET: The Turkish Online Journal of Educational Technology – April 2015, volume 14 issue 2

Short Serious Games Creation under the Paradigm of Software Process and Competencies as Software Requirements. Case Study: Elementary Math Competencies

Arturo BARAJAS-S.
Computer Science Department, Universidad Autónoma de Aguascalientes, México
abarajas, fjalvar@correo.uaa.mx

Francisco J. ÁLVAREZ-R.
Computer Science Department, Universidad Autónoma de Aguascalientes, México

Ricardo MENDOZA-G.
Computer Science Department, Universidad Autónoma de Aguascalientes, México

Ana C. OVIEDO-DE-LUNA
Computer Science Department, Universidad Autónoma de Aguascalientes, México

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. Added to this, there is no documented technique to ensure correct implementation of a competency in a videogame. This research proposes a Short Serious Game Development Process founded in Software Engineering paradigms and complemented by previous efforts on large scale development of digital learning resources. This paper focuses in a technique called Competency-Based Decomposition that achieves implementing a formal competency into a short serious game, with which the formal learning process will be complemented to improve the way students learn. Through a case study will be demonstrated its utility by implementing the process and the technique in the whole of mathematics competencies for sixth grade of elementary school in Mexico. The result of applying the proposed process for study case is a collection of video games that satisfactorily implements the competencies and its contents, its expected learning and its knowledge areas specified for sixth grade of elementary school in Mexico by the Ministry of Public Education.

INTRODUCTION
Through the experience gained by the different entities of software developers has identified the need to manage a software project for it to be successful.

To manage a project, four desirable characteristics of a software development team are identified (Reyes Delgado, 2005): the creation of a set of defined processes, the quality of products and, efficacy and efficiency efforts. To achieve the proper management of a software project should be performed, in the first instance, the creation of the defined processes of the organization through the use of best practices and formal software engineering methods and matured to match to the actual process of the organization.

Defined software development processes receive much attention in research, but are rarely used in industry for the development of software systems. One of the main reasons is that very little is known about the integration, interpretation, definition and adoption of software process and the precise role of processes in the lifecycle of software remains very diffuse (Plat & J. Toetenel, 1992).

Despite all the stresses generated in research centers, as mentioned in (Plat & J. Toetenel, 1992), globally there is a significant percentage of software development companies that do not use software processes for the development of projects. This problem can also be attributed to the fact that many entrepreneurs and software developers ignore the potential benefits of using software processes and their definitions for both quality of product and the quality of the process, and therefore the project (Chatzoglou, 1997).

When thinking about a large scale resource production you should think in a production that involves the creation of a set of software products through a development process based on standards, methodologies, process guidance and best practices of software engineering (Oktaba & Ibargüengoitia González, 1998). At this point, the Software Engineering provides a mechanism for the development of affordable software systems, and through organizations such as the SEI (Software Engineering Institute) and ISO (International Standardization Organization), have generated international standards for assurance of quality in software development processes and the management of resources and models to measure the maturity of software development processes, such as CMMI (Capability maturity Model Integration), Rational Unified Process (RUP), Software process Improvement and Capability Determination (SPICE), Process Model for Software Industry (MoProSoft, internationally known as ISO 29100), Personal Software Process (PSP) and Team Software Process (TSP). (Sommerville, 2005) (Pressman, 2006) (Kulpa & Johnson, 2003)

But when talking about digital educational resources, "*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.*" (Velázquez Amador et al., 2011)

PROBLEMS OF THE LARGE SCALE DEVELOPMENT

As mentioned in (Barajas Saavedra, Muñoz Arteaga, Álvarez Rodríguez, & García Gaona, 2009) and (Velázquez Amador, et al., 2011), 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 are (Barajas Saavedra, Muñoz Arteaga, Álvarez Rodríguez, & García Gaona, 2009), (Velázquez Amador, et al., 2011), (Vidani & Chittaro, 2009), (Masuch & Rueger, 2005):

1. The difficulty of developing these resources, as they are resources with particular complexity by relying on pedagogical aspects.
2. Lack of well-defined development processes and experiences documented.
3. Lack of standard methodologies to guide and organize game development.
4. Game development in an educational environment have to face some severe restrictions in the development process compared to professional game development. This implies manpower, development time, and budget.
5. Lack of mechanism to guarantee the correct implementation of pedagogical aspects into the games, like for example a "Serious Game Requirements Management" or "Serious Game Quality Assurance".

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 providing solution to the lack of well-defined development processes for large scale production of serious video games, presenting a proposal for a development process with fundamentals in software engineering practices (Barajas Saavedra, Álvarez Rodríguez, Muñoz Arteaga, Santaolaya Delgado, & Collazos Ordóñez, 2014), the results of using this process for the production of various video games (Álvarez Rodríguez, Barajas Saavedra, & Muñoz Arteaga, 2014), and the results of usability testing of video games with students (Barajas Saavedra, Álvarez Rodríguez, Muñoz Arteaga, Santaolaya Delgado, & Collazos Ordóñez, 2014). Solving, in this way, the problems identified within this subject of investigation (Barajas Saavedra, 2009), that is to say: (1) the experts in contents have not been provided with simple and intuitive tools that automate the large scale production; (2) the game producers do not have the rationale that supports the structuring or design of the serious game, or the experience in the competencies in which the videogame applies; (3) for the production of a serious game neither a structured nor based on software engineering process exists that guarantees the consistency and standardization of the production to increase and to guarantee the quality of products.

This paper will present in detail the mechanism to guarantee that the pedagogical aspects (competencies, knowledge areas, contents and expected learning) are correctly implemented into the short serious games through a technique called **Competency-Based Decomposition**.

SHORT SERIOUS GAMES (SSG) DEVELOPMENT PROCESS

A Short Serious Game is a serious game that must have the following elements, regardless of their purpose (training, education, etc.) and its competencies:

1) **Pedagogic aspects**, which include the next elements:
   a) Learning needs of the individual or group of individuals.
   b) The social and cultural context of the individual or group of individuals.
   c) Learning methodology (includes consideration of the learning model and learning styles). This aspect covers the elements "Pedagogic considerations", "Learner specification" and "Context" proposed by

TOJET: The Turkish Online Journal of Educational Technology – April 2015, volume 14 issue 2

deFreitas and Oliver in (de Freitas & Jarvis, 2006) and (de Freitas & Oliver, 2006).

2) **Technical aspects** including:
   a) Considerations for game-play and story (Zyda, 2005).
   b) Level of fidelity, interactivity, immersion, fun, etc.
3) **Integration aspects** that include:
   a) Considerations for game-based learning (Martens, Diener, & Steffen, 2008).
   b) Considerations for inclusion of materials in formal classes.
   c) Considerations of context for the implementation of digital educational resources (de Freitas & Jarvis, 2006).

In **Figure 1** can be seen the SSG Development Process proposed by this research, which has the next features:

1. is founded in the traditional Software Engineering paradigms;
2. provides developers and game designers with a process that will lead them clearly through the production of an educational video game;
3. provides a framework for the integration of experts from different disciplines to develop an short serious game;
4. allows to implement the process in a transparent way because the game is considered as a software product;
5. provides, at the stage of requirements, the ability to develop products that tell teachers how to integrate the game with their classes.

Besides, this process enables SSG Developers to correctly manage SSG Requirements with Software Engineering best practices. Also, this process provides a new technique called Competency-Based Decomposition that transforms a competency and its components (contents, expected learnings, and knowledge areas) into a manageable and measureable software requirement so developers can successfully implement or develop at large scale those requirements (competencies) in the SSG.

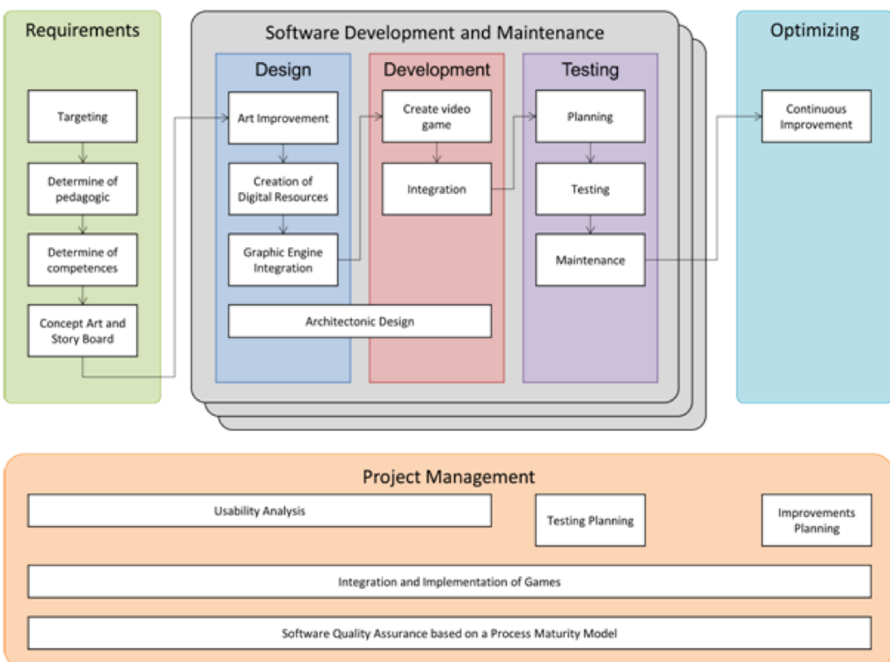


Figure 1. Short Serious Game Development Process.

Then, the fulfilment of the requirements must be ensured in order to guarantee product quality. The compliance with requirements must be seen from the views: pedagogical, educational and ludic.

Next section presents a review of the quality aspects for digital educational resources and serious games, and presents a set of characteristics a short serious game must meet in order to have a good grade of quality.

QUALITY OF THE SHORT SERIOUS GAMES

In the particular case of educational resources studied in this research, (Velázquez Amador, et al., 2011) mentions that the quality of a digital educational resource covers various aspects of software development using an object-oriented paradigm, and issues related to pedagogy. Therefore, is identified the existence of technical and pedagogical aspects, and usability and content components, which are considered as aspects that determine the quality.

1. Technical aspects include reuse and adaptability, as well as those established by the software engineering as utility, reliability, among others.
2. Pedagogical aspects contemplate everything that facilitates the teaching-learning process, as we have examples, assessments, self-assessments, feedback, and a pedagogical objective expressed under any taxonomy, to mention some, Bloom's Taxonomy. The relationship between teaching methods and quality of the resource depends on the learning style of the user, so that John recommends that the modalities of digital resources include auditory, visual and kinesthetic recommendation that videogames cover perfectly.
3. In the content items are those that give information about the complexity of the subject and the level of detail that addresses the content.
4. The aspects of usability of a digital resource concern the presentation of information (fonts, colors, sizes, etc.) and the disposition thereof (symmetrically, asymmetrically, using positive and negative space, etc.). From the point of view of software engineering usability it means ease of use and learning of an object created by humans.

Bearing in mind the quality aspects for serious games, and the analyzed literature on video games and learning objects, a non-exhaustive set of basic features that represent a good starting point to achieve a usable product with a good grade of quality were identified:

1. Short and focused on a single knowledge area to guarantee portability of the video game. In case of a Game Scenario can implement all the knowledge areas of a competency through a set of mini-games or in a single game.
2. Graphical user interface with aesthetic and minimalist design, friendly, and pedagogically evaluated;
3. Cases with formal reasoning;
4. Cases randomly generated to prevent the student memorize the answers to problems;
5. Challenging content and generating competition among students using the game, i.e., cases with different levels of difficulty.

COMPETENCY-BASED DECOMPOSITION: A REQUIREMENTS IDENTIFICATION TECHNIQUE

This "Short Serious Game Requirements Management" was not found in the literature review done, so this paper will present a mechanism to match a formal competency with a non-formal content, identifying the aspects (contents and expected learnings) and factors that should be implemented in the production of the game so that satisfactorily cover the expectation of the competency within a scholar grade and guarantee the quality of the serious game through the fulfilment of the requirements. This process is called **Competency-based decomposition** (**CBD**), which is a proven successful way to accomplish the production of a digital educational resources that was applied for the development of the project "Business-Academia-Government Linkage Model for the Development of IT Capabilities of Human Resources" (Known in Spanish as "Modelo de Vinculación Empresa-Academia-Gobierno para el Desarrollo en Capacidades de Capital Humano en Tecnologías de la Información") (Velázquez Amador, et al., 2011).

Before continuing, the definition (based upon the review of the work in (Mulder, Weigel, & Collins, 2007) and (Díaz Barriga, 2006)) used in this research for competency is as follows: "Competencies are all mental resources of individuals that are used to master tasks, acquire knowledge and achieve a good performance in some specified abilities with a certain skill level."

With this procedure it is proposed to completely cover the contents and learnings that accompany a subject in a syllabus, thus ensuring the appropriation of knowledge and learning outcomes for a particular competency.

TOJET: The Turkish Online Journal of Educational Technology – April 2015, volume 14 issue 2

To perform the CBD is necessary to complete the following steps for each subject to analyze.

1. To identify the standards, goals and graduate profiles (SGGP) of the subject analyzed. This step is very important as the products of the subsequent steps must be aligned to these elements.
2. To identify the contents and expected learning of the syllabus.
3. To group, in knowledge areas, the contents and expected learnings in accordance with SGGP.
4. To organize knowledge areas in accordance with SGGP.
5. To identify competencies from the knowledge areas grouping.
6. To organize competencies and their knowledge areas in accordance with SGGP.

It is very important to stress that every competency and its knowledge areas must be attainable from the point of view of the Software Engineering, since, for example, the Study Program for Sixth Grade Mathematics published by the Ministry of Education, provides a set of math competencies, namely:

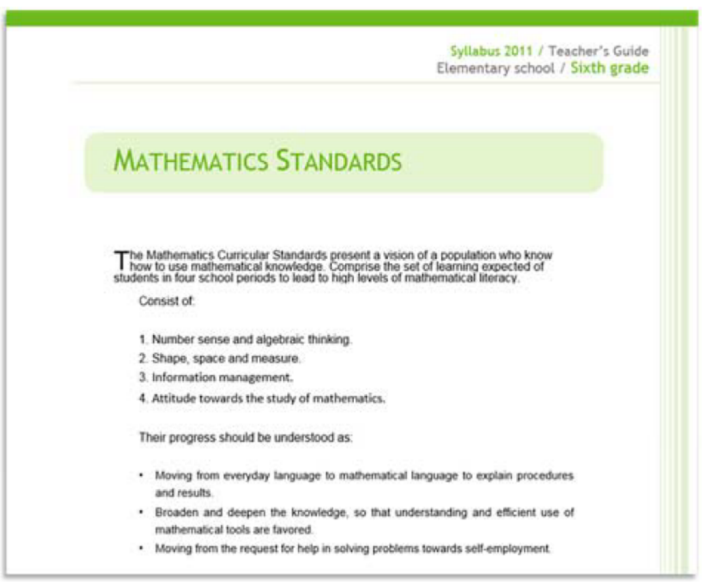
1. Solve problems independently.
2. Communicate mathematical information.
3. Validate procedures and results.
4. Efficiently handling techniques.

Where all of them are "Competencies for life", which, from the point of view of the Software Engineering, are very complex to manage and measure due to their multifactor nature.

In the next paragraphs is shown the application of this CBD process which was applied in this research to identify all the competencies for sixth grade mathematics to carry out the production of video games.

USING CBD TO IDENTIFY SOFTWARE REQUIREMENTS
This section will show the process to apply the CBD step by step using the Sixth grade math of Elementary school in México.

Step 1. To identify the standards, goals and graduate profiles.
In the next figures is shown the standards (**Figure 2**), goals (**Figure 3**) and graduate profiles (**Figure 4**) from the syllabus analyzed.


Syllabus 2011 / Teacher's Guide
Elementary school / Sixth grade

MATHEMATICS STANDARDS

The Mathematics Curricular Standards present a vision of a population who know how to use mathematical knowledge. Comprise the set of learning expected of students in four school periods to lead to high levels of mathematical literacy.

Consist of:

1. Number sense and algebraic thinking.
2. Shape, space and measure.
3. Information management.
4. Attitude towards the study of mathematics.

Their progress should be understood as:

- Moving from everyday language to mathematical language to explain procedures and results.
- Broaden and deepen the knowledge, so that understanding and efficient use of mathematical tools are favored.
- Moving from the request for help in solving problems towards self-employment.

Figure 2. Standards of the study of mathematics for elementary education established in the Syllabus 2011 published by the Mexican Ministry of Education. (Secretaría de Educación Pública, 2011)

TOJET: The Turkish Online Journal of Educational Technology – April 2015, volume 14 issue 2

Syllabus 2011 / Teacher's Guide
Elementary school / Sixth grade

Purpose of the study of mathematics for elementary education

At this stage of their education as a result of the study of mathematics, it is expected that students:

- Know and use the properties of the decimal system to interpret or communicate amounts in different ways. Explain the similarities and differences between the properties of the decimal system and other systems, both positional and non-positional.
- Use mental math, estimation results or write operations with natural numbers and addition and subtraction with fractions and decimal numbers to solve additive and multiplicative problems.
- Know and use the basic properties of angles and different types of lines as well as circle, triangles, quadrilaterals, regular and irregular polygons, prisms, pyramids, cone, cylinder and sphere to make some buildings and calculate measures.
- Use and interpret various codes for orientation in space and locate objects or places.
- Express and interpret measures with different types of unit, to calculate perimeters and areas of triangles, quadrilaterals, regular and irregular polygons.
- Engage in search processes, organization, analysis and interpretation of data in images, text, tables, bar graphs and other carriers to provide information or answer questions for themselves or others. Represent data using tables and bar charts.
- Identify sets of quantities that vary proportionately or irregularly, calculating missing values and percentages, and apply the proportionality constant factor (with natural numbers) in simple cases.

Figure 3. Purposes or goals of the study of mathematics for elementary education established in the Syllabus 2011 published by the Mexican Ministry of Education. (Secretaría de Educación Pública, 2011)

Syllabus 2011 / Teacher's Guide
Elementary school / Sixth grade

Third school term, the end of the sixth grade, between 11 and 12 years old

In this period Curricular Standards correspond to three thematic axis: Number sense and algebraic thinking, Shape, space and measure and Information handling.

After the third period, students know how to communicate and interpret natural numbers, fractional or decimal numbers as well as solve problems using additive and multiplicative conventional algorithms. Calculate perimeters and areas and can describe and build and solid figures. They use reference systems to locate points in the plane or to interpret maps. Also perform processes of collecting, organizing, analyzing and presenting data.

Based on the teaching methodology proposed for study in this course, students are expected to also acquire mathematical knowledge and skills, develop attitudes and values that are essential in the construction of mathematical competence.

1. Numeric sense and algebraic thinking
During this period the axis includes the next topics:

1.1. Numbers and number systems.
1.2. Additive problems.
1.3. Multiplicative problems.

The Curricular Standards for this axis are the next ones. The student:

1.1.1. Reading, writing and comparing natural, fractions and decimal numbers.

1.2.1. Solving additive problems with fractional or decimal numbers, using conventional algorithms.

1.3.1. Solving problems that implies multiply or dividing natural numbers using conventional algorithms.
1.3.2. Solving problems that implies multiplying or dividing fractional or decimal numbers using conventional algorithms.

Figure 4. Graduate profile of mathematics for elementary education established in the Syllabus 2011 published by the Mexican Ministry of Education. (Secretaría de Educación Pública, 2011).

TOJET: The Turkish Online Journal of Educational Technology – April 2015, volume 14 issue 2

Step 2. To identify the contents and expected learning of the syllabus.
In the Syllabus 2011 can be found all the subjects that integrate a scholar grade, and each grade is divided into blocks.

Each block is integrated in its first level by the central axis, in its second level by the topics, and in its third level by the contents. This can be seen in **Figure 5**. As you can see there are only three axes in the figure, this is due to that the fourth axis "Attitude towards the study of mathematics" is implicitly evaluated by the other three axes.

Block I

COMPETENCIES TO ENHANCE: Solve problems independently • Communicate mathematical information • Validate procedures and results • Efficiently handling techniques

EXPECTED LEARNING	CENTRAL AXES		
	NUMBER SENSE AND ALGEBRAIC THINKING	FORM, SPACE AND MEASURE	INFORMATION MANAGEMENT
• Solve problems involving read, write and compare natural, fractional and decimal numbers, specifying the comparison criteria. • Solve additive problems with natural, decimal and fractional numbers involving two or more transformations. • Describes routes and calculates the real distance from one point to another on maps.	NUMBERS AND NUMBER SYSTEMS • Reading, writing and comparing natural, fractions and decimal numbers. Explanation of comparison criteria. ADDITIVE PROBLEMS • Solving additive problems with natural, decimal and fractional numbers, varying the structure of problems. Study or reaffirmation of conventional algorithms. MULTIPLICATIVE PROBLEMS • Solving multiplicative problems with fractional or decimal values through informal procedures.	FIGURES AND BODIES • Identifying the symmetry axes of a figure (polygonal or not polygonal) and mutually symmetrical shapes, through different resources. SPATIAL LOCATION • Choosing a code to communicate the location of objects in a grid. Establishing of common codes for locating objects. MEASURE • Calculating real distances though rough measurement from one point to another or a map.	PROPORTIONALITY AND FUNCTIONS • Calculation of percentage amounts by various methods (application of correspondence "per 100, n", implementing a common or decimal fraction, using 10% as base). ANALYSIS AND DATA REPRESENTATION • Reading data in tables and circle graphs to answer diverse questioning.

Figure 5. Extract of the syllabus for sixth grade math of elementary school. This figure shows the competencies to enhance, the expected learning, the central axes, the topics and the contents for the Block I. The syllabus is integrated by five blocks. Note that the fourth axis is not shown due to is evaluated implicitly in the other three. (Secretaría de Educación Pública, 2011)

Step 3. To group, in knowledge areas, the contents and expected learnings.
After identifying the contents and expected learning, the grouping resulted in the next knowledge areas:

1. Areas
2. Cartesian plane
3. Combinations
4. Cross product
5. Decimal system
6. Fractions
7. Graphic representation of results
8. Handling of solid figures
9. Lengths
10. Odds
11. Operations
12. Patterns
13. Percentages
14. Perimeters
15. Shapes and polygons
16. Time
17. Values of unity
18. Volume
19. Weight/Mass

Step 4. To organize knowledge areas.
The process of organizing the knowledge areas resulted in the creation of "groups" that later will be competencies.

1. Competency 1
   a. Operations
   b. Decimal system
   c. Fractions
2. Competency 2
   a. Shapes and polygons
   b. Handling of solid figures
   c. Cartesian plane
3. Competency 3
   a. Lengths
   b. Volume
   c. Weight/Mass
   d. Perimeters
   e. Areas
   f. Time
4. Competency 4

TOJET: The Turkish Online Journal of Educational Technology – April 2015, volume 14 issue 2

- a. Graphic representation of results

5. Competency 5
   - a. Patterns
   - b. Values of unity

- c. Cross product
- d. Percentages

6. Competency 9
   - a. Combinations
   - b. Odds

Step 5. To identify competencies from the knowledge areas.
The identified competencies are:

1. The numbers, relationships and operations
2. Geometry
3. Measures and Conversions
4. Information processing
5. Processes of change
6. The prediction and chance

Step 6. To organize competencies and their knowledge areas.
The Competency-Based Decomposition process is graphically shown in the following figure (see **Figure 6**). The final result of this process, is shown in **Figure 7**.

Figure 6. This approach allows to match a formal competency with a non-formal content, identifying the aspects and factors that should be implemented in the production of the game so that satisfactorily cover the expectation of the competency within a scholar grade.

TOJET: The Turkish Online Journal of Educational Technology – April 2015, volume 14 issue 2

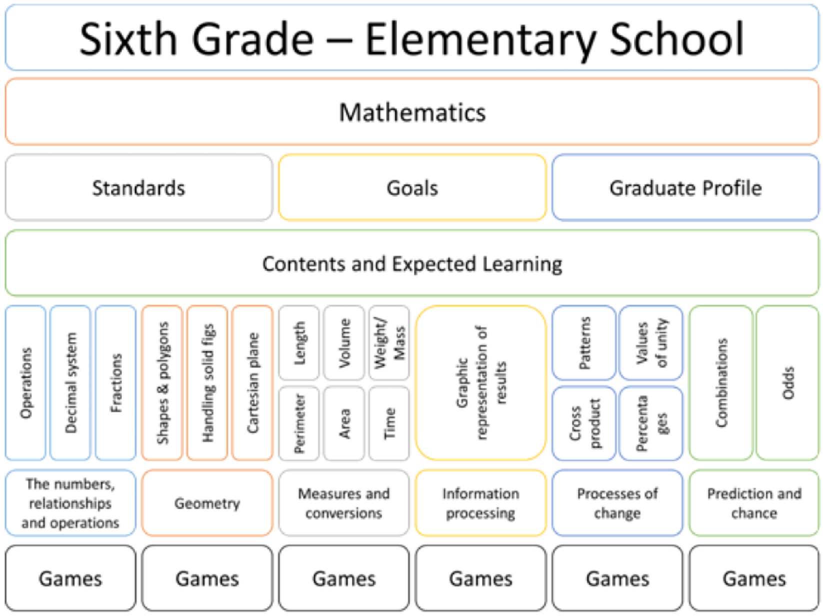


Figure 7. Result of the Competency-Based Decomposition applied to the subject Mathematics of sixth grade of elementary school.

CASE STUDY: SIXTH GRADE VIDEO GAMES

As a proof of concept of our approach the research conducted a case study using as scenario "the development of educational games to cover all the official competencies for sixth grade for elementary school in Mexico". Competencies shown in **Figure 7** lead us to create a collection of fifty educational videogames oriented to increase learning encouraging appropriation of specific math-competencies. A summary of this list is presented in **Table 1**.

Table 1. Extract of developed video games.

Video games	***Knowledge areas***	***Language***
pokeMath	Operations	JavaME
MathChallenge	Operations	.NET
	Weight/mass	.NET
DS3A	Operations	JavaME
SpaceMath	Operations	Flash
Fracciones	Fractions	JavaME
GeoBodies	Shapes and polygons	JavaME
CubeLand	Handling of solid figures	OpenGL
Submarino	Cartesian plane	JavaME
GolfMeter	Lengths	JavaME
miHuerta	Volume	JavaME
Áreas	Areas	JavaME
Ubicación	Values of unity	JavaME
Regla de Tres	Cross product	JavaME
Kaxan	Percentages	JavaME
WWE	Odds	JavaME
Marcianos	Shapes and polygons	Android
Time Rider	Time	JavaME/Android
Time Champ	Time	JavaME/Android
Jinete Solitario	Lengths	JavaME/Android

TOJET: The Turkish Online Journal of Educational Technology – April 2015, volume 14 issue 2

Perimeters	Perimeters	JavaME/Android
Softy	Combinations	JavaME/Android
MathFractions	Fractions	JavaME/Android

TESTING THE VIDEO 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" 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(Hernández Sampieri, Fernández Collado, & Baptista Lucio, 2010): (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.

RESULTS OF KNOWLEDGE EVALUATION

The team applied linear regression to the results obtained during testing for each knowledge area. The information allow to determine trends in student's scores before and after use short serious games. The overall findings are graphically depicted in **Figure 8** where diamonds-line displays the results obtained during initial examination. Squares-line displays the results of the evaluation performed after short serious games use.

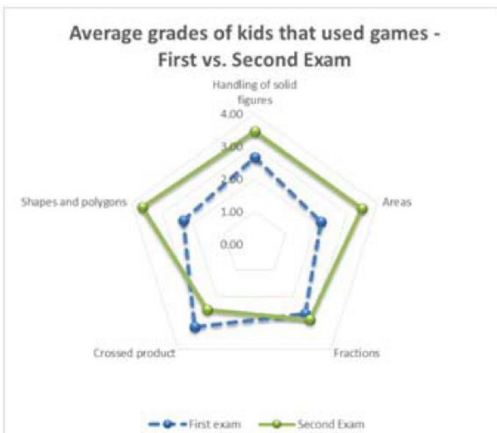


Figure 8. Overall result of the students in different areas of knowledge tested.

As the reader can see, there are improvements in four knowledge areas, this is due to the students achieved a higher level of adoption of the competencies implemented in the short serious games they used.

The "Crossed Product" game, which shows a decrease in the adoption of the competency, was developed with a question bank instead of randomly-generated problems, so the students memorized suck question bank and did not achieve the intended adoption of the competency.

DISCUSSION

The correct implementation of the competencies and the characteristics of the short serious games is extremely important because this is the only way to guarantee that the students of users will achieve a higher level of adoption of the competencies implemented in the games.

TOJET: The Turkish Online Journal of Educational Technology – April 2015, volume 14 issue 2

As the reader can see, the "Crossed Product" game did not achieve its purpose: transfer the competency into the students due to a deviation in its development.

CONCLUSIONS AND FUTURES WORK

This research proposes a short serious game development process that includes an explicit requirements management which allows the identification and modeling of the software requiremets from a set of implicit educative competencies of an official syllabus.

This process makes available to research or (independent) development groups, universities and companies a clear guide to the development of a short serious game. It also eases the implementation of the process itself because it has a documental support that guides the team through the development of the products. This process also allows managing the product quality through checkpoints in the provided documentation, achieving in this way develop a high quality product with a high level of fulfilment of the competencies (requirements).

The CBD process allows clearly identify the competencies to implement in the short serious games, since in many cases this aspect is not taken into account during the development process (if a development process exists). The CBD process takes as inputs common elements in the syllabus and turns them into short serious game programmable and measurable competencies (requirements).

Once identified the competencies, the short serious game development process is capable of building software products, from those requirements (which include learning activities and learning contents), with a high quality level and meeting the correct implementation of the competencies.

This research has created and tested (with real world students) a big set of short serious games, achieving an improvement in the competency adoption due to the correct implementation of requirements (competencies, learning activities and learning contents) into the games.

The short serious game process is being translated into SPEM and ISPW-6 with a variability model and will be published online once it is finished. In this way it will be turned into a Serious Game Development Framework that will be accessible to anyone interested in developing short serious games.

REFERENCES

Álvarez Rodríguez, F., Barajas Saavedra, A., & Muñoz Arteaga, J. (2014, May 16). Serious Game Design Process, Study Case: Sixth Grade Math. Creative Education, 05(09), 647-656. doi:doi:10.4236/ce.2014.59077

Barajas Saavedra, A., Álvarez Rodríguez, F., Muñoz Arteaga, J., Santaolaya Delgado, R., & Collazos Ordóñez, C. (2014). A serious games development process using competency approach. Case Study: Elementary School Math. In A. I.-O. (AIPO) (Ed.), XV International Conference on Human Computer Interaction (pp. 572-579). Puerto de la Cruz, Tenerife, España: AIPO. Retrieved September 30, 2014

Barajas Saavedra, A., Muñoz Arteaga, J., Álvarez Rodríguez, F., & García Gaona, M. (2009). Developing Large Scale Learning Objects for Software Engineering Process Model. 2009 Mexican International Conference on Computer Science, 203-208. doi:DOI 10.1109/ENC.2009.46

Chatzoglou, P. D. (1997). Use of Methodologies: an Empirical Analysis of their Impact on the Economics of the Development Process. European Journal of Information Systems, 6, 256-270.

de Freitas, S., & Jarvis, S. (2006). A framework for developing serious games to meet learner needs. I/ITSEC '06: Proceedings of the International Conference on Interservice/Industry Training, Simulation and Education.

de Freitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? Computers & education, 46(3), 249-264.

Díaz Barriga, Á. (2006). El enfoque de compentecias en la educación. ¿Una alternativa o un disfraz de cambio? Revista Perfiles Educativos(111), 7-36. Retrieved September 2013, from http://www.iisue.unam.mx/perfiles/perfiles_articulo.php?clave=2006-111-7-36&url=2006/n111a2006/mx.peredu.2006.n111.p7-36.pdf

Kulpa, M. K., & Johnson, K. A. (2003). Interpreting the CMMI: A Process Improvement Approach. Boca Raton, Florida, Estados Unidos: Auerbach Publications CRC Press LLC.

Martens, A., Diener, H., & Steffen, M. (2008). Game-based Learning with Computers - Learning, Simulations, and Games. Transactions on Edutainment, 172-190.

Masuch, M., & Rueger, M. (2005, January 28-29). Challenges in collaborative game design developing learning environments for creating games. Third International Conference on Creating, Connecting and

Collaborating through Computing, 67-74. doi:10.1109/C5.2005.7
Mulder, M., Weigel, T., & Collins, K. (2007, March). The concept of competence in the development of vocational education and training in selected EU member states: a critical analysis. Journal of Vocational Education & Training, 59(1), 67-88. doi:10.1080/13636820601145630
Oktaba, H., & Ibargüengoitia González, G. (1998). Software Process Modeled with Objects: Static View. Computación y Sistemas, 1(4).
Plat, N. v., & J. Toetenel, H. (Septiembre de 1992). Application and benefits of formal methods in software development. Software Engineering Journal, 7(5), 335-346.
Pressman, R. S. (2006). Software engineering: a practitioner's approach (Sexta ed.). McGraw-Hill.
Reyes Delgado, P. Y. (2005). Tesis de Maestría Diseño de un Instrumento de Auto-evaluación para Diagnosticar el Estatus de las Organizaciones en México con Respecto al Modelo ProSoft: Proceso de Gestión de Procesos de la Categoría de Gestión. México.
Secretaría de Educación Pública. (2011). Programas de estudio 2011 - Guía para el maestro - Educación básica - Primaria - Sexto grado (First Electronic Edition ed.). Cuauhtémoc, México, D.F., México: Gobierno Federal SEP. Retrieved September 15, 2014, from http://www.curriculobasica.sep.gob.mx/images/PDF/prog_primaria/PRIM_6to2011.pdf
Sommerville, I. (2005). Software enginnering (Septima ed.). Pearson Education.
Velázquez Amador, C. E., Álvarez Rodríguez, F. J., Garza González, L., Sicilia, M. Á., Mora Tavarez, J. M., & Muñoz Arteaga, J. (2011, Noviembre). Una Experiencias en el Desarrollo Masivo de Objetos de Aprendizaje Empleando Parámetros de Calidad y un Proceso de Gestión Bien Definido. IEEE - Revista Iberoamericana de Tecnologías del Aprendizaje, 6(4), 155-163.
Vidani, A. C., & Chittaro, L. (2009, March 23-24). Using a Task Modeling Formalism in the Design of Serious Games for Emergency Medical Procedures. 2009. VS-GAMES '09. Conference in Games and Virtual Worlds for Serious Applications, 95-102. doi:10.1109/VS-GAMES.2009.24
Zyda, M. (2005, September). From visual simulation to virtual reality to games. Computer, 38(9), 25-32. doi:10.1109/MC.2005.297

REDIE 2016

Barajas Saavedra, A., Álvarez Rodríguez, F. J., Muñoz Arteaga, J., & Oviedo de Luna, A. (2016). Process for Modeling Competencies for Developing Serious Games. Revista Electrónica de Investigación Educativa.

redie
Revista Electrónica de Investigación Educativa
http://redie.uabc.mx | ISSN: 1607-4041

M. en C. Arturo Barajas Saavedra
PRESENTE.

Por este medio, le notificamos que hemos tomado una decisión sobre su presentación en la *Revista Electrónica de Investigación Educativa*, "PROCESS FOR MODELING COMPETENCIES FOR DEVELOPING SERIOUS GAMES".

Nuestra decisión es: **Artículo aceptado (con cambios mínimos)**

Nuestras felicitaciones y sinceros agradecimientos.

ATENTAMENTE

Ensenada, B. C., 19 de agosto de 2015

DRA. EDNA LUNA SERRANO
EDITORA CIENTÍFICA

La Revista Electrónica de Investigación Educativa es una publicación editada por el Instituto de Investigación y Desarrollo Educativo de la Universidad Autónoma de Baja California.

PROCESS FOR MODELING COMPETENCIES FOR DEVELOPING SERIOUS GAMES.

Arturo Barajas Saavedra

abarajas@correo.uaa.mx

Francisco Javier Álvarez Rodríguez

fjalvar@correo.uaa.mx

Jaime Muñoz Arteaga

jmauaa@gmail.com

Ana Cecilia Oviedo de Luna

Oviedo.ana@gmail.com

Universidad Autónoma de Aguascalientes

Av. Universidad 940, Colonia Ciudad Universitaria

Aguascalientes, Ags, México.

Abstract

Nowadays, serious games play an outstanding role in the adoption of competencies since they provide immersion, fun, motivation and a high level of engagement among user. This research proposes a process called Competency-based Decomposition that allows to identify and model the competencies of a syllabus for the development of serious games to ensure the correct implementation of pedagogical aspects. The correct implementation of pedagogical aspects is extremely important to ensure a high level of adoption of the competencies by the users of the games. The focus on this research is to guarantee the correct implementation of pedagogical aspects (learning activities and contents, expected learning, etc.) in the production of serious games. This article presents the theoretical foundations of the research and details of the Competency-Based Decomposition process, including the application process and its application in the subject of

Mathematics for sixth grade of elementary school. The results obtained in this research are the successful identification of six competencies and 19 areas of knowledge, and the production of 50 short serious games based on the identified competencies and areas of knowledge. These games have been tested on students, resulting in an improvement in learning.

Keywords: Educative technology, short serious games, competencies

Resumen

Hoy en día, los juegos serios poseen un rol sobresaliente en la adopción de competencias ya que proveen inmersión, diversión, motivación y un alto grado de compromiso en los usuarios. Esta investigación propone un proceso denominado Descomposición basada en Competencias que permite identificar y modelar las competencias de un programa de estudios para asegurar la correcta implementación de los aspectos pedagógicos en el desarrollo de juegos serios. La correcta implementación de los aspectos pedagógicos es extremadamente importante para asegurar la apropiación de las competencias por los usuarios de los juegos. El enfoque de esta investigación es el de garantizar la correcta implementación de los aspectos pedagógicos (actividades de aprendizaje y contenidos, aprendizajes esperados, etc.) en la producción de juegos serios. Este artículo presenta los fundamentos teóricos de la investigación, el detalle del proceso de la Descomposición Basada en Competencias, su procedimiento de aplicación y su aplicación en la materia de Matemáticas para sexto grado de primaria. Los resultados obtenidos en esta investigación son la exitosa identificación de seis competencias y 19 áreas de conocimiento y la producción de 50 videojuegos serios cortos con base en las competencias y áreas de conocimiento identificadas. Dichos videojuegos han sido probados en estudiantes, obteniendo como resultado una mejora en el aprendizaje.

Palabras clave: Tecnología educativa, juegos serios cortos, competencias

INTRODUCTION

General basic education is oriented to contribute in achieving better levels of intelligence, feelings and personality in students. Aimed to complement these efforts, several strategies has been implemented to incorporate technology (equipment, educational software, Web 2.0 tools, among others) within both, public and private schools from elementary to higher education. (INEGI, 2009)

However, and despite the efforts made by teachers in elementary school, it is clear – based on the ENLACE (by its acronym in Spanish, National Assessment of Academic Achievement in Schools) assessment results – that educational level of students is barely improving in elementary school students, considering basic topics on Math, Science, and Spanish (Secretaría de Educación Pública, 2013).

There is a need to integrate more efficient mechanisms in non-formal environment for students and increase learning opportunities beyond the classroom. Mechanisms with great potential are video games.

One of the aspects to solve in order to achieve a better way to learn is to produce educative contents. In recent years, this problem has become a topic of discussion among the international research community (Ibrahim & Jaafar, 2009), and it has been proposed the use of serious games in order to reduce the gap. Researchers have published multiple models, frameworks, including development processes.

However, result of a literature review in this research is clear that none has explicitly clarified how to implement the pedagogical aspects in educational digital resources, neither have clarify how to manage the development of these resources in order to finish projects efficiently and with a quality production. Quality is given in terms of user satisfaction and full learning needs implementation (learning contents, learning activities, expected learning, pedagogical aspects and competencies). Efficiency is given in terms of rework.

PROBLEM OUTLINE

During project "Business-Academia-Government Linkage Model for the Development of IT Capabilities of Human Resources" (known in Spanish as "Modelo de Vinculación Empresa-Academia-Gobierno para el Desarrollo en Capacidades de Capital Humano en Tecnologías de la Información") implementation (Velázquez Amador, et al., 2011), the need to convert a set of competencies (and areas of knowledge) in learning needs was identified. This, in order to be able to produce educative digital resources. Back then, a first approach of the Competency-based Decomposition was carried out by this research team, resulting in the production of about one thousand learning objects.

So, from the experience gained during the Product Quality Management in the project, it has been identified that those educative digital resources produced with processes ad-hoc do not guarantee the efficient completion of the development neither the quality production of the resources nor that the learning needs are implemented entirely to facilitate the adoption of competencies, because that development depends on the degree of experience of developers in different areas of knowledge (pedagogy, digital content design, game design, process management, etc.) (Barajas Saavedra A. , Álvarez Rodríguez, Muñoz Arteaga, Santaolaya Delgado, & Collazos Ordóñez, 2014) (Álvarez Rodríguez, Barajas Saavedra, & Muñoz Arteaga, 2014).

This paper presents the improved and formalized process in order to achieve such transformation addressing the problems related to the correct implementation of the leaning needs (learning contents, learning activities, expected learning, pedagogical aspects and competencies) through the use of the process called **Competency-based Decomposition** (CBD), which, as said in the previous paragraphs, is a proven successful way to accomplish the production of a digital educational resources, in this case, short serious games.

Next sections present the basic concepts and definitions used in this research to design the CBD process.

REVIEW OF LITERATURE

This section presents a review of the literature of competencies related to serious games, in order to establish theoretical concepts that support this research. Besides, the definitions and concepts establishes the foundation for the development of short serious games.

Competencies

In terms of approach, there have been three main traditions in competence research since the middle of the last century: (Mulder, Weigel, & Collins, 2007)

1. The behaviorist approach stresses the importance of observing successful and effective job performers and determining what differentiates them from their less successful counterparts.
2. The generic approach is aimed more at identifying the common abilities that explain variations in performance.

3. The definition of competence in the cognitive approach includes all of the mental resources of individuals that are used to master tasks, acquire knowledge and achieve a good performance.

Any definition of the term "competency" should include a combination of three elements: a) information, b) the development of a skill and, c) put into action in a unique situation. The best way to observe a competency is in the combination of these three aspects, which means that all competency requires mastery of specific information, while calls for the development of a skill or rather a set of skills derived from processes for information, but in a problem situation, that is, in a real unique situation, where competition can be generated. (Díaz Barriga, 2006)

The definition of “competencies” used for this research, created from the previous definitions and concepts published by Diaz Barriga (Díaz Barriga, 2006) and Mulder et al. (Mulder, Weigel, & Collins, 2007), is as follows: “Competencies are all mental resources of individuals that are used to master tasks, acquire knowledge and achieve a good performance in some specified abilities with a certain skill level.”

Short Serious Games (SSG)

A Short Serious Game is a videogame that must have the following elements, regardless of their purpose (training, education, etc.) and its competencies:

1) **Pedagogic aspects**, which include the next elements:
   a) Learning needs of the individual or group of individuals.
   b) The social and cultural context of the individual or group of individuals.
   c) 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 in (de Freitas & Jarvis, 2006) and (de Freitas & Oliver, 2006).

2) **Technical aspects** including:
   a) Considerations for game-play and story (Zyda, 2005).
   b) Level of fidelity, interactivity, immersion, fun, etc.
3) **Integration aspects** that include:
   a) Considerations for game-based learning (Martens, Diener, & Steffen, 2008).
   b) Considerations for inclusion of materials in formal classes.
   c) Considerations of context for the implementation of digital educational resources (de Freitas & Jarvis, 2006).

Bearing in mind the analyzed literature on games and learning objects, a non-exhaustive set of basic features that represent a good starting point to achieve a usable product with a good grade of quality were identified:

1. Short and focused on a single area of knowledge;
2. Graphical user interface pedagogically evaluated;
3. Cases with formal reasoning;
4. Cases randomly generated;
5. Challenging content and generating competition among students using the game.

Related Work

This section shows the main ideas of the reviewed related articles to this research.

The article by Tejada Fernández (Tejada Fernández, 2005) emphasizes that education should appoint a special economic resource for the production of learning materials, and stresses the importance of using digital learning resources. It also establishes the means and strategies for assessment of learning by competencies.

COMPETENCY-BASED DECOMPOSITION: A PROCESS FOR MODELING COMPETENCIES

The CBD process is a mechanism to match a formal competency with a non-formal content, identifying the aspects and factors that should be implemented in the production of the game so that satisfactorily cover the expectation of the competencies within a scholar grade and guarantee the quality of the serious game through the fulfilment of the learning needs. . With this procedure it is proposed to completely cover the contents and learnings that accompany a subject in a syllabus, thus ensuring the appropriation of knowledge and learning outcomes for a particular competency.

To perform the CBD is necessary to complete the following steps for each subject to analyze (**Figure 1**).

1. To identify the standards, goals and graduate profiles (SGGP) of the subject analyzed. This step is very important as the products of the subsequent steps must be aligned to these elements.
2. To identify the contents and expected learning of the syllabus.
3. To group, in areas of knowledge, the contents and expected learnings in accordance with SGGP.
4. To organize knowledge areas in accordance with SGGP.
5. To identify competencies from the knowledge areas grouping.
6. To organize competencies and their knowledge areas in accordance with SGGP.

Dávila Balcarce et al. (Dávila Balcarce & Velásquez Contreras, 2007) show the positive results of an evaluation as a methodological resource for education of two collaborative games. Also is stressed that for the improvement of the tested ludic applications for learning is necessary to create better educative contents.

Garrido Miranda (Garrido Miranda, 2013) states that video games are a systems environment that shows one way to configure a set of features that are pedagogically desirable and expected.

Almiron et al. (Almiron & Porro, 2014) established that the use of ICT in education is a good learning strategy. Also the authors establish that students have changed and they are not subjects for the actual teaching system.

The literature review reveals that there is a need for the production of digital educational resources, such is the case, that a number of assessment tools are proposed in different educational levels, and even the different actors are involved in the teaching-learning process (teachers, professionals are evaluated, students, and even parents). However, no paper proposes how to properly develop the resources, assuming that the production of educational (digital) resources is a competence completely acquired by teachers.

This paper therefore proposes a mechanism which ensures that this competence is acquired by those who design or produce educational (digital) resources, and in this way ensure that the student receives and adopts competencies and learning outcomes.

The next sections present the CBD process, its application, and an example of use including the results of applying it to a real subject.

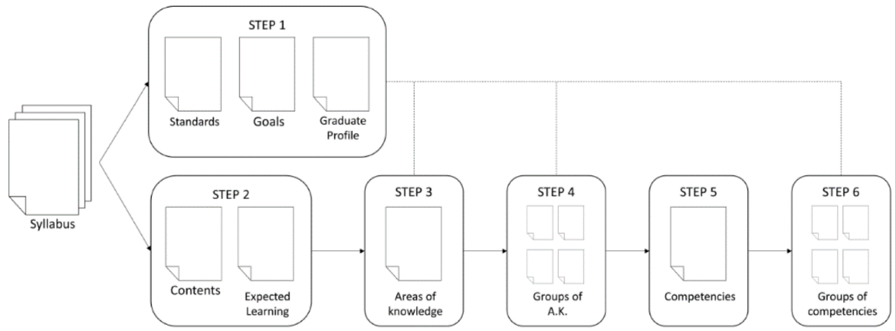


Figure 1. Graphic view of the Competency-based Decomposition process.

It is very important to stress that every competency and its knowledge areas must be attainable from the point of view of the Software engineering, since, for example, the Study Program for Sixth Grade Mathematics published by the Ministry of Education, provides a set of math competencies, namely:

1. Solve problems independently.
2. Communicate mathematical information.
3. Validate procedures and results.
4. Efficiently handling techniques.

Where all of them are "Competencies for life", which, from the point of view of the Software Engineering, are very complex to manage and measure due to their multifactor nature.

In the next paragraphs is shown the application of this CBD process which was applied in this research to identify all the competencies for sixth grade mathematics to carry out the production of games.

METHODOLOGY

This section will show the process to apply the CBD step by step using the Sixth grade math syllabus of Elementary school in México.

Step 1

In the next figures is shown the standards (**Figure 2**), goals (**Figure 3**) and graduate profiles (**Figure 4**) from the syllabus analyzed.

Step 2

In the Syllabus 2011 can be found all the subjects that integrate a scholar grade, and each grade is divided into blocks.

Each block is integrated in its first level by the central axis, in its second level by the topics, and in its third level by the contents. This can be seen in **Figure 5**. As you can see there are only three axes in the figure, this is due to that the fourth axis “Attitude towards the study of mathematics” is implicitly evaluated by the other three axes.

Step 3

In order to perform this step, you must review in detail the contents and expected learning, for example, as you can observe in **Figure 5** in “Number sense and algebraic thinking” axis there are two contents: 1) Additive problems and 2) Multiplicative problems; so they can be grouped into an area of knowledge called “Operations”.

MATHEMATICS STANDARDS

The Mathematics Curricular Standards present a vision of a population who know how to use mathematical knowledge. Comprise the set of learning expected of students in four school periods to lead to high levels of mathematical literacy.

Consist of:

1. Number sense and algebraic thinking.
2. Shape, space and measure.
3. Information management.
4. Attitude towards the study of mathematics.

Their progress should be understood as:

- Moving from everyday language to mathematical language to explain procedures and results.
- Broaden and deepen the knowledge, so that understanding and efficient use of mathematical tools are favored.
- Moving from the request for help in solving problems towards self-employment.

Figure 2. Standards of the study of mathematics for elementary education established in the Syllabus 2011 published by the Mexican Ministry of Education. (Secretaría de Educación Pública, 2011)

Purpose of the study of mathematics for elementary education

At this stage of their education as a result of the study of mathematics, it is expected that students:

- Know and use the properties of the decimal system to interpret or communicate amounts in different ways. Explain the similarities and differences between the properties of the decimal system and other systems, both positional and non-positional.
- Use mental math, estimation results or write operations with natural numbers and addition and subtraction with fractions and decimal numbers to solve additive and multiplicative problems.
- Know and use the basic properties of angles and different types of lines as well as circle, triangles, quadrilaterals, regular and irregular polygons, prisms, pyramids, cone, cylinder and sphere to make some buildings and calculate measures.
- Use and interpret various codes for orientation in space and locate objects or places.
- Express and interpret measures with different types of unit, to calculate perimeters and areas of triangles, quadrilaterals, regular and irregular polygons.
- Engage in search processes, organization, analysis and interpretation of data in images, text, tables, bar graphs and other carriers to provide information or answer questions for themselves or others. Represent data using tables and bar charts.
- Identify sets of quantities that vary proportionately or irregularly, calculating missing values and percentages, and apply the proportionality constant factor (with natural numbers) in simple cases.

Figure 3. The purposes or goals of the study of mathematics for elementary education established in the Syllabus 2011 published by the Mexican Ministry of Education. (Secretaría de Educación Pública, 2011)

Third school term, the end of the sixth grade, between 11 and 12 years old

In this period Curricular Standards correspond to three thematic axis: Number sense and algebraic thinking, Shape, space and measure and Information handling.

After the third period, students know how to communicate and interpret natural numbers, fractional or decimal numbers as well as solve problems using additive and multiplicative conventional algorithms. Calculate perimeters and areas and can describe and build and solid figures. They use reference systems to locate points in the plane or to interpret maps. Also perform processes of collecting, organizing, analyzing and presenting data.

Based on the teaching methodology proposed for study in this course, students are expected to also acquire mathematical knowledge and skills, develop attitudes and values that are essential in the construction of mathematical competence.

1. Numeric sense and algebraic thinking
During this period the axis includes the next topics:

1. Numbers and number systems.
2. Additive problems.
3. Multiplicative problems.

The Curricular Standards for this axis are the next ones. The student:

1.1.1. Reading, writing and comparing natural, fractions and decimal numbers.
1.2.1. Solving additive problems with fractional or decimal numbers, using conventional algorithms.
1.3.1. Solving problems that implies multiply or dividing natural numbers using conventional algorithms.
1.3.2. Solving problems that implies multiplying or dividing fractional or decimal numbers using conventional algorithms.

Figure 4. Graduate profile of mathematics for elementary education established in the Syllabus 2011 published by the Mexican Ministry of Education. (Secretaría de Educación Pública, 2011).

COMPETENCIES TO ENHANCE: Solve problems independently • Communicate mathematical information • Validate procedures and results • Efficiently handling techniques			
EXPECTED LEARNING	CENTRAL AXES		
	NUMBER SENSE AND ALGEBRAIC THINKING	FORM, SPACE AND MEASURE	INFORMATION MANAGEMENT
• Solve problems involving read, write and compare natural, fractional and decimal numbers, specifying the comparison criteria. • Solve additive problems with natural, decimal and fractional numbers involving two or more transformations. • Describes routes and calculates the real distance from one point to another on maps.	NUMBERS AND NUMBER SYSTEMS • Reading, writing and comparing natural, fractions and decimal numbers. Explanation of comparison criteria. ADDITIVE PROBLEMS • Solving additive problems with natural, decimal and fractional numbers, varying the structure of problems. Study or reaffirmation of conventional algorithms. MULTIPLICATIVE PROBLEMS • Solving multiplicative problems with fractional or decimal values through informal procedures.	FIGURES AND BODIES • Identifying the symmetry axes of a figure (polygonal or not polygonal) and mutually symmetrical shapes, through different resources. SPATIAL LOCATION • Choosing a code to communicate the location of objects in a grid. Establishing of common codes for locating objects. MEASURE • Calculating real distances though rough measurement from one point to another or a map.	PROPORTIONALITY AND FUNCTIONS • Calculation of percentage amounts by various methods (application of correspondence "per 100, n", implementing a common or decimal fraction, using 10% as base). ANALYSIS AND DATA REPRESENTATION • Reading data in tables and circle graphs to answer diverse questioning.

Figure 5. Extract of the syllabus for sixth grade math of elementary school. This figure shows the competencies to enhance, the expected learning, the central axes, the topics and the contents for the Block I. The syllabus is integrated by five blocks. Note that the fourth axis is not shown due to is evaluated implicitly in the other three. (Secretaría de Educación Pública, 2011)

After identifying the contents and expected learning, the grouping resulted in the next knowledge areas:

1. Areas
2. Cartesian plane
3. Combinations
4. Cross product
5. Decimal system
6. Fractions
7. Graphic representation of results

8. Handling of solid figures
9. Lengths
10. Odds
11. Operations
12. Patterns
13. Percentages
14. Perimeters
15. Shapes and polygons
16. Time
17. Values of unity
18. Volume
19. Weight/Mass

Step 4
As in the previous step, you must review the areas of knowledge, for example, areas of knowledge 5, 6 and 11, accordingly to the SGGP, can be grouped in one competency. The process of organizing the knowledge areas resulted in the creation of "groups" that later will be competencies.

1. Competency 1
    a. Operations
    b. Decimal system
    c. Fractions
2. Competency 2
    a. Shapes and polygons
    b. Handling of solid figures
    c. Cartesian plane
3. Competency 3
    a. Lengths
    b. Volume
    c. Weight/Mass
    d. Perimeters
    e. Areas
    f. Time
4. Competency 4
    a. Graphic representation of results
5. Competency 5
    a. Patterns
    b. Values of unity
    c. Cross product
    d. Percentages
6. Competency 9
    a. Combinations
    b. Odds

Step 5

You must name the previous groups with competencies names accordingly to the SGGP.

The identified competencies are:

1. The numbers, relationships and operations
2. Geometry
3. Measures and Conversions
4. Information processing
5. Processes of change
6. The prediction and chance

Step 6

The last step is to create a map of the competencies and their areas of knowledge, you can create this map using a graphic or a table.

In **Figure 6** is shown a graphic template for displaying the results of the Competency-Based Decomposition process.

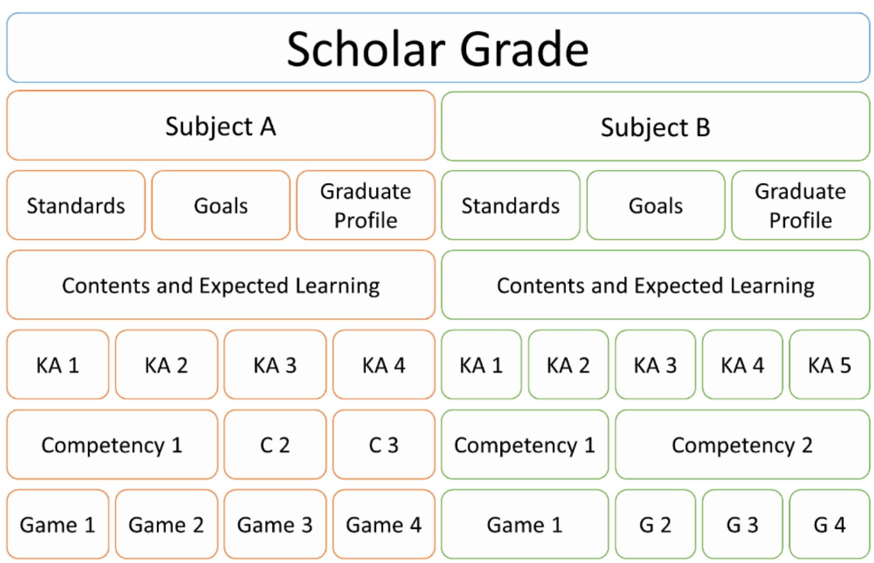


Figure 6. This approach allows to match a formal competency with a non-formal content, identifying the aspects and factors that should be implemented in the production of the game so that satisfactorily cover the expectation of the competency within a scholar grade.

RESULTS

Results of the application of the CBD process to sixth grade Math subject

From the application of the CBD process to the subject of Mathematics for sixth grade of elementary school the next areas of knowledge and competencies where identified.

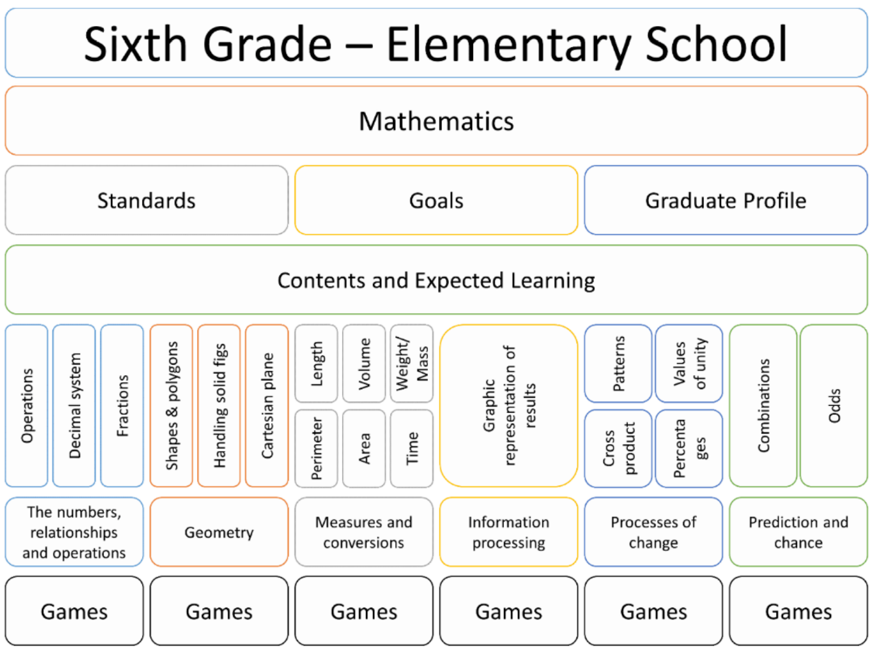


Figure 7. Result of the Competency-Based Decomposition applied to the subject Mathematics of sixth grade of elementary school.

Results of the production of short serious games

The production of short serious games is of about 50 in the next competencies and areas of knowledge:

1. The number, relationship and operations Fractions
    a. Operations
    b. Fractions
2. Geometry
    a. Shapes and polygons
    b. Handling of solid figures
    c. Cartesian plane
3. Measures and conversions
    a. Perimeters
    b. Lengths
    c. Areas
    d. Volume
    e. Time
    f. Weight/mass
4. Processes of change
    a. Cross product
    b. Patterns
    c. Percentages
    d. Values of unity
5. Prediction and chance
    a. Odds

Results of using the produced short serious game (knowledge assessment)

After production phase of short serious 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” located in La Paz, Ojuelos, Jalisco. The children from this school, and the school itself, have many needs, so the use of IT to access information helps to alleviate some of them.

The process performed for the test was as follows(Hernández Sampieri, Fernández Collado, & Baptista Lucio, 2010):

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 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 games use.
8) The collected data were analyzed with SPSS software.

The collected data allow to determine trends in student’s scores before and after use short serious games. The overall findings are graphically depicted in **Figure 8** where dotted-line displays the results obtained during initial examination. Solid-line displays the results of the evaluation performed after short serious games use.

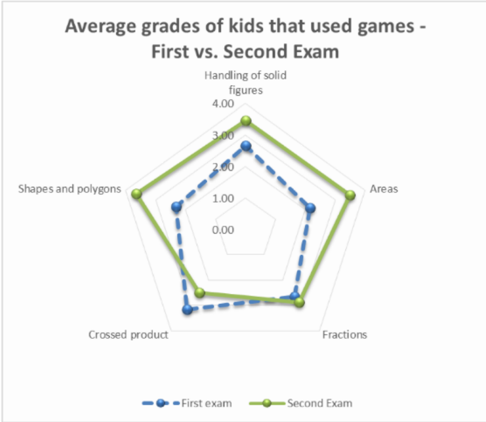


Figure 8. Overall result of the students in different areas of knowledge tested.

As the reader can see, there are improvements in four knowledge areas, this is due to the students achieved a higher level of adoption of the competencies implemented in the short serious games they used.

The "Crossed Product" game, which shows a decrease in the adoption of the competency, was developed with a question bank instead of randomly-generated problems, so the students memorized such question bank and did not achieve the intended adoption of the competency.

DISCUSSION

The correct implementation of the competencies and the characteristics of the short serious games is extremely important because this is the only way to guarantee that the students of users will achieve a higher level of adoption of the competencies implemented in the games.

As the reader can see, the “Crossed Product” game did not achieve its purpose: transfer the competency into the students due to a deviation in its development.

CONCLUSIONS AND FUTURES WORK

The CBD process allows clearly identify the competencies to implement in the short serious games, since in many cases this aspect is not taken into account during the development process (if a development process exists). The CBD process takes as inputs common elements in the syllabus and turns them into short serious game programmable and measurable competencies (learning needs).

Once identified the competencies, the short serious game development process is capable of building software products, from those learning needs, with a high quality level and meeting the correct implementation of the competencies.

This research has created and tested (with real world students) a big set of short serious games, achieving an improvement in the competency adoption due to the correct implementation of learning needs into the games.

The established objectives of the research were:

1. To create a process that ease teacher and pedagogues the task of transforming a syllabus into competencies and areas of knowledge to develop all materials and resources needed to teach.
2. To test the process in a real subject and from the identified competencies and areas of knowledge develop a set of short serious games.
3. To test the developed short serious games with real students to identify if there is any improvement.

Finally, we can say objectives have been successfully reached as we create the CBD process and use it in a real subject, develop a set of short serious games and test these games with students.

The next step in this research is to use this CBD process to review a Bachelor's Degree Career to ensure this process can be applied in any context.

REFERENCES

Almiron, M. E., & Porro, S. (2014). ICT in Teaching: An Analysis of Cases. *Revista Electrónica de Investigación Educativa, 16*(2). Retrieved January 2015, from http://redie.uabc.mx/vol16no2/contenido-almiron-porro.html

Álvarez Rodríguez, F., Barajas Saavedra, A., & Muñoz Arteaga, J. (2014, May 16). Serious Game Design Process, Study Case: Sixth Grade Math. *Creative Education, 05*(09), 647-656. doi:doi:10.4236/ce.2014.59077

Barajas Saavedra, A., Álvarez Rodríguez, F., Muñoz Arteaga, J., Santaolaya Delgado, R., & Collazos Ordóñez, C. (2014). A serious games development process using competency approach. Case Study: Elementary School Math. In A. I.-O. (AIPO) (Ed.), *XV International Conference on Human Computer Interaction* (pp. 572-579). Puerto de la Cruz, Tenerife, España: AIPO. Retrieved September 30, 2014

Dávila Balcarce, G., & Velásquez Contreras, Á. (2007). Evaluation of the Aplication of Shared Games: "Devorón" and "Temporal". *Revista Electrónica de Investigación Educativa, 9*(2). Retrieved January 2015, from http://redie.uabc.mx/vol9no2/contenido-davila.html

de Freitas, S., & Jarvis, S. (2006). A framework for developing serious games to meet learner needs. *I/ITSEC '06: Proceedings of the International Conference on Interservice/Industry Training, Simulation and Education*.

de Freitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers & education, 46*(3), 249-264.

Díaz Barriga, Á. (2006). El enfoque de compentecias en la educación. ¿Una alternativa o un disfraz de cambio? *Revista Perfiles Educativos*(111), 7-36. Retrieved September 2013, from http://www.iisue.unam.mx/perfiles/perfiles_articulo.php?clave=2006-111-7-36&url=2006/n111a2006/mx.peredu.2006.n111.p7-36.pdf

Garrido Miranda, J. M. (2013). Strategy Video Games: Some Principles for Teaching. *Revista Electrónica de Investigación Educativa, 15*(1). Retrieved January 2015, from http://redie.uabc.mx/vol15no1/contenido-garridojm.html

Ibrahim, R., & Jaafar, A. (2009, August 5-7). Educational Games (EG) Design Framework: Combination of Game Design, Pedagogy and Content Modeling. *2009 International*

Conference on Electrical Engineering and Informatics ICEEI '09, 1, 293-298. doi:10.1109/ICEEI.2009.5254771

INEGI. (2009, Diciembre 7). *Enciclomedia ¿Qué es?* Retrieved Diciembre 7, 2009, from Enciclomedia Una forma diferente de aprender y enseñar: http://www.inegi.gob.mx/inegi/contenidos/espanol/ciberhabitat/escuela/enciclomedia/

Martens, A., Diener, H., & Steffen, M. (2008). Game-based Learning with Computers - Learning, Simulations, and Games. *Transactions on Edutainment*, 172-190.

Mulder, M., Weigel, T., & Collins, K. (2007, March). The concept of competence in the development of vocational education and training in selected EU member states: a critical analysis. *Journal of Vocational Education & Training, 59*(1), 67-88. doi:10.1080/13636820601145630

Secretaría de Educación Pública. (2011). *Programas de estudio 2011 - Guía para el maestro - Educación básica - Primaria - Sexto grado* (First Electronic Edition ed.). Cuauhtémoc, México, D.F., México: Gobierno Federal SEP. Retrieved September 15, 2014, from http://www.curriculobasica.sep.gob.mx/images/PDF/prog_primaria/PRIM_6to2011.pdf

Secretaría de Educación Pública. (2013). *Estadísticas ENLACE 2012.* Retrieved Octubre 25, 2012, from Evaluación Nacional del Logro Académico en Centros Escolares Educación Básica: http://www.enlace.sep.gob.mx/ba/

Tejada Fernández, J. (2005). Competencies-Based Work in the Practicum: How to Organize and Evaluate It. *Revista Electrónica de Investigación Educativa, 7*(5). Recuperado el January de 2015, de http://redie.uabc.mx/vo7no2/contenido-tejada.html

Velázquez Amador, C. E., Álvarez Rodríguez, F. J., Garza González, L., Sicilia, M. Á., Mora Tavarez, J. M., & Muñoz Arteaga, J. (2011, Noviembre). Una Experiencias en el Desarrollo Masivo de Objetos de Aprendizaje Empleando Parámetros de Calidad y un Proceso de Gestión Bien Definido. *IEEE - Revista Iberoamericana de Tecnologías del Aprendizaje, 6*(4), 155-163.

Zyda, M. (2005, September). From visual simulation to virtual reality to games. *Computer, 38*(9), 25-32. doi:10.1109/MC.2005.297

IEEE Latinoamérica

Arturo Barajas

De:	IEEE Latin America Transactions <editorchefeieeer9@gmail.com> en nombre de Editor in Chief IEEE R9 <editor-in-chief-r9@ieee.org>
Enviado el:	miércoles, 9 de septiembre de 2015 10:59
Para:	abarajas@correo.uaa.mx
Asunto:	Re: Paper Submission #3175 for RevistaIEEE-AL

Dear author

At the moment we can not predict deadlines.

We ask for a little patience.

Your paper is being evaluated. Once we have the opinion of the reviewers, they will be sent to the registered email to the author.

The magazine has many papers at this time and few active reviewers, only in 2014 we had over 700 submissions. And in 2015 we have over 650 submissions.

We have 4 regular issues per year with an average of 50 articles published in each, and this year 2015 we are conducting more issues to reduce our problem.

We ask for your understanding and please feel free to contact when needed.

Check the paper status:

1- Follow the link: http://www.ewh.ieee.org/reg/9/etrans/eng/

2- Chose Papers Submission.

3- Click in the link: http://www.revistaieeela.pea.usp.br/

4- Choose the Check Status.

5- Put the paper ID and Password. (To recover your login or password, click the button "(I forgot it)".

6- The status of paper open.

1

Modelo de Verificación y Validación para la Producción de Videojuegos Serios Cortos

A. Barajas-Saavedra and F.J. Álvarez-Rodríguez, J. Muñoz Arteaga, R. Santaolaya Salgado, César A. Collazos, J.A. Hurtado Alegría

***Abstract*— Nowadays, serious games play an outstanding role in the adoption of competencies since they provide immersion, fun, motivation and a high level of engagement among user through the implementation of a phenomena based learning. The correct implementation is extremely important to ensure a high level of adoption of the competencies by the users of the games. The focus on this research is oriented to achieve the correct implementation of requirements through in the production of short serious games. Then, this article presents a model based upon requirements traceability and inspections to verify and validate the correct implementation of requirements and the successful production of quality short serious games.**

***Keywords*— short serious games, education technology, software engineering, verification, validation**

I. INTRODUCCION

HOY en día, el uso de videojuegos y otros recursos digitales educativos se ha convertido en una práctica común, a tal grado que, en las diversas plataformas comerciales la oferta de dichos recursos es enorme. En 2015 appfigures [1] reportó que al cierre de 2014 Apple y Google contaban, respectivamente, con 1.21 millones y 1.43 millones de aplicaciones de este tipo en sus tiendas. Las aplicaciones categorizadas como juegos y educación están entre las primeras cinco de mayor crecimiento en cantidad en la tienda de Apple, mientras que en la tienda de Google la categoría de juegos es la de mayor crecimiento [1]. Aunado a lo anterior, la tienda de Apple tiene un 21.45% de juegos y un 9.95% de aplicaciones de educación [2], y la tienda de Google posee un 14.8% y 6.1% respectivamente [3]. Por tanto, en el mercado actual existen aproximadamente 678,810 aplicaciones relacionadas a juegos y educación.

Cada una de estas aplicaciones, ya sea de juegos o educación, promueve la adquisición de ciertas "competencias" en los usuarios. Un ejemplo de estas "competencias" pueden ser encontradas en las aplicaciones diseñadas por la compañía Toca Boca [4], donde en su sitio Web, en la sección "Para padres" ("For parents" en inglés) [5], presentan las "competencias" de cada una de sus aplicaciones. Sin embargo, se desconoce si esas aplicaciones han sido desarrolladas con un control de calidad que asegure la adquisición de las competencias. Las "competencias" que promueven esas aplicaciones están dadas en términos genéricos y no en términos pedagógicos consistentes con un desarrollo sistemático en el área.

Algunos trabajos, relacionados a la industria del software, muestran que un porcentaje significativo de empresas de desarrollo de software no usan procesos para el desarrollo de sus proyectos, quizás por limitaciones en los presupuestos, agendas apretadas o, principalmente, por el desconocimiento de los beneficios potenciales de usar procesos de software respecto a la calidad y la productividad. [6]

Particularmente para el desarrollo de los videojuegos, se tiene que estas aplicaciones son difíciles de producir, puesto que involucran a expertos de distintas áreas de conocimiento y, hasta donde sabemos, no existen procesos, ni metodologías explícitamente definidas para su desarrollo [7]. Por lo tanto, es poco viable que los recursos hayan sido desarrollados bajo una supervisión pedagógica que respalde su correcto funcionamiento y una adecuada adquisición de las competencias. [8]

Barajas et al. [9] proponen un proceso extensible para la producción de videojuegos serios cortos (VSC), los cuales poseen tres aspectos: pedagógicos, técnicos y de integración, que además poseen cinco características:

1. Cortos y enfocados en un área de conocimiento simple (desde el punto de vista pedagógico).
2. Interfaz de usuario evaluada pedagógicamente.
3. Casos con razonamiento formal.
4. Casos generados aleatoriamente.
5. Contenido retador y generador de desafíos.

Cabe resaltar que la característica de "cortos" es debido a que los productos se enfocan solamente a una única área de conocimiento, por lo tanto la extensión del juego o el tiempo que requiere el usuario para terminar el juego es corto. La interfaz debe ser evaluada pedagógicamente para lograr que los usuarios usen el juego y perciban al juego como agradable y amigable. Los casos deben poseer razonamiento formal y ser generados aleatoriamente para evitar que los usuarios memoricen las respuestas de un banco de preguntas y que no mecanicen la forma de solución. Finalmente, el juego debe ser retador para atraer la atención de los usuarios y promover el uso entre iguales.

Estas características han sido identificadas en el transcurso de la investigación a partir de la producción y las pruebas con los usuarios, y son relevantes ya que así se garantiza la mejora en el logro de las competencias.

A pesar de esta propuesta, aún persiste el problema de ¿cómo asegurar que los requerimientos se propaguen a través

A. Barajas-Saavedra, Universidad Autónoma de Aguascalientes, Aguascalientes, México, abarajas@correo.uaa.mx
F.J. Álvarez-Rodríguez, Universidad Autónoma de Aguascalientes, Aguascalientes, México, fjalvar@correo.uaa.mx
J. Muñoz Arteaga, Universidad Autónoma de Aguascalientes, Aguascalientes, México, jmunozar@correo.uaa.mx
R. Santaolaya Salgado, CENIDET, Morelos, México, rene@cenidet.edu.mx
César A. Collazos Ordóñez, Universidad del Cauca, Popayán, Colombia, ccollazo@unicauca.edu.co
J.A. Hurtado Alegría, Universidad del Cauca, Popayán, Colombia, julioarielhurtado@gmail.com

Appendix B – Competency-Based Decomposition

Competency-Based Decomposition (CBD)

The CBD process is a mechanism to match a formal competency with a non-formal content, identifying the aspects and factors that should be implemented in the production of the game so that satisfactorily cover the expectation of the competencies within a scholar grade and guarantee the quality of the serious game through the fulfilment of the learning needs. . With this procedure it is proposed to completely cover the contents and learnings that accompany a subject in a syllabus, thus ensuring the appropriation of knowledge and learning outcomes for a particular competency.

To perform the CBD is necessary to complete the following steps for each subject to analyze (Fig. 32).

1. To identify the standards, goals and graduate profiles (SGGP) of the subject analyzed. This step is very important as the products of the subsequent steps must be aligned to these elements.
2. To identify the contents and expected learning of the syllabus.
3. To group, in areas of knowledge, the contents and expected learnings in accordance with SGGP.
4. To organize knowledge areas in accordance with SGGP.
5. To identify competencies from the knowledge areas grouping.
6. To organize competencies and their knowledge areas in accordance with SGGP.

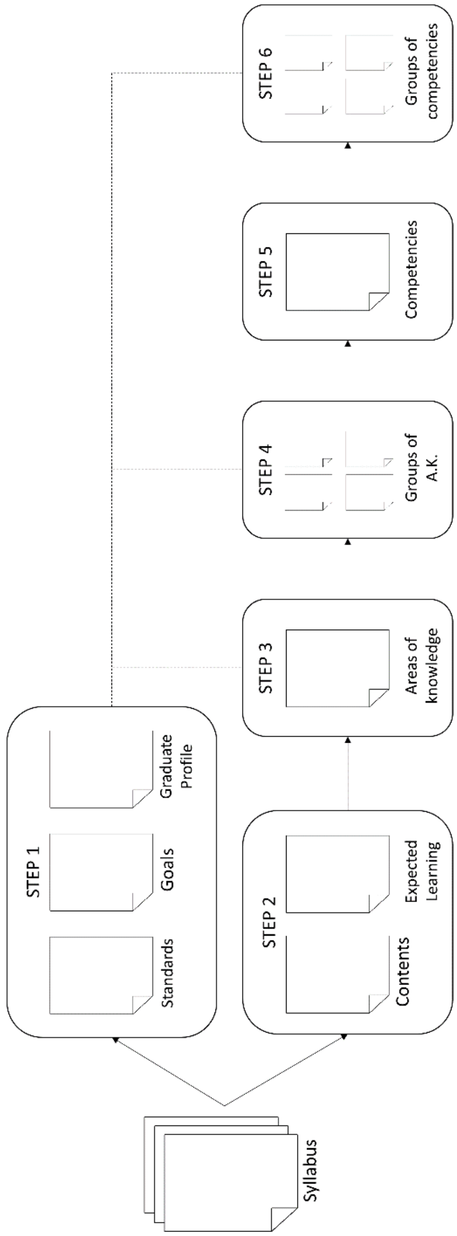


Fig. 32. Graphic view of the Competency-based Decomposition process.

With this procedure it is proposed to completely cover the contents and learnings that accompany a subject in a syllabus, thus ensuring the appropriation of knowledge and learning outcomes for a particular competency.

It is very important to stress that every competency and its knowledge areas must be attainable from the point of view of the Software Engineering, since, for example, the Study

Program for Sixth Grade Mathematics published by the Ministry of Education, provides a set of math competencies, namely:

1. Solve problems independently.
2. Communicate mathematical information.
3. Validate procedures and results.
4. Efficiently handling techniques.

Where all of them are “Competencies for life”, which, from the point of view of the Software Engineering, are very complex to manage and measure due to their multifactor nature.

Using CBD for sixth grade Math

This section will show the process to apply the CBD step by step using the Sixth grade math of Elementary school in México.

Step 1. To identify the standards, goals and graduate profiles.

In the next figures is shown the standards (Fig. 33), goals (Fig. 34) and graduate profiles (Fig. 35) from the syllabus analyzed.

MATHEMATICS STANDARDS

The Mathematics Curricular Standards present a vision of a population who know how to use mathematical knowledge. Comprise the set of learning expected of students in four school periods to lead to high levels of mathematical literacy.

Consist of:

1. Number sense and algebraic thinking.
2. Shape, space and measure.
3. Information management.
4. Attitude towards the study of mathematics.

Their progress should be understood as:

- Moving from everyday language to mathematical language to explain procedures and results.
- Broaden and deepen the knowledge, so that understanding and efficient use of mathematical tools are favored.

Moving from the request for help in solving problems towards self-employment

Fig. 33. Standards of the study of mathematics for elementary education established in the Syllabus 2011 published by the Mexican Ministry of Education. (Secretaría de Educación Pública, 2011)

Purpose of the study of mathematics for elementary education

At this stage of their education as a result of the study of mathematics, it is expected that students:

- Know and use the properties of the decimal system to interpret or communicate amounts in different ways. Explain the similarities and differences between the properties of the decimal system and other systems, both positional and non-positional.
- Use mental math, estimation results or write operations with natural numbers and addition and subtraction with fractions and decimal numbers to solve additive and multiplicative problems.
- Know and use the basic properties of angles and different types of lines as well as circle, triangles, quadrilaterals, regular and irregular polygons, prisms, pyramids, cone, cylinder and sphere to make some buildings and calculate measures.
- Use and interpret various codes for orientation in space and locate objects or places.
- Express and interpret measures with different types of unit, to calculate perimeters and areas of triangles, quadrilaterals, regular and irregular polygons.
- Engage in search processes, organization, analysis and interpretation of data in images, text, tables, bar graphs and other carriers to provide information or answer questions for themselves or others. Represent data using tables and bar charts.

Identify sets of quantities that vary proportionately or irregularly, calculating missing values and percentages, and apply the proportionality constant factor (with natural numbers) in simple cases.

Fig. 34. Purposes or goals of the study of mathematics for elementary education established in the Syllabus 2011 published by the Mexican Ministry of Education. (Secretaría de Educación Pública, 2011)

Third school term, the end of the sixth grade, between 11 and 12 years old

In this period Curricular Standards correspond to three thematic axis: Number sense and algebraic thinking, Shape, space and measure and Information handling.

After the third period, students know how to communicate and interpret natural numbers, fractional or decimal numbers as well as solve problems using additive and multiplicative conventional algorithms. Calculate perimeters and areas and can describe and build and solid figures. They use reference systems to locate points in the plane or to interpret maps. Also perform processes of collecting, organizing, analyzing and presenting data.

Based on the teaching methodology proposed for study in this course, students are expected to also acquire mathematical knowledge and skills, develop attitudes and values that are essential in the construction of mathematical competence.

1. Numeric sense and algebraic thinking

During this period the axis includes the next topics:

1. Numbers and number systems.
2. Additive problems.
3. Multiplicative problems.

The Curricular Standards for this axis are the next ones. The student:

1.1.1. Reading, writing and comparing natural, fractions and decimal numbers.
1.2.1. Solving additive problems with fractional or decimal numbers, using conventional algorithms.
1.3.1. Solving problems that implies multiply or dividing natural numbers using conventional algorithms.

Solving problems that implies multiplying or dividing fractional or decimal numbers using conventional algorithms.

Fig. 35. Graduate profile of mathematics for elementary education established in the Syllabus 2011 published by the Mexican Ministry of Education. (Secretaría de Educación Pública, 2011).

Step 2. To identify the contents and expected learning of the syllabus.

In the Syllabus 2011 can be found all the subjects that integrate a scholar grade, and each grade is divided into blocks.

Each block is integrated in its first level by the central axis, in its second level by the topics, and in its third level by the contents. This can be seen in Fig. 36. As you can see there are only three axes in the figure, this is due to that the fourth axis “Attitude towards the study of mathematics” is implicitly evaluated by the other three axes.

COMPETENCIES TO ENHANCE: Solve problems independently • Communicate mathematical information • Validate procedures and results • Efficiently handling techniques			
EXPECTED LEARNING	CENTRAL AXES		
	NUMBER SENSE AND ALGEBRAIC THINKING	FORM, SPACE AND MEASURE	INFORMATION MANAGEMENT
• Solve problems involving read, write and compare natural, fractional and decimal numbers, specifying the comparison criteria. • Solve additive problems with natural, decimal and fractional numbers involving two or more transformations. • Describes routes and calculates the real distance from one point to another on maps.	NUMBERS AND NUMBER SYSTEMS • Reading, writing and comparing natural, fractions and decimal numbers. Explanation of comparison criteria. ADDITIVE PROBLEMS • Solving additive problems with natural, decimal and fractional numbers, varying the structure of problems. Study or reaffirmation of conventional algorithms. MULTIPLICATIVE PROBLEMS • Solving multiplicative problems with fractional or decimal values through informal procedures.	FIGURES AND BODIES • Identifying the symmetry axes of a figure (polygonal or not polygonal) and mutually symmetrical shapes, through different resources. SPATIAL LOCATION • Choosing a code to communicate the location of objects in a grid. Establishing of common codes for locating objects. MEASURE • Calculating real distances though rough measurement from one point to another or a map.	PROPORTIONALITY AND FUNCTIONS • Calculation of percentage amounts by various methods (application of correspondence "per 100, n", implementing a common or decimal fraction, using 10% as base). ANALYSIS AND DATA REPRESENTATION • Reading data in tables and circle graphs to answer diverse questioning.

Fig. 36. Extract of the syllabus for sixth grade math of elementary school. This figure shows the competencies to enhance, the expected learning, the central axes, the topics and the contents for the Block I. The syllabus is integrated by five blocks. Note that the fourth axis is not shown due to is evaluated implicitly in the other three. (Secretaría de Educación Pública, 2011)

Step 3. To group, in knowledge areas, the contents and expected learnings.

After identifying the contents and expected learning, the grouping resulted in the next knowledge areas:

1. Areas
2. Cartesian plane
3. Combinations
4. Cross product
5. Decimal system

6. Fractions
7. Graphic representation of results
8. Handling of solid figures
9. Lengths
10. Odds
11. Operations
12. Patterns
13. Percentages
14. Perimeters
15. Shapes and polygons
16. Time
17. Values of unity
18. Volume
19. Weight/Mass

Step 4. To organize knowledge areas.

The process of organizing the knowledge areas resulted in the creation of "groups" that later will be competencies.

1. Competency 1
    a. Operations
    b. Decimal system
    c. Fractions
2. Competency 2
    a. Shapes and polygons
    b. Handling of solid figures
    c. Cartesian plane
3. Competency 3
    a. Lengths
    b. Volume
    c. Weight/Mass

   d. Perimeters
   e. Areas
   f. Time
4. Competency 4
   a. Graphic representation of results
5. Competency 5
   a. Patterns
   b. Values of unity
   c. Cross product
   d. Percentages
6. Competency 9
   a. Combinations
   b. Odds

Step 5. To identify competencies from the knowledge areas.

The identified competencies are:

1. The numbers, relationships and operations
2. Geometry
3. Measures and Conversions
4. Information processing
5. Processes of change
6. The prediction and chance

Step 6. To organize competencies and their knowledge areas.

The Competency-Based Decomposition process is graphically shown in the following figure (see Fig. 37). The final result of this process, is shown in Fig. 38.

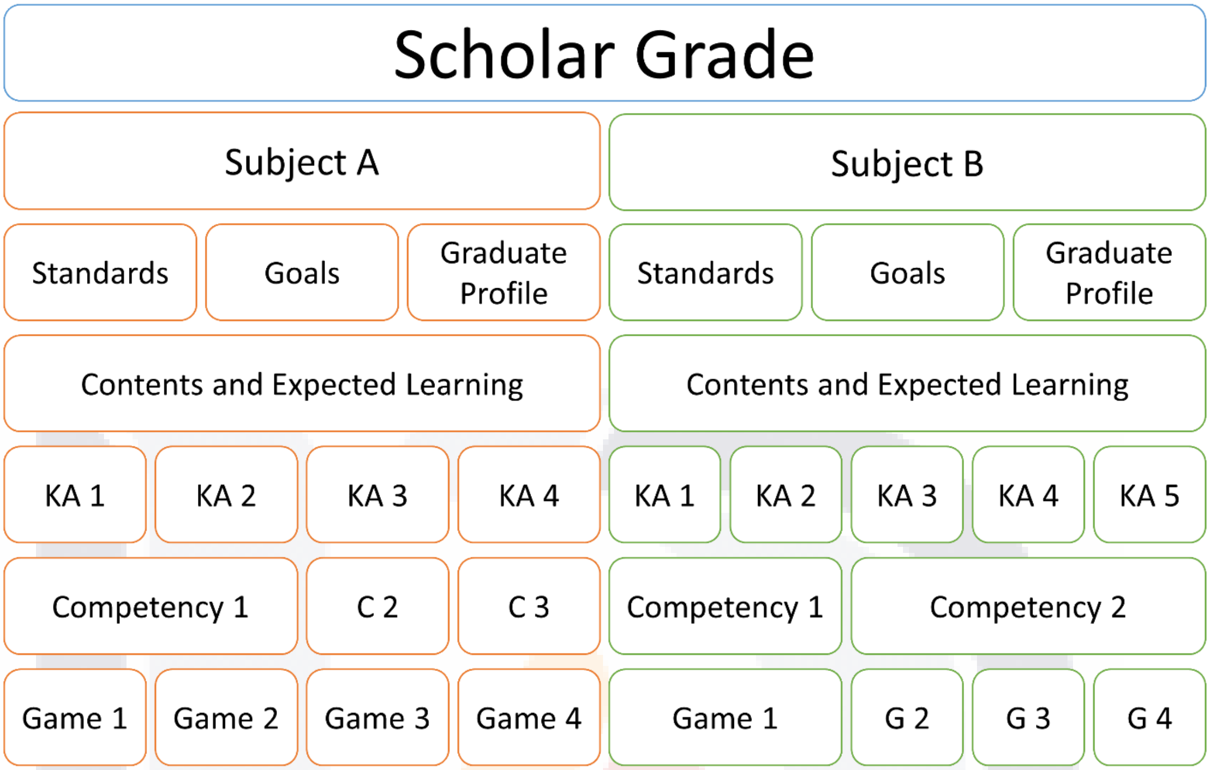


Fig. 37. This approach allows to match a formal competency with a non-formal content, identifying the aspects and factors that should be implemented in the production of the game so that satisfactorily cover the expectation of the competency within a scholar grade.

Results of the application of the CBD process to sixth grade Math subject

From the application of the CBD process to the subject of Mathematics for sixth grade of elementary school the next areas of knowledge and competencies where identified.

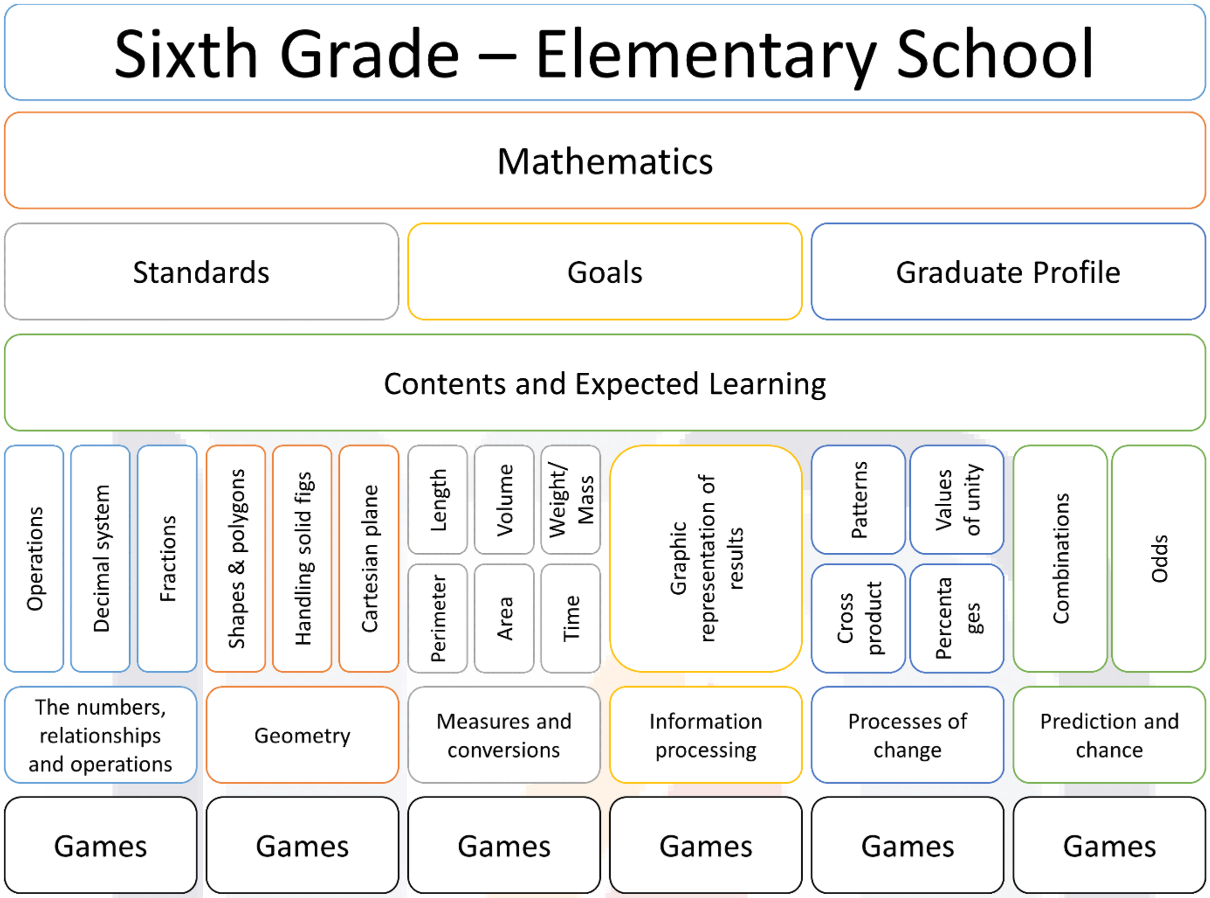


Fig. 38. Result of the Competency-Based Decomposition applied to the subject Mathematics of sixth grade of elementary school.

Using CBD for Engineering Degree syllabus

As a proof of the flexibility and reusability of the CBD process, it was applied to a Bachelor's Degree syllabus, specifically, to Bachelor of Computer.

The objective of this application was to identify whether the process was able to support the identification of the competencies of a study program in another context.

As a result it was found that not only were identified competencies, but also lined up and optimized for the generation of a new career, Software Developer Engineering.

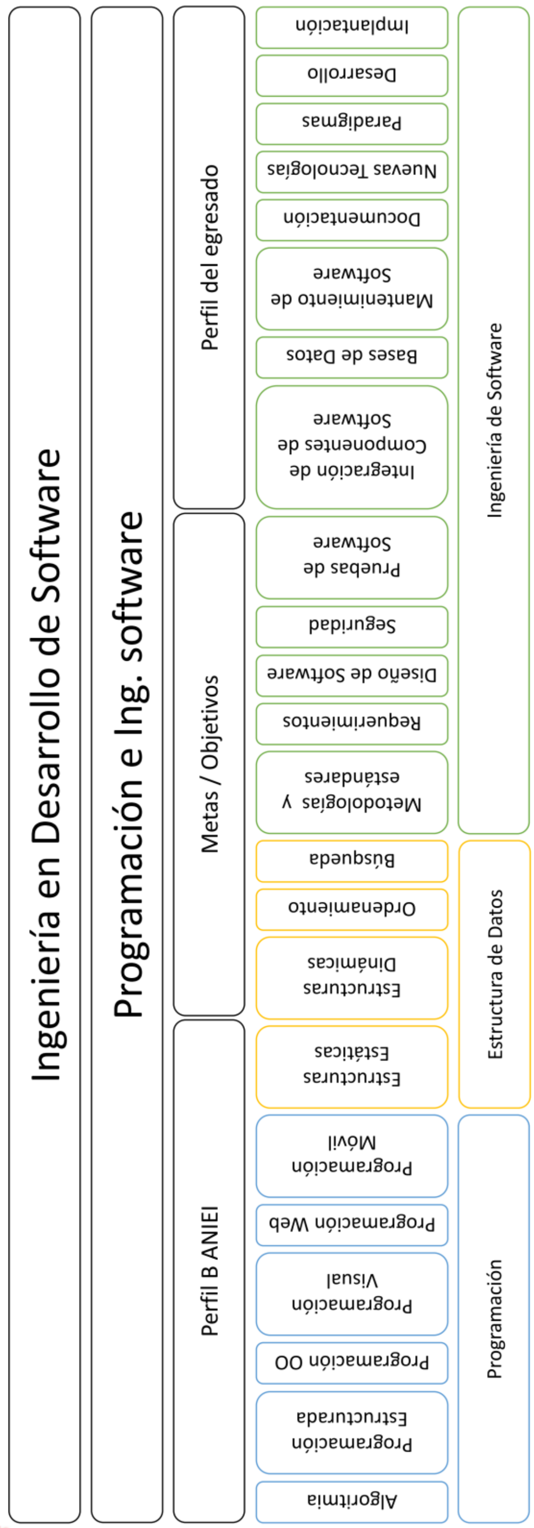
In the next pages are shown the results of the application. In first place, you can find the identification of the competencies per "Area of Knowledge" established in the Profile B of the ANIEI standards. In second place, you can find the identification of the competencies per Semester of the career.

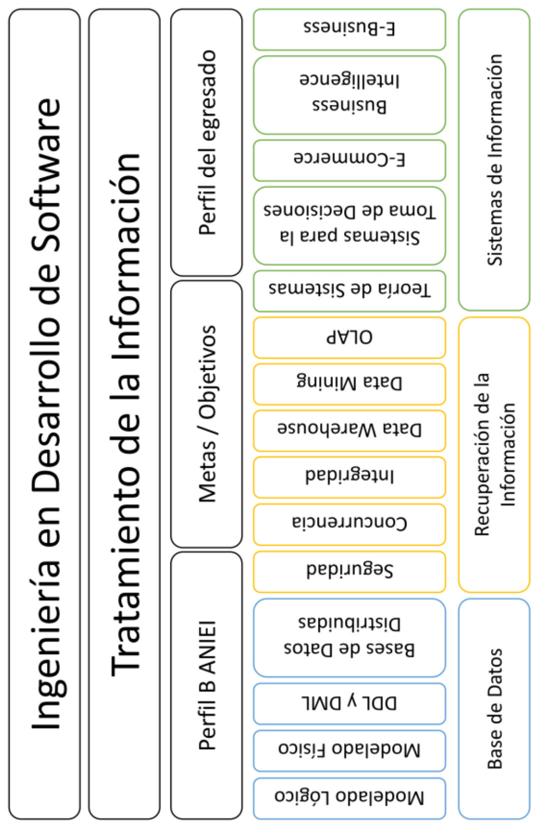
Areas

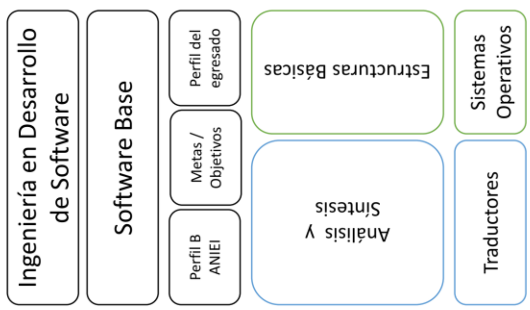
Aplicación de la DBC para la Revisión del Plan de Estudios de Licenciatura en Computación de la UABCS

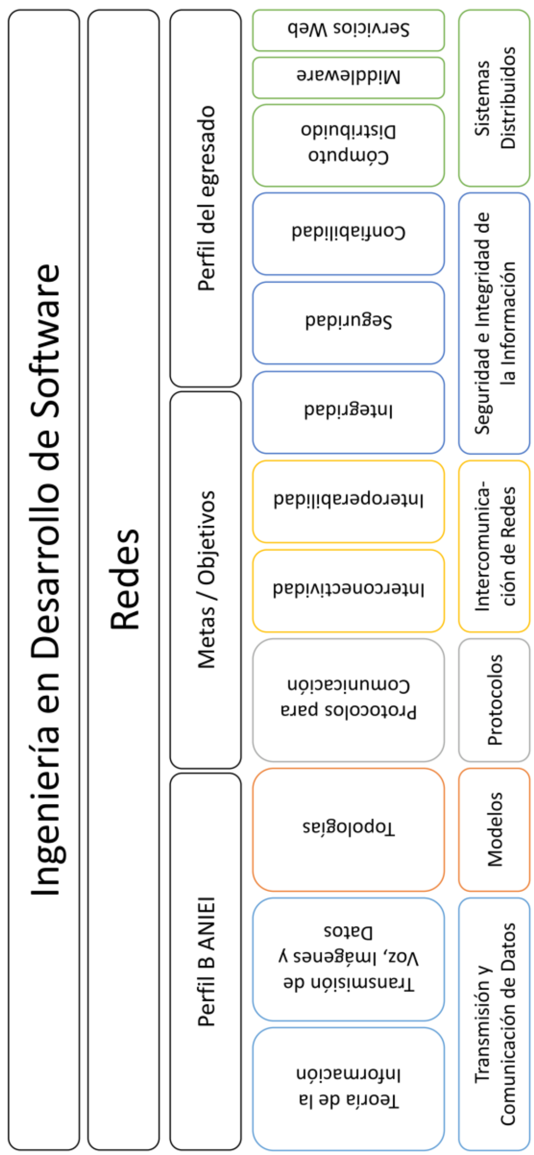
A partir de la revisión se generará el Plan de Estudios para la carrera de Ingeniería en Desarrollo de Software

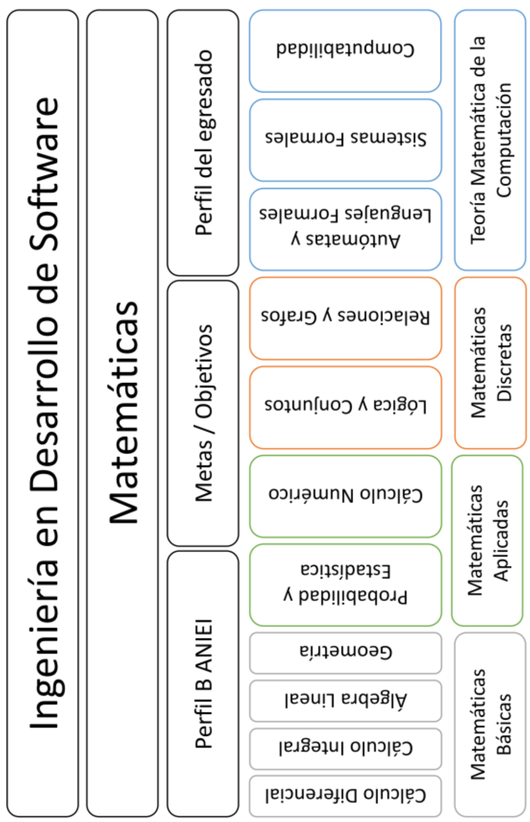
Aplicación de la DBC por Área de Conocimiento del Perfil B de ANIEI

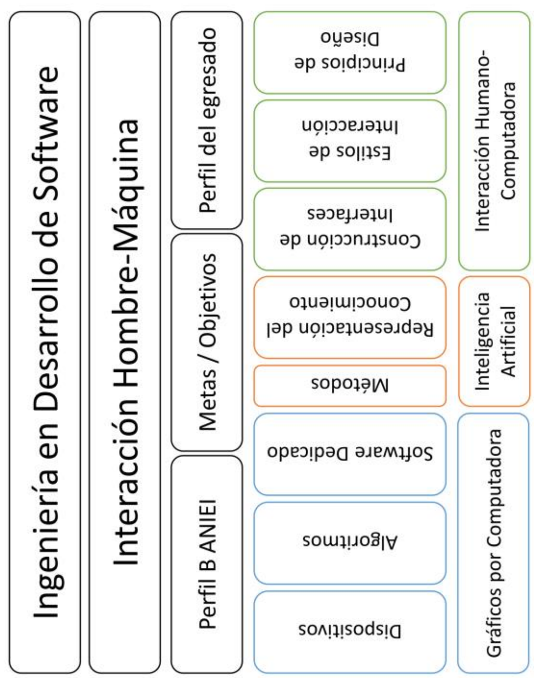

Ingeniería en Desarrollo de Software
Programación e Ing. software
Perfil B ANIEI
Metas / Objetivos
Perfil del egresado
Algoritmia
Programación Estructurada
Programación OO
Programación Visual
Programación Web
Programación Móvil
Estructuras Estáticas
Estructuras Dinámicas
Ordenamiento
Búsqueda
Metodologías y estándares
Requerimientos
Diseño de Software
Seguridad
Pruebas de Software
Integración de Componentes de Software
Bases de Datos
Mantenimiento de Software
Documentación
Nuevas Tecnologías
Paradigmas
Desarrollo
Implantación
Programación
Estructura de Datos
Ingeniería de Software

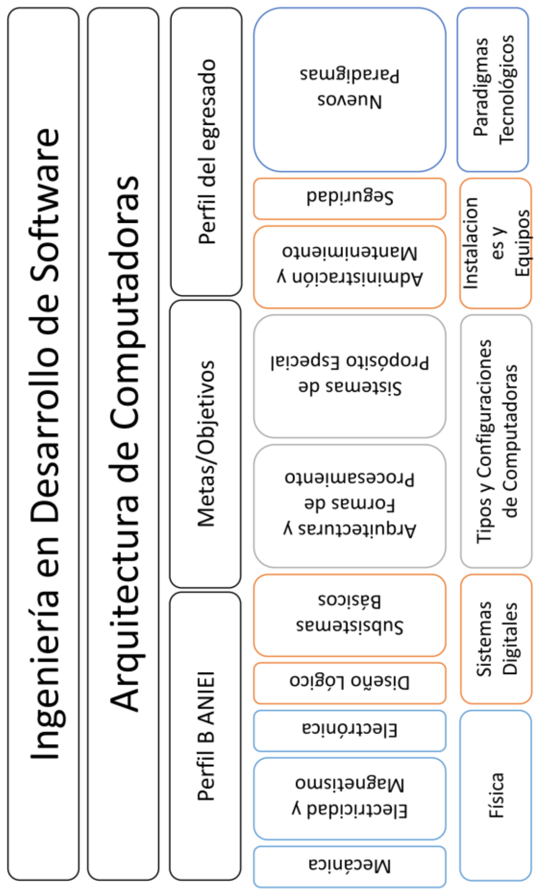

Ingeniería en Desarrollo de Software
Tratamiento de la Información
Perfil B ANIEI
Metas / Objetivos
Perfil del egresado
Modelado Lógico
Modelado Físico
DDL y DML
Bases de Datos Distribuidas
Seguridad
Concurrencia
Integridad
Data Warehouse
Data Mining
OLAP
Teoría de Sistemas
Sistemas para la Toma de Decisiones
E-Commerce
Business Intelligence
E-Business
Base de Datos
Recuperación de la Información
Sistemas de Información

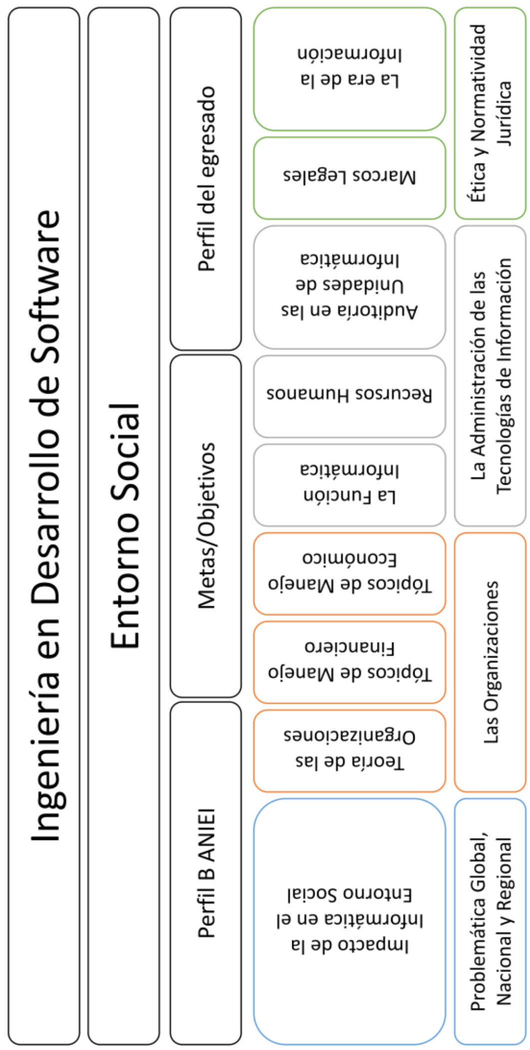

Ingeniería en Desarrollo de Software
Software Base
Perfil del egresado
Metas / Objetivos
Perfil B ANIEI
Estructuras Básicas
Análisis y Síntesis
Sistemas Operativos
Traductores


Ingeniería en Desarrollo de Software
Redes
Perfil B ANIEI
Metas / Objetivos
Perfil del egresado
Teoría de la Información
Transmisión de Voz, Imágenes y Datos
Topologías
Protocolos para Comunicación
Interconectividad
Interoperabilidad
Integridad
Seguridad
Confiabilidad
Cómputo Distribuido
Middleware
Servicios Web
Transmisión y Comunicación de Datos
Modelos
Protocolos
Intercomunica-ción de Redes
Seguridad e Integridad de la Información
Sistemas Distribuidos


Ingeniería en Desarrollo de Software
Matemáticas
Perfil B ANIEI
Metas / Objetivos
Perfil del egresado
Cálculo Diferencial
Cálculo Integral
Álgebra Lineal
Geometría
Probabilidad y Estadística
Cálculo Numérico
Lógica y Conjuntos
Relaciones y Grafos
Autómatas y Lenguajes Formales
Sistemas Formales
Computabilidad
Matemáticas Básicas
Matemáticas Aplicadas
Matemáticas Discretas
Teoría Matemática de la Computación


Ingeniería en Desarrollo de Software
Interacción Hombre-Máquina
Perfil B ANIEI
Metas / Objetivos
Perfil del egresado
Dispositivos
Algoritmos
Software Dedicado
Métodos
Representación del Conocimiento
Construcción de Interfaces
Estilos de Interacción
Principios de Diseño
Gráficos por Computadora
Inteligencia Artificial
Interacción Humano-Computadora


Ingeniería en Desarrollo de Software
Arquitectura de Computadoras
Perfil B ANIEI
Metas/Objetivos
Perfil del egresado
Mecánica
Electricidad y Magnetismo
Electrónica
Diseño Lógico
Subsistemas Básicos
Arquitecturas y Formas de Procesamiento
Sistemas de Propósito Especial
Administración y Mantenimiento
Seguridad
Nuevos Paradigmas
Física
Sistemas Digitales
Tipos y Configuraciones de Computadoras
Instalaciones y Equipos
Paradigmas Tecnológicos

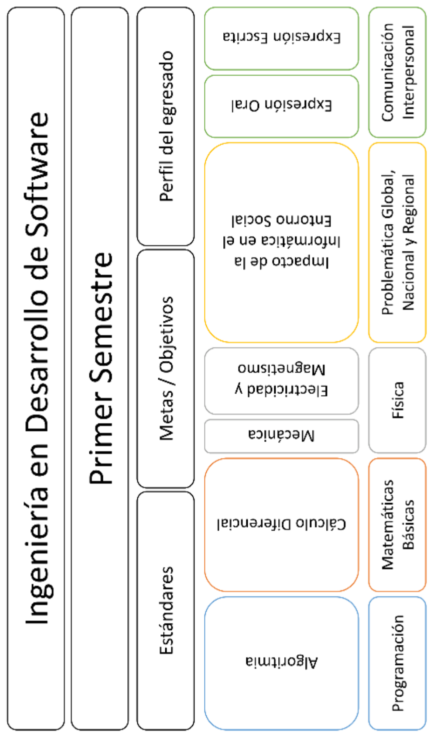

Ingeniería en Desarrollo de Software
Entorno Social
Perfil B ANIEI
Metas/Objetivos
Perfil del egresado
Impacto de la Informática en el Entorno Social
Teoría de las Organizaciones
Tópicos de Manejo Financiero
Tópicos de Manejo Económico
La Función Informática
Recursos Humanos
Auditoría en las Unidades de Informática
Marcos Legales
La era de la Información
Problemática Global, Nacional y Regional
Las Organizaciones
La Administración de las Tecnologías de Información
Ética y Normatividad Jurídica

Semesters

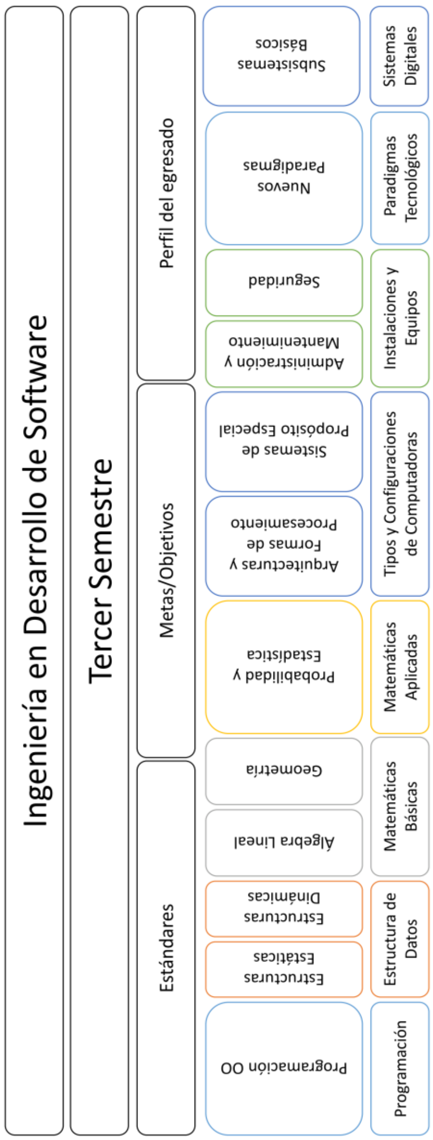
Aplicación de la DBC para la Revisión del Plan de Estudios de Licenciatura en Computación de la UABCS

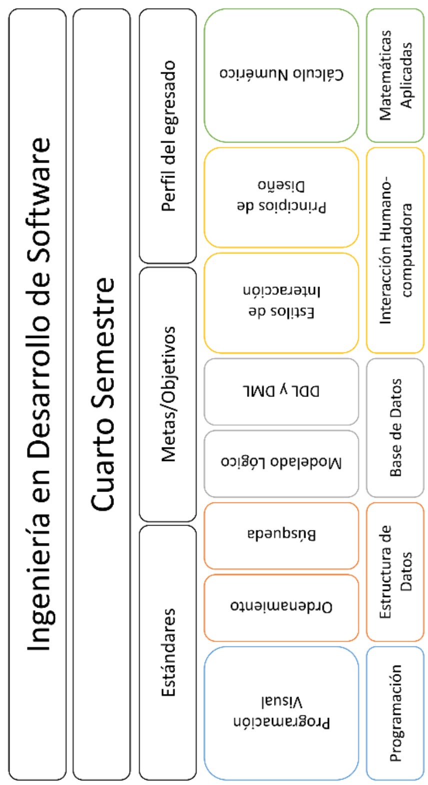
A partir de la revisión se generará el Plan de Estudios para la carrera de Ingeniería en Desarrollo de Software

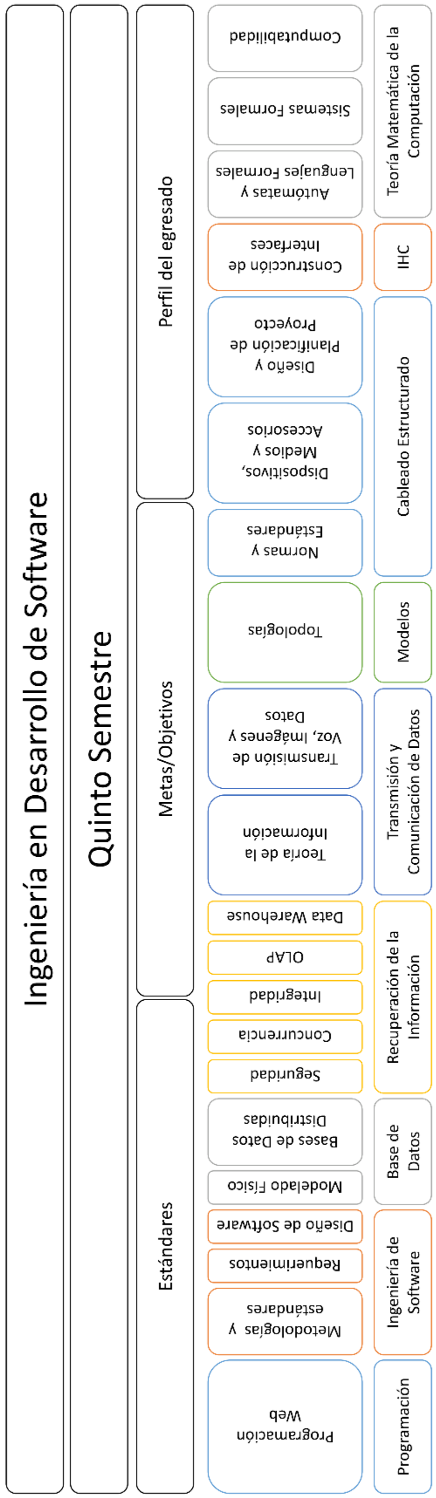
Aplicación de la DBC por Semestre

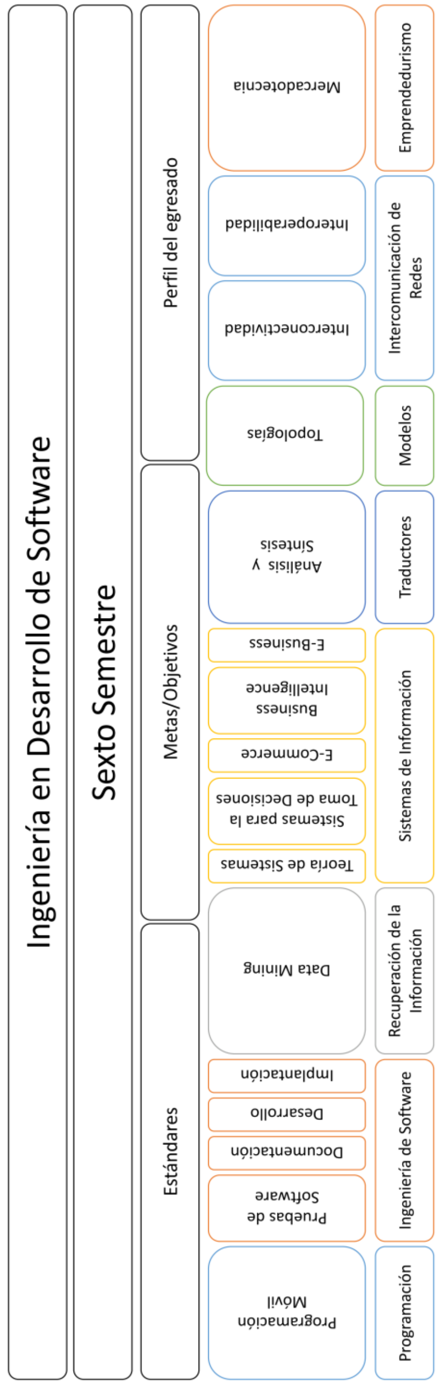

Ingeniería en Desarrollo de Software
Primer Semestre
Estándares
Metas / Objetivos
Perfil del egresado
Algoritmia
Cálculo Diferencial
Mecánica
Electricidad y Magnetismo
Impacto de la Informática en el Entorno Social
Expresión Oral
Expresión Escrita
Programación
Matemáticas Básicas
Física
Problemática Global, Nacional y Regional
Comunicación Interpersonal

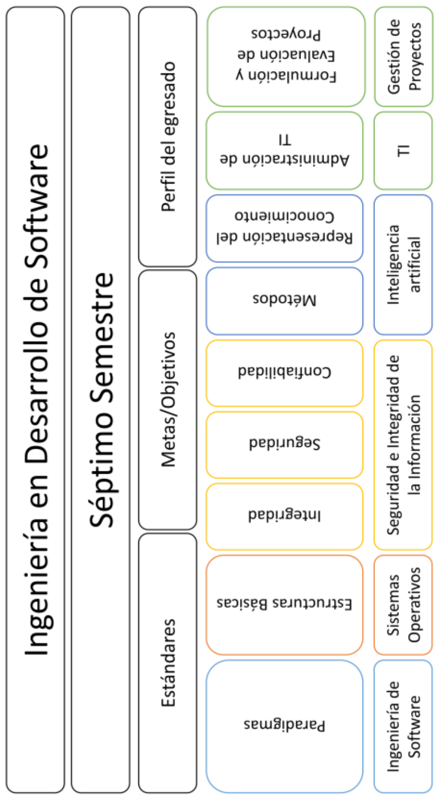

Ingeniería en Desarrollo de Software
Segundo Semestre
Estándares
Metas / Objetivos
Perfil del egresado
Programación Estructurada
Cálculo Integral
Lógica y Conjuntos
Relaciones y Grafos
Electrónica
Diseño Lógico
Marcos Legales
La Era de la Información
Programación
Matemáticas Básicas
Matemáticas Discretas
Física
Sistemas Digitales
Ética y Normatividad Jurídica

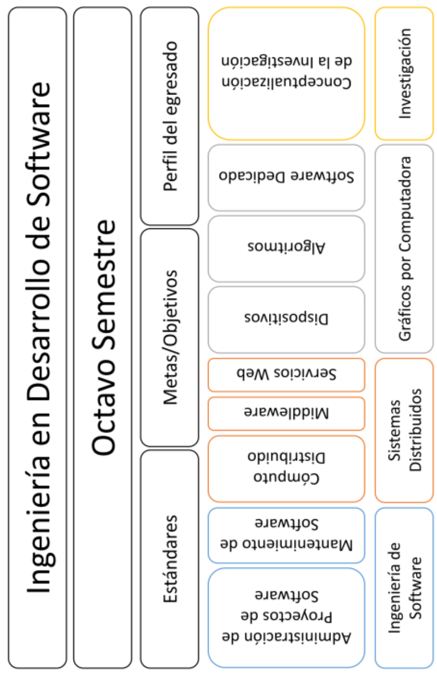

Ingeniería en Desarrollo de Software
Tercer Semestre
Estándares
Metas/Objetivos
Perfil del egresado
Programación OO
Estructuras Estáticas
Estructuras Dinámicas
Álgebra Lineal
Geometría
Probabilidad y Estadística
Arquitecturas y Formas de Procesamiento
Sistemas de Propósito Especial
Administración y Mantenimiento
Seguridad
Nuevos Paradigmas
Subsistemas Básicos
Programación
Estructura de Datos
Matemáticas Básicas
Matemáticas Aplicadas
Tipos y Configuraciones de Computadoras
Instalaciones y Equipos
Paradigmas Tecnológicos
Sistemas Digitales

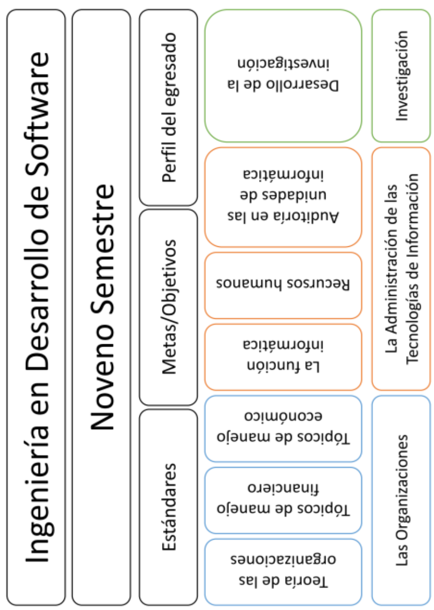

Ingeniería en Desarrollo de Software
Cuarto Semestre
Estándares
Metas/Objetivos
Perfil del egresado
Programación Visual
Ordenamiento
Búsqueda
Modelado Lógico
DDL y DML
Estilos de Interacción
Principios de Diseño
Cálculo Numérico
Programación
Estructura de Datos
Base de Datos
Interacción Humano-computadora
Matemáticas Aplicadas


Ingeniería en Desarrollo de Software
Quinto Semestre
Estándares
Metas/Objetivos
Perfil del egresado
Programación Web
Metodologías y estándares
Requerimientos
Diseño de Software
Modelado Físico
Bases de Datos Distribuidas
Seguridad
Concurrencia
Integridad
OLAP
Data Warehouse
Teoría de la Información
Transmisión de Voz, Imágenes y Datos
Topologías
Normas y Estándares
Dispositivos, Medios y Accesorios
Diseño y Planificación de Proyecto
Construcción de Interfaces
Autómatas y Lenguajes Formales
Sistemas Formales
Computabilidad
Programación
Ingeniería de Software
Base de Datos
Recuperación de la Información
Transmisión y Comunicación de Datos
Modelos
Cableado Estructurado
IHC
Teoría Matemática de la Computación


Ingeniería en Desarrollo de Software
Sexto Semestre
Estándares
Metas/Objetivos
Perfil del egresado
Programación Móvil
Pruebas de Software
Documentación
Desarrollo
Implantación
Data Mining
Teoría de Sistemas
Sistemas para la Toma de Decisiones
E-Commerce
Business Intelligence
E-Business
Análisis y Síntesis
Topologías
Interconectividad
Interoperabilidad
Mercadotecnia
Programación
Ingeniería de Software
Recuperación de la Información
Sistemas de Información
Traductores
Modelos
Intercomunicación de Redes
Emprendedurismo


Ingeniería en Desarrollo de Software
Séptimo Semestre
Estándares
Metas/Objetivos
Perfil del egresado
Paradigmas
Estructuras Básicas
Integridad
Seguridad
Confiabilidad
Métodos
Representación del Conocimiento
Administración de TI
Formulación y Evaluación de Proyectos
Ingeniería de Software
Sistemas Operativos
Seguridad e Integridad de la Información
Inteligencia artificial
TI
Gestión de Proyectos


Ingeniería en Desarrollo de Software
Octavo Semestre
Estándares
Metas/Objetivos
Perfil del egresado
Administración de Proyectos de Software
Mantenimiento de Software
Cómputo Distribuido
Middleware
Servicios Web
Dispositivos
Algoritmos
Software Dedicado
Conceptualización de la Investigación
Ingeniería de Software
Sistemas Distribuidos
Gráficos por Computadora
Investigación


Ingeniería en Desarrollo de Software
Noveno Semestre
Perfil del egresado
Metas/Objetivos
Estándares
Desarrollo de la investigación
Auditoría en las unidades de informática
Recursos humanos
La función informática
Tópicos de manejo económico
Tópicos de manejo financiero
Teoría de las organizaciones
Investigación
La Administración de las Tecnologías de Información
Las Organizaciones

Appendix C – SSG Verification and Validation

Requirements traceability

Requirements traceability is concerned with recovering and documenting the source of requirements, predicting the effects of requirement. Tracing is fundamental to performing impact analysis when requirements change. A requirement should be traceable backward to the requirements and stakeholders that motivated it (from a software requirement back to the system requirement(s) that it helps satisfy, for example). Conversely, a requirement should be traceable forward into the requirements and design entities that satisfy it (for example, from a system requirement into the software requirements that have been elaborated from it, and on into the code modules that implement it, or the test cases related to that code and even a given section on the user manual which describes the actual functionality) and into the test case that verifies it. (IEEE Computer Society, 2014) (International Institute Of Business Analysis, 2015)

A traceability matrix is "*a graph that links requirements with their source and allows monitoring through all project's life cycle*". (Guía de los Fundamentos para la Dirección de Proyectos (Guía del PMBOK), 2008).

In this research, this instrument/artifact is composed by the next sections:

1. Set of requirements. In this section you must establish all the identified requirements; in the **Requirement code** column you must fill in a code for identifying the requirement along all documentation; in the **Requirement** column you must fill in the requirement and its description.
2. Traceability matrix. In this section you must establish if every requirement is being implemented in every task, activity, deliverable or phase mentioned below. In the column of the **Requirement code** you must fill in all the codes of the identified requirements and indicate with a "Yes" or a "No" if the requirement is being applied in the element of the corresponding row.

3. Summary of requirements status. In this section you must establish the status of every requirement. In the **Requirement code** you must fill in the code of every identified requirement, in the **Status** column you must fill in the current status of the requirement (e.g. established, accepted, in process, under construction, finished, etc.), in the **Progress (%)** column you must fill in the overall progress of the requirement, and in the **Comments** column you can add any additional comment of the status of the requirement.

The whole instrument can be found in Appendix D – Formats.

Revisions and inspections

Revisions and inspections include two elements (IEEE Computer Society, 2014) (Guía de los Fundamentos para la Dirección de Proyectos (Guía del PMBOK), 2008):

1. Measure and review to determine if work and deliverables meet the requirements and the product acceptance criteria;
2. Ensure that there are no errors, mistaken assumptions, lack of clarity or deviations in the executions of the processes.

Inspections can be performed through a checklist, which allows to validate and verify that all the requirements of the SSG tend to be implemented to 100% in the product.

The created checklist in this research includes the five phases of the development of a SSG (Barajas Saavedra A. , Álvarez Rodríguez, Mendoza González, & Oviedo de Luna, 2015):

1. Requirements
2. Technical aspects
3. Design
4. Construction
5. Test

Next, the main elements of the checklist:

1. Requirements. Here you must verify and validate that:
    a. Pedagogical aspects meet SSG definition.
    b. Didactic situation is correct, i.e., all problems must be randomly created and force the student to use formal reasoning. In addition, the didactic situation must be challenging.
    c. Conceptual art and all aesthetics meet the SSG definition, established pedagogical aspects and pedagogically assessed.
2. Technical aspects. In this phase you must verify and validate that:
    a. Game's conceptual overview are clearly established and meet the Requirements elements.
    b. Selected platform allow to implement the expected scope.
    c. Interface specification is clearly established and can be developed in the selected platform.
    d. Conceptual art and aesthetics are clearly established and meet the Requirements elements.
3. Design
    a. Art work and digital resources meet the SSG definition and the Requirements elements, taking into account the production time of the resources.
4. Construction
    a. Construction and programming meet the SSG definition and the Requirements elements, taking into account the production time of the resources.
5. Test
    a. The game meets the SSG definition and the Requirements elements, taking into account:
        i. Length of a turn.
        ii. Focused on a single area of knowledge.

iii. Graphical interface meet the Requirements elements and the Technical aspects.
iv. Cases meet the Requirements elements.

The whole instrument can be found in Appendix D – Formats.

Appendix D – Formats

In the next pages all the necessary formats for implementing the process are shown.

Also, the formats are attached to SPEM 2.0 model included in the CD.

Short Serious Game Design Document Part 1– Learning Needs

Date

Project Name

Short Serious Game Design Document – Learning Needs

Catrina Project

SGDD v0.0

Page **1** of **2**

1 Learning needs

1.1 Problem statement

1.2 Specific learning needs

Short Serious Game Design Document Part 2 – Competencies As Software Requirements

Date | Project Name

Short Serious Game Design Document – Competencies As Software Requirements

Catrina Project

SGDD v0.0 | Page **1** of **2**

Date Project Name

2 Competencies as Software Requirements Document (C.A.R.D.)

2.1 Standards, goals and graduate profiles (S.G.G.P.)

To identify the standards, goals and graduate profiles (SGGP) of the subject analyzed. This step is very important as the products of the subsequent steps must be aligned to these elements.

2.2 Contents and expected learning

To identify the contents and expected learning of the syllabus.

2.3 Contents and expected learnings grouping

To group, in areas of knowledge, the contents and expected learnings in accordance with S.G.G.P.

2.4 Areas of knowledge organization

To organize knowledge areas in accordance with S.G.G.P.

2.5 Competencies identification

To identify competencies from the knowledge areas grouping.

2.6 Competencies organization

To organize competencies and their knowledge areas in accordance with S.G.G.P.

SGDD v0.0 Page **2** of **2**

Short Serious Game Design Document Part 3 – Game Pedagogical Planning

Date

Project Name

Short Serious Game Design Document – Game Pedagogical Planning

Catrina Project

SGDD v0.0

Page **1** of **4**

Date Project Name

3 Game Pedagogical Planning (Ga.P.P.)

3.1 Goals

In this section you must clearly establish the goals of the game accordingly to the expected results of their usage by the users.

3.2 Pedagogical aspects

Here must be described the aspects to be covered by the game in terms of the expected competencies to be covered.

3.3 Learning theory

Here must set the learning theory to be used. For a list of learning theories go to the attached document named “Learning Theories in a Brief”.

3.4 Learning style

Here must be set if the game has to emphasize in some learning style, as to say:

1. Visual (spatial): You prefer using pictures, images, and spatial understanding.
2. Aural (auditory-musical): You prefer using sound and music.
3. Verbal (linguistic): You prefer using words, both in speech and writing.
4. Physical (kinesthetic): You prefer using your body, hands and sense of touch.
5. Logical (mathematical): You prefer using logic, reasoning and systems.
6. Social (interpersonal): You prefer to learn in groups or with other people.
7. Solitary (intrapersonal): You prefer to work alone and use self-study.

3.5 Competencies to cover

Here must be listed the competencies to be covered.

3.6 Expected learning

Here must be detailed all the outcomes expected after using the game.

3.7 Contents

Here must be listed the contents to be covered by the game.

3.8 Conceptual overview

In this section must be detailed the game concept including:

3.8.1 Game abstract

3.8.2 Objectives to be achieve by the game

3.8.3 Game justification

3.8.4 Core gameplay

SGDD v0.0  Page **2** of **4**

Date | Project Name

3.8.5 Game features

Genre	
Number of players	
Target platforms	
Game theme	
History summary	

3.8.6 Player characteristics

3.8.7 Initial scope

3.9 Planned activities

Here must be detailed the activities included in the game, taking into account the next aspects:

1. Mechanics
   - 1.1. Game elements categories
   - 1.2. Core game elements
   - 1.3. Rules
     - 1.3.1. Interaction rules
     - 1.3.2. Artificial Intelligence
   - 1.4. Game world elements
   - 1.5. Game log elements
   - 1.6. Other elements
   - 1.7. Assets list
2. Dynamics
   - 2.1. Game World
     - 2.1.1. Game theme details
     - 2.1.2. Missions/levels/chapters Flow
     - 2.1.3. Game detailed history
   - 2.2. Missions/levels/chapters elements
     - 2.2.1. Objectives
       - 2.2.1.1. Primary
       - 2.2.1.2. Secondary
     - 2.2.2. Rewards
       - 2.2.2.1. Implicit
       - 2.2.2.2. Explicit
     - 2.2.3. Challenges
     - 2.2.4. Other Missions/levels/chapters elements
   - 2.3. Missions/levels/chapters description
   - 2.4. Special areas
   - 2.5. Game interface

SGDD v0.0 | Page **3** of **4**

Date Project Name

2.6. Controls interface
2.7. Game learning
2.8. Game Balance

SGDD v0.0  Page **4** of **4**

Short Serious Game Design Document Part 4 – Conceptual Art and Aesthetics

Date | Project Name

Short Serious Game Design Document – Conceptual Art and Aesthetics

Catrina Project

SGDD v0.0 | Page **1** of **10**

4 Conceptual Art and Aesthetics (C.A.A.)

4.1 Sketches

In this section you must fill in the tables with the required information. You must create as many Sketch sections as you need.

NOTE: You must create all sketches for graphical user interfaces as well as for characters, objects, environments, etc. Also you must ensure the coverage of the competency or the area of knowledge to guarantee the knowledge acquisition by the user.

4.1.1 Sketch [Code]

Code	
Version	
Date	
Elaboration time	
Responsible	
Competency/Area of knowledge	
Description	

Sketch

Competency/Area of knowledge coverage

Interaction description

4.1.2 Sketch [Code]

Code	
Version	
Date	
Elaboration time	
Responsible	
Competency/Area of knowledge	
Description	

Sketch

Competency/Area of knowledge coverage

Interaction description

4.2 Wireframes

In this section you must fill in the tables with the required information. You must create as many Wireframe sections as you need.

NOTE: You must create all wireframes for graphical user interfaces as well as for characters, objects, environments, etc. Also you must ensure the coverage of the competency or the area of knowledge to guarantee the knowledge acquisition by the user.

4.2.1 Wireframe [Code]

Code	
Version	
Sketch code	
Sketch version	
Date	
Elaboration time	
Responsible	
Competency/Area of knowledge	
Description	

Wireframe

Competency/Area of knowledge coverage

Interaction description

4.2.2 Wireframe [Code]

Code	
Version	
Sketch code	
Sketch version	
Date	
Elaboration time	
Responsible	
Competency/Area of knowledge	
Description	

Wireframe

Competency/Area of knowledge coverage

Interaction description

4.3 Mock-ups

In this section you must fill in the tables with the required information. You must create as many Mock-up sections as you need.

NOTE: You must create all mock-ups for graphical user interfaces as well as for characters, objects, environments, etc. Also you must ensure the coverage of the competency or the area of knowledge to guarantee the knowledge acquisition by the user.

4.3.1 Mock-up [Code]

Mockup code	
Version	
Wireframe code	
Wireframe version	
Date	
Elaboration time	
Responsible	
Competency/Area of knowledge	
Description	

Mock-up

Competency/Area of knowledge coverage

Interaction description

4.3.2 Mock-up [Code]

Code	
Version	
Wireframe code	
Wireframe version	
Date	
Elaboration time	
Responsible	
Competency/Area of knowledge	
Description	

Mock-up

Competency/Area of knowledge coverage

Interaction description

Short Serious Game Design Document Part 5 – Technical Solution

Date Project Name

Short Serious Game Design Document – Technical Solution

Catrina Project

SGDD v0.0 Page **1** of **3**

5 Technical Solution (T.S.)

5.1 Platform

Choose the platform in which the game will run

Platform	Device		Chosen?
Mobile	iOS		
	Android		
	Windows Phone		
	BlackBerry		
Desktop	Windows		
	Windows Store Apps		
	Mac		
	Linux		
Web	Web player		
Consoles	PS3		
	PS4		
	PSVITA		
	PS Mobile		
	Xbox One		
	Xbox 360		
	Wii U		

5.2 Interface specification

Describe the types of devices, software, competencies, or platforms, as appropriate, to which development will focus its interface.

Specification

5.3 Interface overview

Establish a detailed description of the proposed development for the interfaces.

General overview

5.4 Proposed technical solution

Set the proposed technical solution to implement in your development.

Proposal

5.5 Constraints and assumptions

5.5.1 Technical constraints

5.5.2 Detailed technical constraints

5.5.3 Business constraints

5.5.4 Detailed business constraints

5.5.5 Assumptions

Short Serious Game Design Document Part 6 – Document Information

Date Project Name

Short Serious Game Design Document – Document Information

Catrina Project

SGDD v0.0 Page **1** of **2**

6 Document information

6.1 Definitions, acronyms and abbreviations

6.2 Document references

Short Serious Game Design Document Part 7 - Attachments

Date

Project Name

Short Serious Game Design Document-Attachments

Catrina Project

SGDD v0.0

Page **1** of **2**

7 Attachments

Game checklist

Date | Project Name

Game checklist

Catrina Project

Requirements Traceability v0.0 | Page 1 of 3

Date Project Name

1 Requirements

- ☐ Pedagogical aspects meet the short serious game definition
    - ☐ Game goals are clearly established
    - ☐ Game goals are less than three goals
    - ☐ Learning theory is clearly established
    - ☐ Learning style is clearly established
    - ☐ Game focus on a single area of knowledge
    - ☐ Area of knowledge is clearly established
    - ☐ Game has less than three expected learnings
    - ☐ Expected learnings are clearly established
    - ☐ Contents are clearly established
    - ☐ Planned activities are clearly established
        - ☐ Planned activities meet above elements
        - ☐ Planned activities are less than three activities
- ☐ The didactic situation is correct
    - ☐ Cases with formal reasoning
    - ☐ Cases randomly generated
    - ☐ Challenging content
    - ☐ Content that generate competition among users
- ☐ Conceptual art and aesthesis meet the short serious game definition and the pedagogical aspects
    - ☐ Interfaces and art work meet the pedagogical aspects
    - ☐ The game design is correct
        - ☐ Graphical user interface pedagogically evaluated

2 Technical aspects

- ☐ Conceptual overview is clearly established and meet all the above elements
    - ☐ Game abstract meet above elements
    - ☐ Objectives to be achieve by the game meet above elements
    - ☐ Game justification meet above elements
    - ☐ Core gameplay meet above elements
        - ☐ Game features meet above elements
        - ☐ Genre
        - ☐ Number of players
        - ☐ Target platforms
        - ☐ Game theme
        - ☐ History summary
    - ☐ Player characteristics meet above elements
    - ☐ Initial scope meet above elements
- ☐ Selected platform allow to implement the expected scope
    - ☐ Platform constraints are clear
- ☐ Interface specification is clearly established
    - ☐ Interface can be developed in the selected platform
- ☐ Conceptual art and aesthetics are clearly established and meet all the above elements

Requirements Traceability v0.0 Page 2 of 3

- ☐ The game design is correct
  - ☐ Graphical user interface has an aesthetic and minimalist design
  - ☐ Graphical user interface is friendly
- ☐ The number of interfaces is less than ten (10)
- ☐ Among the interfaces are included the next
  - ☐ Studio and sponsors logo screens
  - ☐ Menu screen
  - ☐ Game screen
  - ☐ Difficulty screen
  - ☐ Pause screen
  - ☐ Victory screen
  - ☐ Defeat screen
  - ☐ Credits screen
  - ☐ Configuration screen

3 Design

- ☐ Art work and digital resources meet the short serious game definition and the pedagogical aspects
  - ☐ Art work meet the pedagogical aspects
  - ☐ Digital resources meet the pedagogical aspects
  - ☐ Art work and digital resources production took less than 100 man hours

4 Construction

- ☐ Construction and programming meet the short serious game definition and the pedagogical aspects
  - ☐ Produced game meets the pedagogical aspects
  - ☐ Game production took less than 100 man hours

5 Test

- ☐ The game meets the short serious game definition and the pedagogical aspects
  - ☐ A typical turn lasts less than 10 minutes
  - ☐ It is focused on a single knowledge area
  - ☐ The graphical user interface has an aesthetic and minimalist design, friendly, and was pedagogically evaluated
  - ☐ The game has cases with formal reasoning
  - ☐ The game has cases randomly generated
  - ☐ The game has cases with different levels of difficulty
  - ☐ The content is challenging and generates competition among users

Requirements traceability

Date | Project Name

Requirements traceability

Catrina Project

Requirements Traceability v0.0 | Page 1 of 2

Date Project Name

1 Set of requirements

In this section you must establish all the identified requirements; in the **Requirement code** column you must fill in a code for identifying the requirement along all documentation; in the **Requirement** column you must fill in the requirement and its description.

Requirement code	Requirement

2 Traceability matrix

In this section you must establish if every requirement is being implemented in every task, activity, deliverable or phase mentioned below. In the column of the **Requirement code** you must fill in all the codes of the identified requirements and indicate with a "Yes" or a "No" if the requirement is being applied in the element of the corresponding row.

Applied in	Requirement code		
	Req01	Req02	...
Ga.P.P.			
Sketch			
Wireframe			
Mock-up			
Digital resources			
Game			
Tested			

3 Summary of requirements status

In this section you must establish the status of every requirement. In the **Requirement code** you must fill in the code of every identified requirement, in the **Status** column you must fill in the current status of the requirement (e.g. established, accepted, in process, under construction, finished, etc.), in the **Progress (%)** column you must fill in the overall progress of the requirement, and in the **Comments** column you can add any additional comment of the status of the requirement.

Requirement code	Status	Progress (%)	Comments

Requirements Traceability v0.0 Page 2 of 2

Appendix E – Pilot projects evidence

In this section you can find an extract of the documentation created for the pilot projects.

Alpinist GaPP

General Pedagogical Planning

General objectives	**To bring a new experience in platform gaming, in which the user will not worry about conventional platform-gaming issues.**
General pedagogical aspects	It's expected that the user learns: -how to take advantage of the abilities to climb and run in different environments (like rough terrain, water etc.) -calculate moves and actions with a given time. -develop a view of field to identify and guess the best path or way to follow.
Learning theory	-Discovery Learning -Self-Determination Theory
Learning style	Here must be set if the game(s) has/have to emphasize in some learning style, as to say: 1. Visual
Competencies covered	Measurement and conversion. Weight Speed Time Mass Volume
Contents	Length, volume, perimeter, weight/mass, area and time
Expected learning	The user will learn to explore while finding the optimal path to a goal. Will learn about time relation and distance while making his way to the goal, with a timer that represents seconds or minutes left. will learn about mass and weight in various types of levels like a swarm with platforms floating in the water. The different traction and friction of a snowy level and the handling of weight comparison when moving obstacles that block your way.
Planned activities	-Calculate time/speed relation to reach the goal. -push objects based on weight.
Conceptual overview	In this section must be detailed the game concept including: 1. You have to make your way by running and climbing, there's a timer you have to keep an eye on, there is no health gauge, and the penalization for being hit is the flinch and the delay that it causes. 2. If the user does not reach in time he loses. 3. The main objective is to reach the goal by different ways not only one linear route. 4. The game is a 2d based platform, you control the character with a 3rd person view. 5. You can move freely, only the time is a constraint. 6. Reaching the goal in time is the key to win. 7. Controls are customizable by defect you use: -direction arrow keys to move -UP arrow to jump

-Z to climb (maintain)

8. Special conditions:
   -you can only climb in walls, not roofs.
   -to start climbing you have to first jump and touch a wall

Alpinist Sketches

Sketches

Documentos para la especificación y diseño de sketches de GUI

Clave	**SK001**
Versión	1.0
Fecha	23/09/2014
Tiempo de elaboración	1 hora
Ingeniero	Daniel Isaí González Aréchiga
Competencia/AC	N/A
Descripción	En esta pantalla el usuario comienza a jugar y entrar al menú de opciones

Sketch

Cumplimiento de la Competencia/Área de conocimiento

N/A

Descripción de la interacción

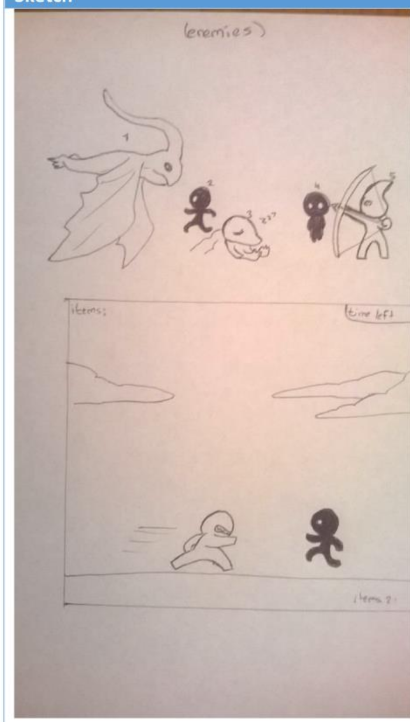
Entradas:

- **Botón de nuevo juego**
- **Botón de opciones**
- **Botón continuar**

Salidas:

- **Botón de nuevo juego :** Inicia una nueva partida desde 0.
- **Botón de opciones:** nos permite cambiar la configuración de los botones, audio, tamaño de pantalla etc.
- **Botón continuar:** nos permite continuar el juego en la parte que se interrumpió.

Clave	SK002
Versión	1.0
Fecha	23/09/2014
Tiempo de elaboración	1 hora
Ingeniero	Daniel González Aréchiga
Competencia/AC	Conversiones y Medidas
Descripción	En esta pantalla se muestra cómo se verán los enemigos en relación al jugador

Sketch


Cumplimiento de la Competencia/Área de conocimiento
Cada enemigo se mueve a una velocidad y fluidez de acuerdo a su tamaño y peso aparente.

Descripción de la interacción
- **Botón de salto:** El jugador salta.

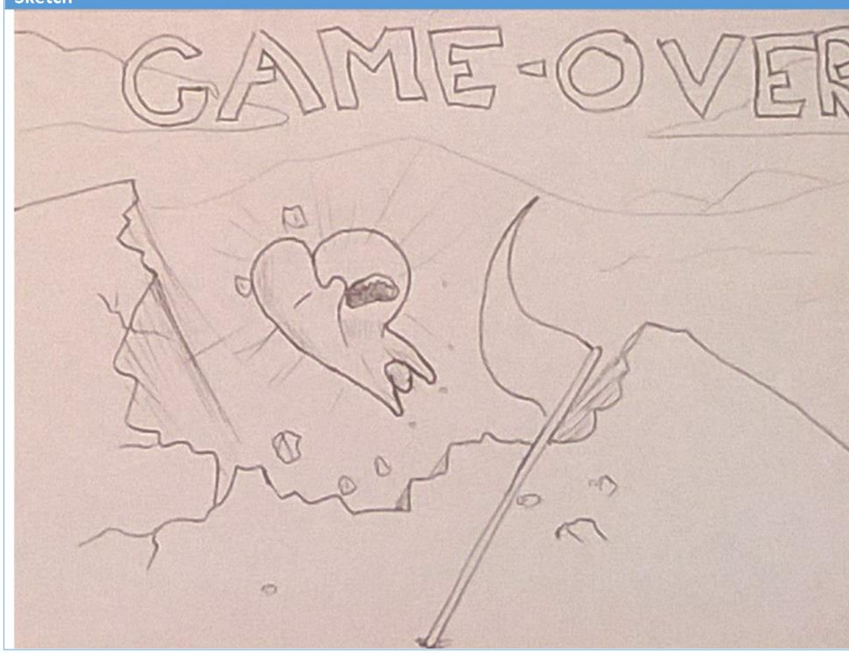
- **Botón de escalar:** El jugador se puede adherir a las paredes mientras esté presionado este botón.
- **Botones de dirección:** El jugador se mueve para la dirección indicada.

Salidas:

- **Botón de Pausa:** Muestra la pantalla del inventario
- **El jugador pierde las vidas:** El jugador regresa al principio del nivel
- **Tocar a un enemigo:** Se reduce el tiempo restante para completar el nivel, y el jugador se cae y tarda en recuperarse.

Clave	SK003
Versión	1.0
Fecha	23/09/2014
Tiempo de elaboración	30 minutos
Ingeniero	Daniel González Aréchiga
Competencia/AC	N/A
Descripción	Esta pantalla se muestra cuando el jugador pierde

Sketch



Cumplimiento de la Competencia/Área de conocimiento

N/A

Descripción de la interacción

Entradas:

- **Cualquier tecla:** volver a empezar el nivel

Salida:

- **N/A**

Clave	SK004
Versión	1.0
Fecha	29/09/2014
Tiempo de elaboración	30 minutos
Ingeniero	Daniel Gonzalez Aréchiga
Competencia/AC	Porcentajes
Descripción	Esta pantalla se muestra al terminar un nivel

Sketch

Cumplimiento de la Competencia/Área de conocimiento

Score: se muestra el puntaje en relación a el tiempo y retrasos recibidos.
Tiempo: En esta pantalla se muestra el tiempo en formato horas minutos y segundos dependiendo.

Descripción de la interacción

Entradas:
- **Cualquier tecla**
- **Botón replay**

Salida:
- **Cualquier tecla:** Transporta al usuario al siguiente nivel
- **Botón replay:** El jugador reinicia el nivel

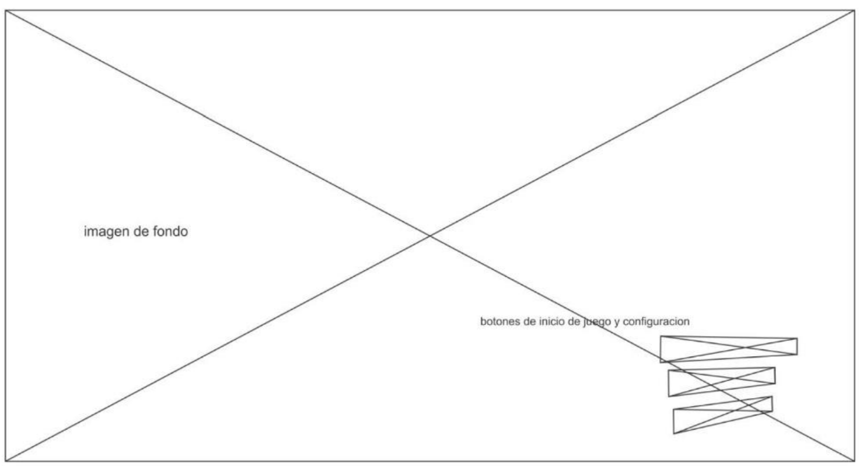
Alpinist Wireframes

WireFrames

Documentos para la especificación y diseño de sketches de GUI

Clave	SK001
Versión	1.0
Fecha	23/09/2014
Tiempo de elaboración	1 hora
Ingeniero	Daniel Isaí González Aréchiga
Competencia/AC	N/A
Descripción	En esta pantalla el usuario comienza a jugar y entrar al menú de opciones

Sketch



Cumplimiento de la Competencia/Área de conocimiento

N/A

Descripción de la interacción

Entradas:

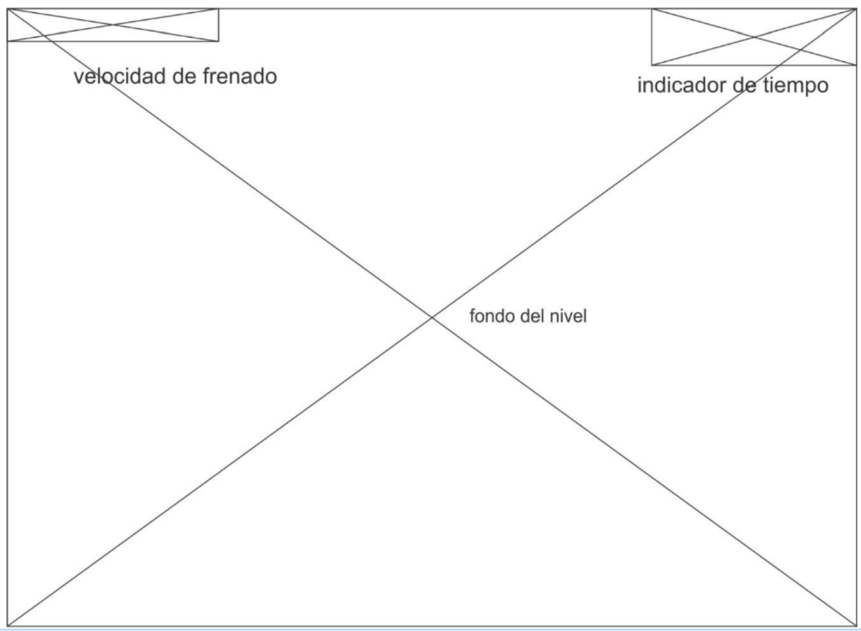
- **Botón de nuevo juego**
- **Botón de opciones**
- **Botón continuar**

Salidas:

- **Botón de nuevo juego :** Inicia una nueva partida desde 0.
- **Botón de opciones:** nos permite cambiar la configuración de los botones, audio, tamaño de pantalla etc.
- **Botón continuar:** nos permite continuar el juego en la parte que se interrumpió.

Clave	SK002
Versión	1.0
Fecha	23/09/2014
Tiempo de elaboración	1 hora
Ingeniero	Daniel González Aréchiga
Competencia/AC	Conversiones y Medidas
Descripción	En esta pantalla se muestran los elementos importantes que afectan la jugabilidad.

Sketch



Cumplimiento de la Competencia/Área de conocimiento

El tiempo está transformado de cuadros por segundo a minutos y segundos, así como la velocidad de frenado representada con números enteros.

Descripción de la interacción

- **Botón de salto:** El jugador salta.
- **Botón de escalar:** El jugador se puede adherir a las paredes mientras esté presionado este botón.
- **Botones de dirección:** El jugador se mueve para la dirección indicada.

Salidas:

- **Botón de Pausa:** Muestra la pantalla del inventario
- **El jugador pierde las vidas:** El jugador regresa al principio del nivel
- **Tocar a un enemigo:** Se reduce el tiempo restante para completar el nivel, y el jugador se cae y tarda en recuperarse.

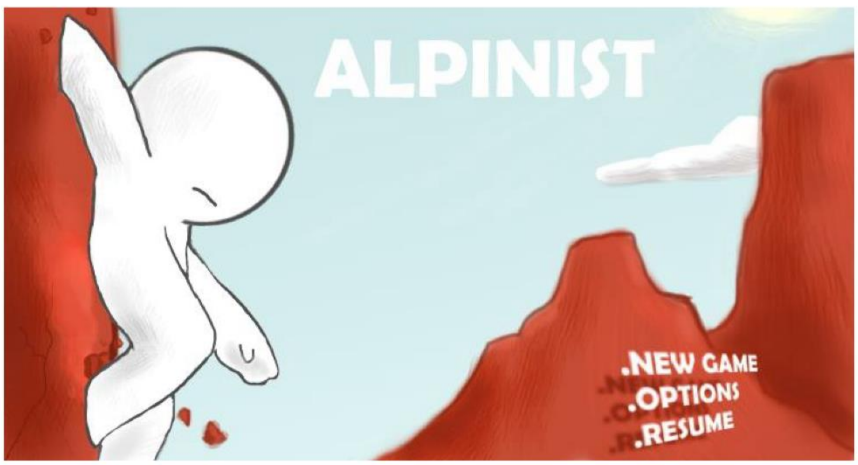
Alpinist Mockups

Mockups

Documentos para la especificación y diseño de mockups de GUI

Clave	SK001
Versión	1.0
Fecha	23/09/2014
Tiempo de elaboración	1 hora
Ingeniero	Daniel Isaí González Aréchiga
Competencia/AC	N/A
Descripción	En esta pantalla el usuario comienza a jugar y entrar al menú de opciones

Sketch



Cumplimiento de la Competencia/Área de conocimiento

N/A

Descripción de la interacción

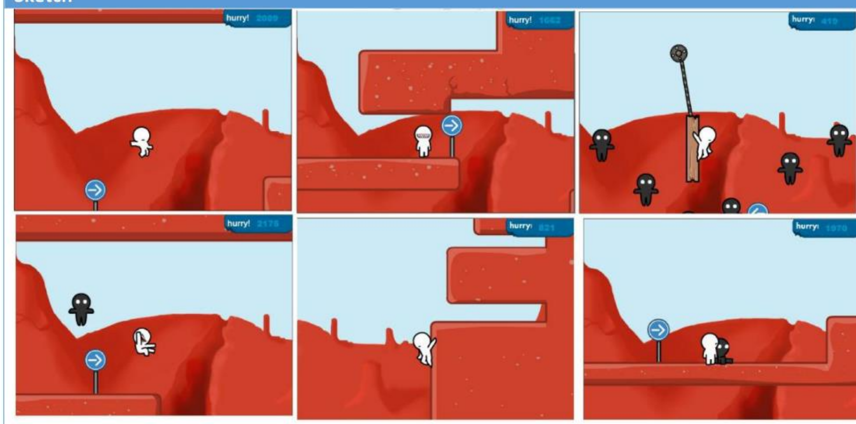
Entradas:

- **Botón de nuevo juego**
- **Botón de opciones**
- **Botón continuar**

Salidas:

- **Botón de nuevo juego :** Inicia una nueva partida desde 0.
- **Botón de opciones:** nos permite cambiar la configuración de los botones, audio, tamaño de pantalla etc.
- **Botón continuar:** nos permite continuar el juego en la parte que se interrumpió.

Clave	SK002
Versión	1.0
Fecha	23/09/2014
Tiempo de elaboración	1 hora
Ingeniero	Daniel González Aréchiga
Competencia/AC	Conversiones y Medidas
Descripción	En esta pantalla se muestra cómo se verán los enemigos en relación al jugador

Sketch


Cumplimiento de la Competencia/Área de conocimiento
Cada enemigo se mueve a una velocidad y fluidez de acuerdo a su tamaño y peso aparente.

Descripción de la interacción

- **Botón de salto:** El jugador salta.
- **Botón de escalar:** El jugador se puede adherir a las paredes mientras esté presionado este botón.
- **Botones de dirección:** El jugador se mueve para la dirección indicada.

Salidas:

- **Botón de Pausa:** Muestra la pantalla del inventario
- **El jugador pierde las vidas:** El jugador regresa al principio del nivel
- **Tocar a un enemigo:** Se reduce el tiempo restante para completar el nivel, y el jugador se cae y tarda en recuperarse.

Clave	SK003
Versión	1.0
Fecha	23/09/2014
Tiempo de elaboración	30 minutos
Ingeniero	Daniel González Aréchiga
Competencia/AC	N/A
Descripción	Esta pantalla se muestra cuando el jugador pierde

Mockup

Cumplimiento de la Competencia/Área de conocimiento

N/A

Descripción de la interacción

Entradas:

- **Cualquier tecla:** volver a empezar el nivel

Salida:

- **N/A**

Clave	SK004
Versión	1.0
Fecha	29/09/2014
Tiempo de elaboración	30 minutos
Ingeniero	Daniel Gonzalez Aréchiga
Competencia/AC	Porcentajes
Descripción	Esta pantalla se muestra al terminar un nivel

Sketch

Cumplimiento de la Competencia/Área de conocimiento

Score: se muestra el puntaje en relación a el tiempo y retrasos recibidos.
Tiempo: En esta pantalla se muestra el tiempo en formato horas minutos y segundos dependiendo.

Descripción de la interacción

Entradas:

- **Cualquier tecla**
- **Botón replay**

Salida:

- **Cualquier tecla:** Transporta al usuario al siguiente nivel
- **Botón replay:** El jugador reinicia el nivel

Geometrix Game GaPP

Planeación Didáctica del Videojuego

Objetivos pedagógicos generales	Mediante el estudio de las Matemáticas En la Educación Básica se pretende que los niños y adolescentes Desarrollen formas de pensar que les permita formar conjeturas y procedimientos para resolver problemas, así como elaborar explicaciones para ciertos hechos numéricos y geométricos Como resultado del estudio de las Matemáticas los objetivos a cumplir de los alumnos es que Conozcan y usen las propiedades básicas de ángulos y diferentes tipos de rectas, así como círculo, triángulos, cuadriláteros, polígonos regulares e irregulares, al realizar algunas construcciones y calcular medidas. Usen e interpreten diversos códigos para orientarse en el espacio y ubicar objetos o lugares
Aspectos pedagógicos generales	Los estudiantes sabrán calcular perímetros, áreas, describir figuras, construir figuras y cuerpos geométricos. Además de poner en práctica el manejo de un sistema de coordenadas en un plano cartesiano.
Teoría del aprendizaje	Basada en Diez nuevas competencias para enseñar - Philippe Perrenoud - SEP 2004
Estilos de aprendizaje	Visual y Kinestésico
Competencias que se favorecen	Geometría
Contenidos y subcontenidos	• Identificación de los ejes de simetría de una figura(poligonal o no) y figuras simétricas entre sí, mediante diferentes recursos • Elección de un código para comunicar la ubicación de objetos en una cuadrícula. Establecimiento de códigos comunes para ubicar objetos • Representación gráfica de pares ordenados en el primer cuadrante en un sistema de coordenadas cartesianas • Anticipación y comprobación de configuraciones geométricas que permiten construir un cuerpo geométrico
Descripción conceptual general	Es un videojuego de plataforma el cual a lo largo de su aventura se aplicarán los diversos conocimientos sobre geometría y posicionamiento sobre un plano cartesiano. El juego consta de varios niveles los cuales tendrán un jefe de nivel, el cual se enfrentará a través de mini juegos que impliquen un conocimiento ya sea sobre la geometría o posicionamiento de plano llevando a un mejor entendimiento de los conceptos, nombres, fórmulas, etc. Uno de los aspectos que estarán en práctica es que a través del paso

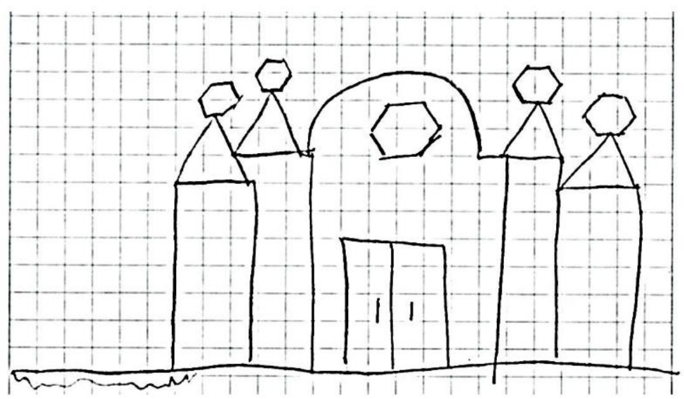
	del nivel ya que el juego contará con un comportamiento aleatorio en cuanto a las soluciones, el jugador tendrá pistas sobre cómo derrotar al jefe final, esto con la idea de que también se alimenta la memoria y el aprendizaje por error. También contará con una sección de tibias las cuales al final de nivel se podrá ganar puntos extras o vidas de acuerdo a la dificultad de la tibia que se conteste. Características: - Tutorial de Introducción durante la ejecución - Destrucción de enemigos comunes mediante aritmética básica - Desplazamiento del mundo por Coordenadas - Utilización de fórmulas y Resultados para la destrucción de enemigos
Aprendizajes Esperados	Conozcan y usen las propiedades básicas de las figuras geométricas. Diferentes tipos de rectas, así como círculo, triángulos, cuadriláteros, polígonos regulares e irregulares, al realizar algunas construcciones y calcular medidas. Usen e interpreten diversos códigos para orientarse en el espacio y ubicar objetos o lugares ,Expresen e interpreten medidas con distintos tipos de unidad, para calcular perímetros y áreas de triángulos, cuadriláteros y polígonos regulares e irregulares
Actividades	El aprendizaje esperado se verá demostrado en la destrucción de los enemigos ya que para destruir a un enemigo se tendrá, que mostrarle su fórmula de área o perímetro, indicarle cuál es su área o perímetro, seleccionando la opción correcta de entre 3 posibles, las cuales para favorecer el razonamiento siempre estarán de una forma distinta, para el aprendizaje de coordenadas, para la destrucción de los enemigos se buscara su posicionamiento mediante un plano cartesiano, utilizando varios códigos de coordenadas tales como (Letra,Letra)(numero,numero)(Figura,Figura)(Letra,numero)(numero,Figura)... etc.

Geometrix Game Sketch

Sketches

Documentos para la especificación y diseño de sketches de GUI

Clave	Castillo
Versión	1.0
Fecha	23/09/2014
Tiempo de elaboración	20 min
Ingeniero	José Luis Falcón Martínez
Competencia	Geometría
Descripción	Al final de cada nivel se tentar que pelear contra un jefe, para indicar el final del nivel cada jefe tendrá un castillo propio

Sketch


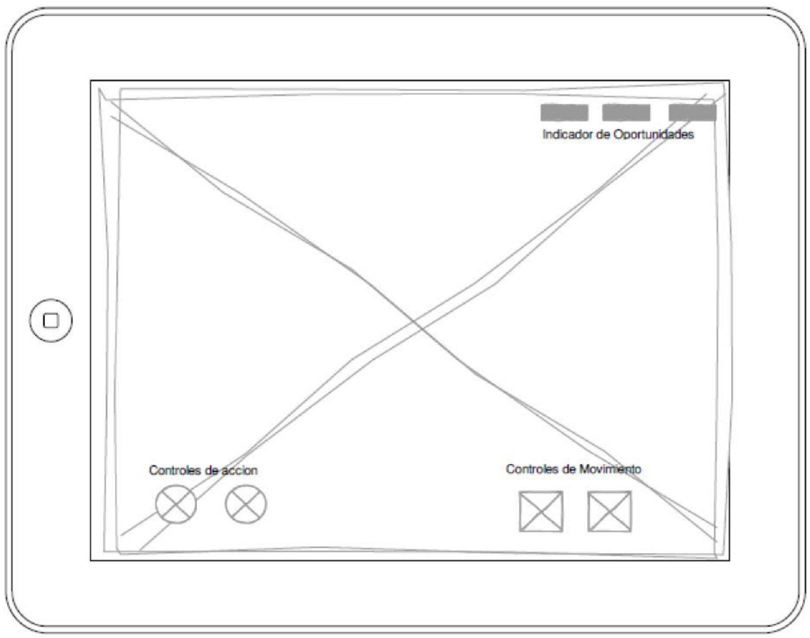
Cumplimiento de la competencia
n/a

Geometrix Game Wireframe

Wireframes

Clave	Game
Versión	1.0
Fecha	02/09/2014
Tiempo de elaboración	8 min
Ingeniero	Alejandro Medina Robles
Competencia	Geometría
Descripción	En esta pantalla se lleva a cabo la interacción principal del usuario, para el desarrollo de móviles la interacción será por medio de los controles de moviente y acción, para pc por medio del teclado

Sketch



Cumplimiento de la competencia
Es donde el personaje principal hace su aparición para el usuario, este inicia a controlarlo por medio de los mandos habilitados

Descripción de la interacción
Inicia la interacción principal

Geometrix Game Mockup

Clave	Menu
Versión	1.0
Clave wireframe	Menu-1
Versión wireframe	1.0
Fecha	4/1/2015
Tiempo de elaboración	15 min
Ingeniero	Alejandro Medina Robles
Competencia/AC	Geometria
Descripción	Pantalla de inicio del juego, con opción de jugar y salir

Mockup

Cumplimiento de la Competencia/Área de conocimiento
N.A. Pantalla inicial de la aplicación.

Descripción de la interacción
Al iniciar la aplicación el usuario podrá seleccionar jugar, haciendo click en "Jugar"

Appendix F – Methodology

The methodology used to conduct this research is:

1. Identification of the problem.
    a. Identify the problem of learning in Mexico.
    b. Identify that the problem is important enough to be studied.
    c. Identify the main areas or topics of the problem, e.g. Mathematics, Spanish, Sciences, etc.
    d. Choose an area to study.
2. Description of the basic theories and the state of the art of the problem.
    a. Describe the problem and its background.
    b. Describe the previous approaches to solve the problem.
    c. Stipulate why those previous approaches have not achieved their goals.
3. Establishment of the proposed solution to the problem.
    a. Identify a mechanism through which problem can be solved.
    b. Stipulate why that mechanism will solve the problem.
4. Description of the basic theories and the state of the art of the proposed solution.
    a. Describe the related works and their contributions, including background and state of the art.
    b. Describe why those related works do not solve the problematic.
    c. Propose a new approach that solves the problematic.
5. Proposal development.
    a. Develop the proposal.
    b. Justify the proposal describing why it solves the problematic.
    c. Describe in great detail the proposal.
6. Testing the proposal through a study case.
    a. Identify potential schools.
    b. Design tests initial and control evaluations. The tests will be designed to evaluate knowledge level of students in the next knowledge areas: Areas, Handling of solid figures, Fractions, Shapes and polygons, and Crossed product.

c. Select school.
d. Select student group.
e. Divide the group was into two parts; taking into account that in both groups, students' average grade must be equally distributed, i.e., the group must be divided according to the average grades of the students.
f. Apply initial evaluation to all students.
g. The test group will use video games in one-hour sessions twice a week for four weeks.
h. At the end of eight sessions, a second test will be applied to identify the impact of video games use.

7. Analysis of the results obtained from the application of the study case.
    a. The collected data will be analyzed with SPSS software.

Appendix G – Work plan

Id	Nombre de tarea	Duración	Comienzo	Fin
1	**DICC**	**755 días**	**lun 14/01/13**	**vie 04/12/15**
2	**Primer semestre**	**120 días**	**lun 14/01/13**	**dom 30/06/13**
3	Revisión de literatura	87 días	lun 14/01/13	mar 14/05/13
4	Elaboración Investigación y Tesis	33 días	mié 15/05/13	dom 30/06/13
5	Evaluación SI 1	0 días	dom 30/06/13	dom 30/06/13
6	**Segundo semestre**	**132 días**	**lun 01/07/13**	**mar 31/12/13**
7	Elaboración Investigación y Tesis	132 días	lun 01/07/13	mar 31/12/13
8	Presentación Ponencia	0 días	mar 31/12/13	mar 31/12/13
9	Evaluación SI 2	0 días	mar 31/12/13	mar 31/12/13
10	Evaluación ST 1	0 días	mar 31/12/13	mar 31/12/13
11	**Tercer semestre**	**129 días**	**mié 01/01/14**	**lun 30/06/14**
12	Elaboración Investigación y Tesis	129 días	mié 01/01/14	lun 30/06/14
13	Presentación Ponencia	0 días	lun 30/06/14	lun 30/06/14
14	Evaluación SI 3	0 días	lun 30/06/14	lun 30/06/14
15	Evaluación ST 2	0 días	lun 30/06/14	lun 30/06/14
16	**Cuarto semestre**	**132 días**	**mar 01/07/14**	**mié 31/12/14**
17	Elaboración Investigación y Tesis	132 días	mar 01/07/14	mié 31/12/14
18	Evaluación SI 4	0 días	mié 31/12/14	mié 31/12/14
19	Evaluación ST 3	0 días	mié 31/12/14	mié 31/12/14
20	**Quinto semestre**	**129 días**	**jue 01/01/15**	**mar 30/06/15**
21	Elaboración Investigación y Tesis	129 días	jue 01/01/15	mar 30/06/15
22	Publicación Journal 1	0 días	mar 30/06/15	mar 30/06/15
23	Evaluación SI 5	0 días	mar 30/06/15	mar 30/06/15
24	Evaluación ST 4	0 días	mar 30/06/15	mar 30/06/15
25	**Sexto semestre**	**113 días**	**mié 01/07/15**	**vie 04/12/15**
26	Elaboración Investigación y Tesis	24 días	mié 01/07/15	lun 03/08/15
27	Elaboración versión final Tesis	89 días	mar 04/08/15	vie 04/12/15
28	Publicación Journal 2	0 días	vie 04/12/15	vie 04/12/15
29	Evaluación SI 6	0 días	vie 04/12/15	vie 04/12/15

Appendix H – Work reviews

First semester

Table 22. First semester reviews

Researcher	Institution	Review	Solving
Dr. Jaime Muñoz	UAA	How you go from e-learning to video games?	Chapter 2
Dr. Jaime Muñoz	UAA	Show concentrate competencies identified for sixth grade.	Chapter 6
Dr. Francisco Acosta	UJAT	Review the work of Luis Montanez to denote ides and differences from the present investigation. This to add as related work.	The work has been reviewed and found to have no relation to the current research work. Therefore, not added as related work.
Dr. Francisco Acosta	UJAT	Improve the research questions and hypotheses because there is no reasonable doubt.	Chapter 1
Dr. Manuel Mora	UAA	Narrow the problematic.	The problem has been delimited to only focus on the design of a process of game development, rather than on the pedagogical aspects inherent in the design of the game.
Dr. Manuel Mora	UAA	What and Why are resolved as the literature review makes clear that there is indeed a problem. The How to be tuned.	
Dr. Manuel Mora	UAA	Review competencies literature.	

Second semester

Table 23. Second semester reviews

Researcher	Institution	Review	Solving
Dr. Genaro Rebolledo	UV	The first observation was made with respect to the finding of a lack of information about game development processes. At this point, Dr. Rebolledo said information does exist and that he participated in projects related to the topic where researchers have contributed much in terms of gaming elements to successful knowledge transfer.	This information will be requested from Dr. Rebolledo to expand the research.
Dr. Genaro Rebolledo	UV	The second observation emphasizes that the research has various contributions, for which it is not clear the main focus of the work, leading to questioning if the scope is clear, its implications and if time is sufficient.	To clarify this recurring observation, the thesis protocol has been rewritten to focus only in the aspect of the game development process, leaving as contextualization all the work on pedagogics and competencies.
Dr. Francisco Acosta	UJAT	There is concern about how the process will be validated from the point view of what type of validation will be performed. There are two possibilities: (1) validate the model pedagogically, or (2) validate the model from the point of view of software engineering.	Both options require a lot of time, so neither will be held. Model validation is carried out by using an illustrative example as a proof-of-concept together with a preliminary study considering some Educational Videogames for Mathematics, along with usability tests.

Third semester

Table 24. Second semester reviews

Researcher	Institution	Review	Solving
Dr. Edgard Benitez		- Utilizar menos texto en las láminas, ir directo a los puntos importantes. - Objetivo general: Aclarar que "útiles" es para aegurar la calidad - Hipótesis: Como comprobar la hipótesis? Pues con los casos de prueba. - Se tiene la documentación relacionada? Sí.	
Dr. Angel Muñoz	UAA	Cual es el avance real de la tesis?	
Dr. Francisco Álvarez	UAA	Qué modificaciones se han hecho desde el seminario anterior al actual	