- ORIGINAL ARTICLE -

Educational Serious Games as a Service: Challenges and Solutions

Juegos Serios Educativos Como Servicio: Retos y Desafíos

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Abstract

Cloud computing is a distributed computing technology that facilitates access to the resources in a dynamic, scalable and highly available manner. One of its service models is SaaS (Software as a Service) which allows executing Web applications in a flexible and elastic way while offering collaborative characteristics. The integration of SaaS in educational environments promotes academic performance and facilitates knowledge management, allowing for storage, exchange, access and synchronization of information. On the other hand, educational serious games promote among the people involved: collaboration, communication, social abilities, critical thinking and problem solving. The main objective of this investigation is to analyze the challenges that SaaS, with its collaborative and multitenancy characteristics present to the execution of educational serious games. This is named ESGaaS - Educational Serious Games as a Service. The analysis was developed based on a review of the existing literature through the methodology known as Systematic Mapping Studies (SMS) [1] which facilitated the generation of investigation questions, search strategies, key words and inclusion and exclusion criteria applied to identify articles in several sources. This investigation facilitated the development of a list of functional characteristics that the educational serious games will acquire when used as software for service.

Keywords: Serious games, educational serious games, cloud computing, software as a service, multi-tenant, Argentina, Costa Rica.

Resumen

La computación en la nube es una tecnología de computación distribuida que ofrece acceso a los recursos de manera dinámica, escalable y con alta disponibilidad. Uno de sus modelos de servicio, es el SaaS (Software as a Service) que permite ejecutar aplicaciones Web de manera flexible y elástica, además de ofrecer características colaborativas. La integración del SaaS en los entornos educativos potencia el rendimiento académico y facilita la gestión del conocimiento permitiendo almacenar, intercambiar, acceder y sincronizar información. Por su parte los juegos serios educativos potencian, entre los involucrados, la colaboración, comunicación, habilidades sociales, pensamiento crítico y resolución de problemas. El objetivo principal de esta investigación consistió en analizar los retos que SaaS, con sus características colaborativas y multi-inquilino, ofrece a la ejecución de juegos serios educativos, lo cual denominamos ESGaaS – Juegos Serios Educativos como Servicio. El análisis fue realizado a partir de una revisión de literatura existente a través de la metodología denominada Systematic Mapping Studies (SMS) [1] la cual permitió generar preguntas de investigación, estrategias de búsqueda, palabras claves y criterios de inclusión y exclusión que fueron aplicadas para localizar artículos en diversas fuentes. Como resultado del trabajo se elabora una lista de características funcionales que los juegos serios educativos adquirirían al ser utilizados como software como servicio.

Palabras claves: Juegos serios, juegos serios educativos, computación en la nube, software como servicio, multi-inquilino, Argentina, Costa Rica.

1. Introduction

Presently, the rapid growth and immersion of technologies in the market has led to the design and implementation of new tools and computing applications that impact directly the economic, educational and social sectors.

One of the reasons for the creation of the concept cloud computing is for the need of having **high availability** of different computational resources, processing of high volumes of information in real

time, as well as the need to offer a public service of technological resources to the users.

The term cloud computing could be defined as, "*a distributed computing technology that provides dynamically scalable computing resources including storage, computation power, and applications delivered as a service over the Internet*" [2].

Cloud computing will have a significant impact in the educational field, specifically to support the teaching and learning processes, in which students, faculty and staff could perform daily in an efficient way and will benefit mainly due to the costs reduction because they will be using the applications available offered by a cloud services supplier. This will allow faculty and students to develop a formative process in a **collaborative** way through the joint edition of documents, investigation group activities, and by facilitating the process of improvement returns (feedback) [3]. Also, unlike a traditional web application, cloud computing allows enhancing the performance, flexibility and scalability of the resources and applications in real time (elasticity).

The specific integration of service models SaaS in educational environments enhances academic performance, effectiveness and efficiency of the students and faculty by facilitating knowledge management since it allows storage, exchange, access and documents and information synchronization in a fast an updated manner; for instance through Google Drive, Dropbox, Sky-Drive, and iCloud, which offer a flexible environment to access materials and to facilitate **collaborative work** amongst several users [2, 4].

Faculty constant education and training on technological competencies are key variables to improve the teaching and learning processes [5]. In this context, Serious Games have acquired a main role in regards to faculty education and/or training by enhancing collaboration, communication, social and/or cultural skills; citizenship, creativity, critical thinking, problem solving and technological competencies [6].

Technical issues observed in cloud computing (high availability, collaboration and multi-tenant) are suitable to form and develop faculty technological competencies. The high availability of cloud computing facilitates keeping educational materials and software available and accessible at all moments and from any place. The concept multi-tenant allows that each player (in our case the teacher) has total availability of the resources, as well as to keep a personal record of the activities. Collaboration among parties offers the necessary feedback to consider advancements and activities developed during the game.

In this way, the faculty can improve their learning from their mistakes and experiences while interacting through a serious game that has been

accessed and requested as a software service in cloud computing.

Based on the above, this article has a revision related to the analysis of the challenges and solutions that SaaS, with its collaborative and multi-tenant characteristics, offers to the execution of educational serious games as software service.

The results of this investigation could be of interest for Higher Education Institutions (HEIs) and teacher training institutions that would like to use and incorporate serious games into their formative processes.

From now on, this article is organized as follows: section 2 corresponds to background related with the definition of the terms cloud computing, SaaS and serious games. Section 3 refers to background. Section 4 corresponds to the methodology used in the investigation developed (SMS, Systematic Mapping Studies), in which section 4.1 describes planning; section 4.2 presents the execution and section 4.3 Mapping results. Then, section 5 is for conclusions and finally section 6 refers to future works.

2. Related Works

Results obtained from different investigators that have used the methodologies of systematic literature reviews, and/or Systematic Mapping Studies to record, describe, analyze and characterize a series of educational serious games were investigated. Among the main investigations analyzed we can find:

- ✓ A multivocal literature review on serious games for software process standards education [7].

- ✓ A systematic literature review on serious games evaluation: An application to software project management [8].

- ✓ A systematic literature review of games-based learning empirical evidence in primary education [9].

- ✓ Engagement in digital entertainment games: A systematic review [10].

- ✓ Digital card games in education: A ten year systematic review [11].

- ✓ An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games [12].

- ✓ An activity theory-based model for serious games analysis and conceptual design [13].

- ✓ A systematic literature review of empirical evidence on computer games and serious

games [14].

Also, an investigation was developed on the experiences that have used educational serious games to maximize formative processes in higher education and that have preferably been offered as software as a service. Among the main serious games identified there are:

- ✓ **DEBORAH Game**. Educational serious game developed in Brazil. Its objective is to maximize abilities in technological and accounting competencies for faculty and students [15, 16]. It is available on line: http://deborahahg.wixsite.com/deborah

- ✓ **AstroCódigo**. Serious game developed in Argentina. Its objective is to solve scenarios in an algorithmic and playful way. In this way, it helps structure the way of thinking, to organize it and to solve problems in an structured way [17, 18, 19, 20]. The game is available in Spanish and English and can be downloaded and installed from http://www.astrocodigo.com/

- ✓ **RITA**. Educational serious game RITA (Robot Inventor to Teach Algorithms) was developed in Argentina. Its objective is to maximize the development of technological abilities and knowledge, specifically in the area of blocks programming by stimulating the logic of programming and algorithmic [21, 22].

- ✓ **Tamagocours**. Serious game developed in France. Its objective is to maximize the abilities in technological competencies and make faculty aware of the author rights related to French educational resources [23, 24, 25].

As previously described, different results have been analyzed in a theoretical level (systematic literature reviews) as well as practical (educational serious games) related to previous experiences of the use of serious games in the educational environment. Although it is evident that some experiences use serious games to favor formative processes, no concrete studies were found to prove that they were offered as a software as a service in cloud computing.

In this context, the main objective of this investigation is to identify the SaaS challenges and solutions to offer the ESGaaS. Also, to identify functional characteristics that educational serious games will acquire when offered as software as a service.

3. Background

Constant technological advancement nowadays has caused the production and management of high data and information. That is why different government, commercial and social institutions have had the need to adjust their information backup and storage processes to guarantee immediate access and availability in a safe mode.

This section presents conceptual bases for Cloud Computing, SaaS and Serious Games, which are the pillars on which the research carried out is based.

3.1. Cloud Computing

Cloud computing can be understood as a new computing model that offers in a shared way a series of services and high level technological resources, which are offered in a public and/or private way, on demand and highly available and that can be accessed by the users through a browser with internet connection.

The cloud model enunciated by NIST (National Institute of Standards and Technology) responds to the definition of 3 service models and 4 deployment models [26, 27, 28].

In regards to service models, cloud computing offers to the users the possibility of consuming resources on demand, through applications such as Software as a Service (SaaS) and also Infrastructure as a Service (IaaS) where users can acquire this services model to use different technological resources (processing, servers, storage and network) in which software could be executed, including applications and operating systems. On the other hand, Platform as a Service (PaaS) is the model in which the user can access the development of applications and their services deployment in internet, of own applications as well as acquired (developed using programming environments supported by the provider), allowing the development of personalized software applications.

In regards to the four deployment models [29, 30, 31, 32], cloud computing offers the possibility for customers to access computing services virtualized through Public cloud, in which the infrastructure is to serve the public or companies in general, which are the property of the organization that sells the services. Also, they could opt for a private cloud, which will facilitate higher agility in regards to the organization's resources management and flexibility (internal administration and infrastructure are managed or controlled only by the organization that offers this service). Other of the deployment models that could be used by the customer is the Community cloud; it offers common services to similar customers, in which several organizations share the computing infrastructure in the cloud, but each component keeps its autonomy.

Finally, the user can use the Hybrid cloud, model that offers mixed infrastructure services, in which the computing infrastructure in the cloud is composed of two or more clouds; either private or public which allow them to send data and applications among them. They are still unique entities, but they are linked through standardized or patented technologies, which allow data and applications portability.

Figure 1, (taken and adapted from the text Bazán [30]) shows how the 3 service models for cloud computing can be integrated. IaaS is an indispensable requirement to be able to have the other two service models. It can also be appreciated that the SaaS is available, directly supported over the infrastructured services. This is the analysis case of this work.
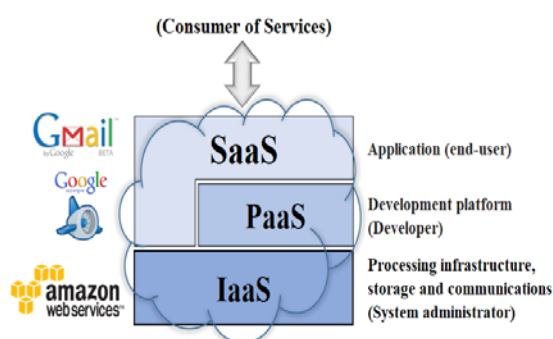

Fig. 1: Cloud Computing Models Integration

This investigation considers cloud computing from the SaaS focus and its support on the IaaS to execute educational serious games. In this context, the most important aspects considered are collaborative work (facilitated by the access to a common repository in a synchronized way), multi-tenant modality (resources grouped to serve multiple customers) and the elastic supply capacity of technological resources.

3.2. Software as a service (SaaS)

SaaS is a service model that allows the customer to use the applications that are running in a cloud infrastructure and which adapts more easily to most of the requirements of all type of organizations, public as well as private and even educational institutions [27, 33, 34, 35].

Applications and services in SaaS can be accessed by the user from different electronic devices through a browser with internet connection from any part of the world, with the particularity that the user feels as if it were his own personalized software [36, 37, 38, 39, 40].

In the case of educational institutions, SaaS could be a viable alternative to solve part of the institutional requirements, specifically referring to the ones related to software and hardware

acquisition needed for the continuous faculty training, in particular, the execution of educational serious games [41, 42, 43, 44].

3.3. Serious game

Serious games are those games that have an explicit educational objective and that have been thoroughly thought as a learning instrument or tool that allow the user to experiment situations similar to real life, learn from their mistakes through immediate feedback and acquire experience without risking his safety and physical integrity, as well as to reduce costs and time [20, 45, 14, 10, 12].

In general, serious games have been developed with the purpose of training and change behavior in business, industry, commercialization, health, government (military training), NGO's, as well as in education, to maximize attitude and behavior changes, through collaboration among players and the exchange of innovative strategies that will maximize the acquisition and development of new competencies and/or technological abilities that allow the generation of significant knowledge among faculty and staff [46, 47, 48].

It is important to rescue that there is a clear difference between traditional video games oriented only to entertaining and serious games, which go beyond a ludic objective. Serious games aside from the entertainment have a specific purpose, which could be learning, skills acquisition, training, attitude and behavior change [49, 50, 51].

The next section describes in detail the methodological process used in this investigation.

4. Methodology

To respond to the objective of this study, the investigation was developed through a descriptive design with a qualitative methodological focus. For this, a revision of the existing literature was developed through the methodology called Systematic Mapping Studies (SMS). Particularly, the investigation was developed through the following three phases: planning, execution and results of the mapping [1, 52].

4.1. Planning the mapping

Planning the mapping was based on different authors, in particular Kitchenham [52], Kitchenham et al [53, 54], Petersen et al [1], Calderón et al [7], who defined a protocol with detailed recommendations to be considered to develop this type of study. Among the decisions made for this investigation, there are: a) generate investigation questions; b) define search strategies in different databases to find articles in magazines, books or chapters, thesis, investigation reports and congress

acts; *c)* define key words and search strings; d*)* define criteria to include or exclude bibliographical material; e*)* define the process for the preliminary selection; f*)* define the process for the final selection.

4.2. Executing the mapping

This section describes in detail the process developed during the corresponding phase of the mapping execution, which includes the decisions made in relation to the definition of a series of aspects such as: research questions (RQs), search strategies, key words and search strings, criteria for bibliographical material inclusion or exclusion, definition of the process to develop a preliminary and final selection of the primary studies found.

4.2.1 Research questions (RQs)

Based on the study objective proposed, 5 research questions were defined which include the appropriate criteria to develop the inclusion and/or exclusion of the bibliographical references.

Research questions have been defined with the objective of serving as a guide to identify the challenges and solutions of the ESGaaS execution. Similarly, research questions aim at serving as a guide to identify the functional characteristics that could acquire educational serious games when offered as a software service.

RQ1. How are the concepts of cloud computing, software as a service and serious games defined?

RQ2. What are the chances of cloud computing and of serious games in education?

RQ3. Which are the technical requirements of the SaaS applications?

RQ4. Which are the general requirements of the educational serious games?

RQ5. Which are the challenges and solutions that could present for the execution of the ESGaaS when considering the technical requirements of the SaaS application and the technical requirements of the Educational Serious Games?

RQ1 facilitates knowing in general about the background for the topic of the study; specifically, concepts directly related to cloud computing, software as a service and serious games which will be addressed from the point of view of different authors. These concepts provide context to the study developed.

Through **RQ2** the purpose is to identify cloud computing possibilities in terms of how it can strengthen knowledge management, mainly through its **collaborative component** which has an important role in the formative processes. Also, another objective of the RQ2 is to identify possibilities of the serious games to maximize the configuration of innovative teaching and learning processes in the HEIs that allow the generation of significant knowledge.

RQ3 allows to inquire the main desirable technical requirements that an application should have in general to be offered as a software service in cloud computing.

In this line, **RQ4** allows identifying the general characteristics that educational serious games should have, based on the findings identified during the bibliographical revision of the different investigations done by specialists in the area in study.

Finally, **RQ5** allows identifying challenges and solutions for the ESGaaS analysis, through the comparative analysis of the findings obtained with RQ3 and RQ4.

4.2.2 Search Strategy

The search strategy used was the consultation of different databases such as **IEEE Xplore Digital Library**[1],**ScienceDirect**[2], also the use the digital institutional repository **SEDICI** (Servicio de Difusión de la Creación Intelectual de la Universidad nacional de La Plata (UNLP))[3] and the **SIBDI** (Sistema de Bibliotecas, Documentación e Información de la Universidad de Costa Rica (UCR))[4], which were selected because they facilitate the access to documents published in national and international magazines, as well as to the congresses minutes with the corresponding assessment and recognition from the international scientific community [55].

4.2.3 Keywords and Search String

Bibliographic references investigation was done for the period between 2005 to 2018. The search was done through key words in Spanish and English such as *ventajas* - advantages, *desventajas* - disadvantages*, características* - characteristics*, computación en la nube* - Cloud Computing*, software como servicio* - software as a service, *juegos serios* - serious games, *educativos* - educational*.

It is important to mention that all key words were considered to develop the investigation; however,

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not all of them were used in the development of the search strings.

4.2.4 Inclusion and Exclusion Criteria

For the <u>inclusion</u> of bibliographical references, the following criteria were used:

- ✓ References in Spanish and in English.

- ✓ Electronic references of complete text.

- ✓ Documents that define the concept cloud computing and/or software as a service.

- ✓ Documents that include characteristics for cloud computing and/or software as a service.

- ✓ Documents that list advantages and disadvantages of cloud computing and/or software as a service.

- ✓ Documents that define or describe the concepts of serious games and/or educational serious games.

- ✓ Documents that identify characteristics of serious games and/or educational serious games.

- ✓ Documents that identify technical requirements of SaaS applications.

For the <u>exclusion</u> of bibliographical references, the following criteria were used:

- ✓ Articles that are not related to research questions

- ✓ Studies not accessible in full-text.

- ✓ Studies that are duplicates of other studies.

- ✓ Non-peer reviewed publications.

- ✓ Articles that are not written in English or Spanish.

4.2.5. Preliminary Selection Process

A preliminary selection process was initiated by executing search strings in the resources selected: there was a reading of titles, key words, and summary of each of the references found. Then the inclusion and exclusion criteria were applied to generate a list of references to be considered for a complete and detailed reading.

In some cases, one reference facilitated access to other bibliography related to the topic of study, either from the same author or from different authors and to which the inclusion and exclusion criteria were applied, depending on the case.

Table 1 shows the amount of references selected according to the search string defined for the topics of cloud computing and serious game.

It breaks down the amount of references found per each search string and the amount of references selected after applying the inclusion and exclusion criteria.

Table 1: Search string defined for cloud computing and serious games.

Search Strings in English and Spanish	References Selected
Educational serious game	
Characteristics of educational serious game	
Ventajas de cloud computing OR Advantages of cloud computing	28
Desventajas de cloud computing OR Disadvantages of cloud computing	
Ventajas de software as a service OR Advantages of software as a service	
Desventajas de software as a service OR Disadvantages of software as a service	30
Características de software as a service OR Characteristics of software as a service	

4.2.6 Final Selection Process

Once the preliminary phase was finished, the process started for the final phase, in which there was a complete reading of the references selected and to which the inclusion and exclusion criteria were applied to assure that they were related to the investigation objective and if not, they were not considered. In our case, the total of primary studies selected during the preliminary selection process were all related to the objective of the investigation.

4.3. Results of the Mapping

This section includes the analysis of the SaaS possibilities for ESGaaS execution in cloud computing. Initially, for this, the possibilities of cloud computing in education are addressed. Then, the technical characteristics of the SaaS applications and of the educational serious games are listed and described. Followed by a comparative analysis among such characteristics to obtain the challenges and solutions for the ESGaaS execution. Finally, a checklist is developed to include the functional characteristics that the educational serious games will acquire when used as software service. The results will be presented according to the RQ´s defined, so that they provide an answer to each of them.

It is important to mention that answer to RQ1 was provided through background development.

4.3.1 Cloud Computing and Educational Serious Games Possibilities (RQ2)

a) Cloud Computing Possibilities

Use and integration of cloud computing in education facilitates strengthening knowledge management (understood as the process or practice that helps capture, create and storage learning experiences to transfer or share with others) through the empowerment of academic performance, efficiency of the university community in general, since users are granted access, there is collaborative editing and the synchronization of digital reference materials at any moment, from any place and using any device with internet connection [2].

The collaborative component offered by cloud computing is vital in formative processes. From the educational point of view, collaboration allows for two or more individuals to share experiences, different points of view, generate discussions and mainly, strengthen the analysis together where the contribution of each participant is reflected in the joint construction of new knowledge.

b) Serious Games Possibilities

Formative processes can be developed at a formal level under the figure of an educational institution or at a company or organization. In this context, [56] textually indicates that "*it has to be understood which are the game mechanics and the learning processes that each videogame proposes to adapt them to the educational needs of each institution, whether it is educational or not.*"

One of the educational usages that has been assigned to serious games in a non-educational environment is the one related to medical simulation, which allows designing simulated learning environments in which they can be used for doctors entertainment or training without putting into risk the safety and physical integrity of the patient and in which students and faculty "*adopt and negotiate postures, make decisions, solve the situation and analyze the experience*" [57]. Also, medical simulation serious games reduce costs and help predict what will happen in real scenarios. They also strengthen "*the development of interactive environments where the student can have control of his own learning while experimenting in different scenarios*" [58].

Due to its collaborative nature, serious games have great potential to serve as support for Higher Education Institutions (HEIs) in the configuration of innovative teaching and learning processes that will strengthen the acquisition and development of new competencies and/or technological abilities which will allow the generation of significant knowledge. Now, the concept of technological competencies is related to "*the capacity, knowledge and attitude related to the use of information technologies and communication in several application functions and contexts*" [59].

One of the present challenges in the educational environment is the development of teaching methods mediated and supported by technologies [60]. Considering this scenario, serious games represent an opportunity to be used to improve those learning experiences, since they promote collaboration, imagination, thought and facilitate the development of technological competencies in the users. In this context, the main challenge of serious games in formal education is to technologically educate faculty and students [48, 6].

In summary, the possibilities of serious games in the educational environment could be favorable since they could be used to reach different purposes related to learning, training, technological competencies acquisition, collaborative work, imagination and thought promotion.

4.3.2 Technical Requirements of a SaaS Application (RQ3)

These are some of the main requirements desirable in an application to run and offer a service through the SaaS model in cloud computing [27, 61]:

- ✓ **Architecture - *Multi-tenant*.** The architecture has to support several customers and providers to maximize the hardware and software resources. Now, "for an application to be multi-tenant, it is necessary to design it for such purpose and also the platform as service has to offer the specific support so that multi-tenant applications can be developed over it." [27]. Also, it has to have a logic data separation. Each tenant has his own information domain; however, they are stored in the same databases.

- ✓ **Versioned-** Be a simple version. There has to be only one version of the application, which is shared with all the tenants.

- ✓ **Security and Access Control –** Mainly for the functions based on permits. There has to be mechanisms to authenticate users and allow the administrator of each tenant to create, manage and eliminate user accounts for that tenant in the user account directory.

- ✓ **Resources Provisioning –** Offer support to provision resources. Applications have to be able to reserve and offer resources for new tenants.

- ✓ **Load Scalability and Balance** – To be scalable and offer load balance mechanisms. The application has to support multiple customers. There has to be scalability mechanisms that consider the use of resources for each tenant.

- ✓ **Domain Container** – Capacity to offer an entry point to the applications from a provider.

- ✓ **Personalization and Configuration** – It has to be easy to personalize and to configure. This means that each tenant can perform his own basic configurations in regards to profile personalization.

- ✓ **Applications Integration -** SaaS applications have to allow communication among each other, but still be independent.

- ✓ **Support Availability** – Offer different support options. Tenants should be able to subscribe, monetize, bill, monitor, manage user accounts, loggings, use control and metrics.

In summary, these requirements or technical attributes are mandatory for applications through the SaaS model to be able to execute and offer a good service.

4.3.3 General Requirements of Educational Serious Games (RQ4)

This section includes the minimum general characteristics that educational serious games should present. They were generated based on a bibliographical revision and as a product of the findings analysis obtained in different investigations developed by specialists in the topic of study. Such characteristics were grouped under three general aspects [62, 63, 64, 65, 66, 67, 68, 69]:

- ✓ **In regards to the application** – This category includes the characteristics directly related with the application; type of license, type of software and type of application to which it is addressed to (mobile devices, desktop or web applications).

- ✓ **In regards to the users** – This category puts together the characteristics directly related to the user; pedagogical purpose, users management, possibilities of the users to personalize and configure the applications, and how the security and access control on behalf of the users to the applications is implemented.

- ✓ **In regards to the services offered**- This category puts together the characteristics directly related to the services offered by the educational serious games applications, such as

availability and support offered by the application, as well as control management of the versions, capacity to offer multimedia services, interaction, ubiquity and the type of guide/help offered.

Table 2 summarizes the minimum general characteristics required from the educational serious games. It is necessary to highlight that these characteristics may vary depending on the author that develops the study, as well as the objectives and purposes of serious games that are been analyzed.

The next section includes a comparative analysis among the characteristics of an application offered under the services model SaaS in cloud computing and the technical characteristics of an application corresponding to an educational serious game, such analysis provides the answer to RQ5.

4.3.4 Challenges and Solutions to Execute ESGaaS. Functional Characteristics (RQ5)

This section includes a comparative analysis among the technical characteristics of the SaaS and the general characteristics of the educational serious games which were covered in sections 4.3.2 and 4.3.3, accordingly. This facilitates enumerating the main challenges and solutions to execute the ESGaaS. At the same time, it allows to identify the functional characteristics that educational serious games will acquire when used as software service.

a) Challenges and Solutions to Execute the ESGaaS

Based on the analysis developed, the following challenges and solutions to execute the ESGaaS have been identified:

- ✓ **Type of Software** – Educational serious games applications on the market are mostly of closed code. The customer cannot modify the source code in the applications. SaaS applications are also close coded, but they offer the possibility of working collaboratively and multi-tenant which favors the HEIs to strengthen their formative processes.

- ✓ **Type of Application** – It is evident the effort made from the educational serious games developers to be able to offer this resource to persons that use different types of applications (desktop, mobile, web); however, more users could be impacted if these applications were offered as a service in SaaS, because SaaS would offer the web application with the multiplatform characteristic, which could be accessed from any type of device through a browser with internet connection, indifferently

of the operating system and without the need to look for and install different applications.

- ✓ **Architecture** – Regarding users capacity, educational serious games are mostly of single-tenant connections and in few cases there are applications registered with the option multi-tenant. This limits the possibility of using the game with a group of students or faculty in which all of them are connected in real time to share, live and build a group academic experience and in a collaborative way. SaaS facilitate multi-tenant connection at all times. This would be a plus that educational serious games could offere if it was promoted as a software service.

- ✓ **Availability-Support** – Educational serious games are mostly available as mobile applications in stores like Google Play Store, App Store, Windows Store and BlackBerry World. In regards to desktop applications, these are available to be executed or "run" in operational systems like Windows, GNU/Linux and Mac OS. Also, they are available as web applications. This would be improved if educational serious games were offered as software service in cloud computing, since SaaS facilitates the execution of multiplatform applications, which are executed from any type of devices through a browser with internet connection.

- ✓ **Versioned** – In regards to versions control, it is evident that there are multiple versions in the market for the same application of an educational serious game, which could be related to the variety of operating systems on the different types of devices existing in the market. This inconvenient would be easily solved if the application is offered as a service in SaaS, because SaaS offers a simple version shared for all the customers. This would guarantee a saving in time and money and would offer a simpler service and easy to access.

- ✓ **Ubiquity** – It is an important characteristic for educational serious games since it allows the user to learn without space and time barriers; however, it depends on the configuration of the application when developing it, so in some cases there is no interaction in real time with the application and the environment. SaaS can offer this service without any inconvenient in real time. This would give added value to educational serious games when executed in SaaS.

- ✓ **Multimedia** – Educational serious games are characterized by their high content of multimedia resources (voice messages, photo captures, sound/video recording, text messages, among others). However, not all educational serious games facilitate multimedia options, in some cases it is recorded that only text messages can be sent, and in some others photos or videos cannot be recorded or sent. These aspects would be improved when executing serious games on SaaS, since SaaS has the capacity to offer the integration of multimedia resources that are needed in real time.

- ✓ **Interactivity** – It is one of the characteristics that is limited in educational serious games. Depending on the application configuration, it could be synchronic or asynchronic between the server-application-player and among players. SaaS would be an excellent option to offer serious games as a service since they have the capacity to offer interactivity totally synchronic and in real time among players and application-server. This facilitates a more interactive, collaborative and in real time learning.

- ✓ **Guide and Help** – Educational serious games register a limitation which is that normally the application and the additional information related to it (help, tutorials, videos, frequent questions) are available in English and very few games offer a second language as an option. SaaS has the capacity to offer applications in several languages since it could integrate educational serious games with other applications that offer the service of software localization to translate and adjust according to the linguistic and technical needs of the customers internationally.

- ✓ **Security and Access Control** – In regards to the characteristic related with security and access control, it is not evident that educational serious games in general offer these options, since only the player has to execute the application to start interacting with the game without a previous record. This limits the possibility of getting a record of the activities and advancements of each player. If the educational serious game application would be applied under the service model, this would guarantee mechanisms to authenticate users and allow the administrator of each subscriber to create, manage, and eliminate users accounts for that subscriber in the directory for user account and get a record of the activities per player.

- ✓ **Personalization and Configuration Capacity.** It is evident that most educational serious games applications do not allow for personalization and configuration. This means that each customer or player is limited to use

the profile offered by default. Among the services offered by SaaS, there is a possibility and option for each subscriber (customer) to do their own basic configurations in regards to profile personalization. This is to make the application more user friendly.

✓ **Logic Data Separation** – Educational serious games applications do not allow for the logic data separation of the players. The opposite occurs with the applications in SaaS; where each tenant (customer) has his own information domain, recorded and stored in the same database. This would benefit HEIs if educational serious games were executed as a software service. This would allow to have more information in a precise way in relation to each player which will facilitate feedback generation in a personalized way when needed.

✓ **Scalability and Load Balance** – In relation to scalability and load balance mechanisms, applications for educational serious games do not record data that make evident that these options can be performed. However, SaaS applications have the capacity to support multiple customers and they also offer the possibility of defining scalability mechanisms that consider the use of resources for each tenant.

✓ **Applications Integration** – In regards to the characteristic related to applications integration, educational serious games do not record information that this function can be performed. SaaS does offer the option for applications to "communicate" among them and keep as independent. This would be an important function to integrate into educational serious games to be able to offer services demanded by a specific customer; for instance, help and tutorials in other languages.

✓ **Resources Provisioning** – Educational serious games do not record data in which it is evident support for provisioning resources. The SaaS model does offer the possibility of reserving and offer resources to subscribers.

✓ **Subscription and Billing** – In regards to support for subscription and billing, it is evident that in educational serious games there is only one general payment for the license use, so there is no other service associated. The opposite happens with the applications offered through the service model SaaS, which allow customers to subscribe, monetize, bill, monitor, manage users accounts, loggings, use control and metrics.

Table 3 shows a summary of the characteristics of educational serious games and SaaS based on the comparative analysis developed.Functional Characteristics of ESGaaS.

Based on the results obtained during the investigation developed, a checklist has been developed with the functional characteristics that educational serious games will acquire when used as software service. They are listed below:

✓ Web application with access from any browser with internet connection and highly available.

✓ Multi-tenant architecture (logic data separation for each user).

✓ Highly available from any place and moment.

✓ Simple version and shared for all customers.

✓ Personalized and configured at a user profile level.

✓ Scalable and with load balance mechanisms.

✓ Offer totally synchronic interactivity.

✓ Offer availability and multiplatform support.

✓ Offer security and access control per user.

✓ Offer applications integration (being independent among each other).

✓ Offer support to provision resources for new subscribers.

✓ Offer support for subscription and billing (monetize, bill, user accounts management, loggings, use control and metrics).

✓ Offer ubiquity, service and multimedia resources in real time.

✓ Offer guide and/or help in different languages.

5. Conclusions

Based on the objectives of the study related to the possibilities offered by cloud computing to execute ESGaaS, the following conclusions were obtained:

✓ Presentation of the definition of the concept for cloud computing, as a result of the theoretical investigation developed, where it is identified that it varied depending on the author who analyzes it; however, there is coincidence in that it is a new model of technological services where it prevails the provisioning of shared resources by demand, in a ubiquitous way with just internet connection. Under this same line, it is identified that among the service models available in cloud computing, SaaS facilitates applications availability to final users, favoring collaboration in a multi-tenant environment and including facilities for security and access control, versioned and scalability in such applications.

✓ It is recognized that serious games have a capacity to enhance different knowledge areas, promote attitude or behavior changes, generate emotions, approach the acquisition of abilities, among others. Serious games present a focus that goes beyond entertainment or fun.

✓ In regard to the possibilities of cloud computing in education, it is highlighted its high collaboration capacity which could help enhance formative processes through sharing experiences, generating discussions and building knowledge together.

✓ In regards to the possibilities of educational serious games, it is evident that like cloud computing, their collaborative characteristic makes them potentially beneficial to serve as a support to HEIs in the configuration of innovative teaching and learning processes oriented to promote the acquisition and development of new competencies and/or technological abilities that facilitate the generation of significant knowledge.

✓ SaaS characteristics were investigated. This facilitated identifying the desired technical attributes that applications to be executed to offer services through the SaaS model have to comply with.

✓ Also, the general characteristics required from the educational serious games were investigated and they were grouped in three categories: a) in regards to application, b) in regards to users, and, c) in regards to the services offered.

✓ Technical characteristics of the SaaS applications were investigated as well as the general characteristics of the educational serious games. Based on this the main contribution of this investigation is developed which is to enumerate the main challenges and solutions for the execution of ESGaaS, as well as the development of a checklist with the functional characteristics that educational serious games will acquire when used as software as a service.

✓ Educational serious games offered as software service in cloud computing significantly improve its functionality and educational purpose through **high availability of resources and multi-tenant capacity**. Also, HEIs will not have to invest in licensing, hardware, security, maintenance and data and information backup, which could reduce implementation costs [35, 42].

6. Future work

This investigation sets the conceptual bases to approach the design and implementation of an educational serious game that considers the functional characteristics defined in this work, supported in the software as a service in cloud computing. Like the design of an architectural and methodological proposal that can be used as a guide for the design of serious games oriented to strengthen the development, formation and/or acquisition of technological competencies.

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Competing interests

The authors have declared that no competing interests exist.

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Table 2: Common general characteristics in educational serious games

Characteristics	General characteristics of educational serious games
In regards to the application	**Type of License.** Applications can be accessed free to a trial version; however, a payment has to be made to be able to use the license which includes the full version of the educational serious game. For instance, serious games *Frequency 1550, The Island* and *Settlers of Manhattan* require payment. Also, no studies were found to show that serious games are offered as software as a service.
	Type of Software. Applications usually are of closed code. This means that the source code is not available for the users.
	Type of Applications. Applications for mobile devices, desktop and web applications. There is a higher tendency to use mobile and web applications.
In regards to users	**Pedagogical Purpose**. The main objective of the serious games is learning and entertainment that will facilitate the development of technological abilities and to form technological competencies.
	Users Management. In most of the them, the prevalent characteristic is that they are applications designed to support only one user at a time.
	Personalization and configuration. Applications for educational serious games do not allow users to personalize or modify the interphases.
	Security and access control. There is no information. Access the applications and start interaction with the game.
In regards to the services offered	**Availability -Support**. Educational serious games are available mainly as mobile applications available at Google Play Store, App Store, Windows Store and BlackBerry World. In regards to desktop applications, these are available to be executed or "run" in operating systems such as Windows, GNU/Linux and Mac OS. Also, they are available as web applications, which are executed from different browsers.
	Versions Control. Most of the applications have an access service to different types of versions and varieties of updated versions, depending on the platform or operating system used to execute it.
	Multimedia. Most of the applications offer a service with multimedia in/out capacity; however, these are done isolated one from another and sometimes they cannot be executed in real time.
	Interactivity. Most of serious games offer among their services asynchronic interactivity with other people (students, teachers, experts). However, more interactivity is needed in a synchronic way and in real time.
	Ubiquity. The application will free learning from space and time barriers (it allows for real time interaction between the application and the environment). For serious games, it has been reflected that most of them do not allow an ubiquitous learning.
	Type of Guide/Help. Educational serious games offer tutorials, videos, manuals, frequent questions or some type of help for the user. However, there is a limitation in general, which is that most of the applications offer them only in English.

Table 3: Comparative analysis among educational serious games and SaaS

Category Analysis	Educational Serious Games	Software as a Service (SaaS)
Type of Software	Closed code.	Closed code.
Type of Application	Desktop, mobile, web.	Web application.
Architecture	Single-Tenant.	Multi-Tenant.
Availability-Support	Mobile: Google Play Store and App Store. Desktop: Windows and / or GNU/Linux. Web: the different browser	Multiplatform
Versioned	Multiple versions.	Simple version.
Ubiquity	Depends on the application configuration.	Capacity to offer the ubiquity service in real time.
Multimedia	Limited multimedia.	Capacity to offer requested multimedia.
Interactivity	Asynchronic	Synchronic
Guide / Help	Mostly in English.	Capacity for multiple languages.
Security and Access Control	No records.	Users authentication.
Personalization and configuration capacity	Little.	Per customer.
Logic data separation	Not offered.	Per tenant.
Scalability and load balance mechanisms	Not done.	Per tenant.
Applications integration	Not done.	SaaS applications communicate among each other and they are independent.
Provisioning of resources	Not done.	Applications reserve and offer resources for new subscribers.
Subscription and billing	General payment for the right to use the license, no additional service associated is offered.	Customers can subscribe, monetize, bill, monitor, manage user accounts, loggings, use control and metrics.