Chapter 24
A Brief Review of Game Engines for Educational and Serious Games Development

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ABSTRACT

Gamification is the use of game design elements to enhance the teaching-learning process and turn a regular, non-game activity into a fun, engaging game. Simultaneously, serious games are proposed as an efficient and enjoyable way of conducting cognitive assessment, as they combine a serious intention with game rules and targets. In this scenario, game engines have emerged as information technologies for serious games and educational games development; however, this development has usually been performed without a guide to identifying game attributes to be present in the game. To address this gap, we present an analysis of the most used game engines to identify game and learning attributes supported for serious and educational games development. Findings from this analysis provide a guide of the most popular game engines that offer the largest support for game attributes, which were also classified by game categories.

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INTRODUCTION

Gamification is the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals (Burke, 2014). Through gamification not only can we create a mindset that encourages students to try new things, to not be afraid of failing (Chung-Ho & Ching-Hsue, 2013), but also students can engage in enjoyable experiences for a learning purpose. The gamification of learning is an educational approach to motivate students to learn by using video game design and game elements in learning environments. Gamification is today considered as an essential driver of innovation in the educational domain, and thus it is important to understand how serious games can be best designed and used as an organizational learning environment (Boughzala, Michel & de Freitas, 2015). Serious games are aimed at a population that is familiar with online games, particularly Generation Y, who are more playful, outgoing, major consumers of training and coaching, and cannot be recruited in the same way as previous generations (Morley, Figueiredo, Baudoin & Salierno,2013; Twenge, Campbell, Hoffman & Lance, 2010). The advantage of serious games as a learning tool mainly relies on their ability to balance entertainment, interactivity, and replay ability of the typical games with the learning objectives of a specific educational goal.

In education, game-based learning is a motivating factor, as games are often attractive for their rules, reward systems, and environments (Prensky, 2005). Gamification is the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals (Burke, 2014). Through gamification we create a mindset that encourages students to try new things, to not be afraid of failing (Chung-Ho & Ching-Hsue, 2013), and it also allows them to engage in enjoyable experiences for the purpose of learning. From this perspective, gamification appears as the use of game mechanics in environments and applications that are not playful to generate and transfer knowledge, thus enabling the development of competencies in human talent; it is related to decision-making activities. At the same time, games have become a very useful tool to bring in knowledge management from the practice of simulated environments in the context of various knowledge fields (Deterding, Dixon, Khaled & Nacke, 2011; Deterding, Sicart, Nacke, O'Hara & Dixon, 2011; Morford, Witts, Killingsworth & Alavosius, 2014; Yamabe & Nakajima, 2012).

An innovative implementation for learning is the use of serious games (SG), commonly motivated by the need to educate and report about or shape a specific topic (Michael & Chen, 2005). A serious game is a game in which education, in its various forms, is the primary goal, rather than entertainment. The advantage of serious games as a learning tool relies on their ability to balance entertainment, interactivity, and replay ability of typical games with the learning objectives of a specific educational goal. Likewise, serious games offer developers ways of reducing or mitigating some costs regarding game technology and content development, and they also keep teams busy between larger, retail-oriented projects. In addition, serious games provide opportunities of experimenting a new gameplay style, and even new types of educational distribution. Knowledge fields where serious games have been adopted include education, medicine, corporations, and military, among others (Susi, Johannesson & Backlund, 2007).

There are two types of game engines, HTML5-based frameworks and proprietary engines. The two allow for the development of Web-based, native mobile, and hybrid applications by using game strategies and techniques (Nagle, 2014). However, due to an extensive variety of both game engines, their selection for developing a particular educational application may be troublesome. In this work, we thus seek to support the selection process of the most suitable game engine(s) for a particular educational application, taking into account activities required for its development. In general, this paper presents an

analysis of current game engines considering learning activities in order to provide a guide to choosing the most suitable game engines for developing educational applications, serious games, or both.

This paper is organized as follows: Section 2 presents the research methodology. Section 3 describes the Games engines for developing educational y serious games and the games engines classifications. Section 4 presents the Learning activities on educational and serious games. Section 5 presents the Literature review. Section 6 presents the evaluation and results of the analysis of HTML5-based frameworks and proprietary games engines for developing educational and serious games, as well as shows the results of the analysis. Section 7 describes the conclusions and future directions to be taken.

RESEARCH METHODOLOGY

The methodology is composed of two stages. At the first stage, we identified game engines providing more support to certain characteristics, such as audio, video, 2D graphics, and 3D graphics among others. At the second stage, we found each one of the attributes supported in each framework, and they served as reference to classify game engines based on the game category that they support. The objective of this analysis was to obtain a guide to choosing the best game engine for the development of educational applications, serious games, or both. At the end of this analysis, we rated importance of game attributes for the educational context and their availability in game categories, according to selected games engines. Nonetheless, note that additional attributes may be required, depending on the type of educational game and the academic level at which an educational game is targeted. Refer to Figure 1.

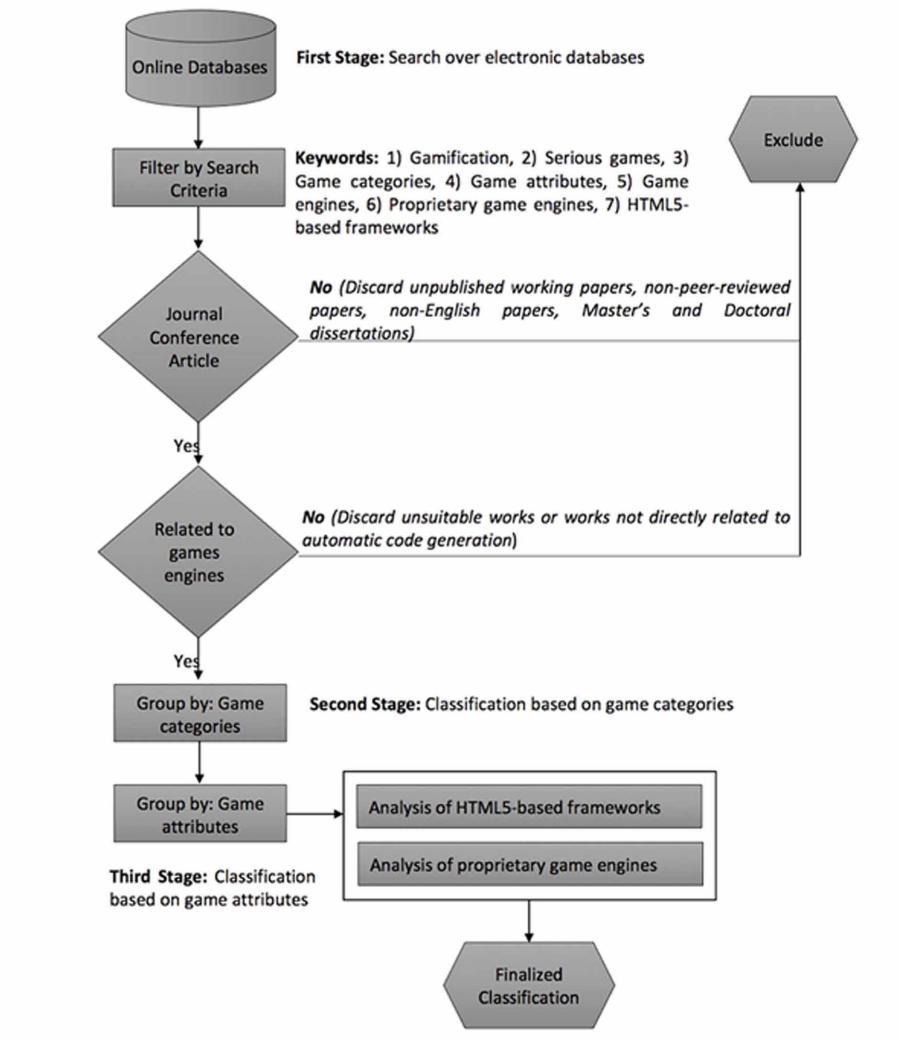
Research on gamification and serious games was conducted on research databases including Association for Computing Machinery (ACM), Wiley editorial, IEEE Computer society, Springer Link, and Science Direct, whereas researched concepts included serious games, gamification, technology enhanced learning, and Information Technology Infrastructure library. We collected and then reviewed 54 papers, 38 of which were directly related to the purpose of this work. Finally, we selected 15 papers for a deeper analysis. Results of researched concepts are presented in Figure 2.

For this research, we followed the classification of proposed by Lameras et al. (2015), who categorized games based on relevancy of attributes and learning activities. The 15 papers were thus reviewed to identify game attributes and game activities for each reported game engine. Also, Lameras et al. proposed four learning attributes: Information transmission, Individual, Collaborative, and Discussion and argumentation; however, in the papers reviewed we only found information transmission, collaborative, and individual attributes. Figure 3 shows the results of the learning attributes review.

The last step in the literature review consisted in organizing papers into a game category based on its learning attributes. In this sense, Lameras et al. proposed five game categories, including rules, goals and choices, tasks/challenges, collaboration and competition, and feedback/assessment. Categories found in papers during the review included collaboration and competition, goals and choices, and task/challenges. Figure 4 shows results of the game categories found.

Results from this review revealed the importance of serious games and gamification research, as we found areas the opportunity that could be effectively addressed by fostering development of educational games or applications with gamification techniques. As mentioned earlier, the review was the first step in the research methodology, and it aimed at identifying opportunity areas where gamification research should be conducted.

Figure 1. Selection criteria flow



Games Engines for Developing Educational and Serious Games

A game engine is a software framework designed for the creation and development of video games for consoles, mobile devices, and personal computers. Typically, a game engine includes support programs, libraries, and an interpreted language to help develop and unite the different components of a project (Viveros and García, 2009). Game engines are classified into HTML5-based frameworks and proprietary game engines. The former are game engines developed in HTML5 language (Viveros and García, 2009), and most of them do not need a special platform or software to be executed. Usually, HTML5-based game engines just need a browser to deploy the application that was created. On the other hand, proprietary game engines are frameworks developed in a specific language and need a platform or software to deploy the application created with them (Viveros and García, 2009).

Figure 2. Results of searched concepts

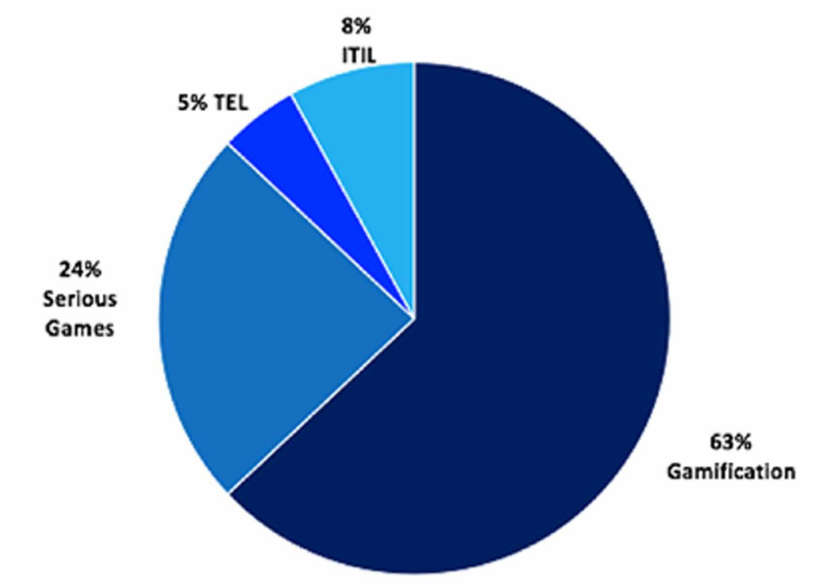
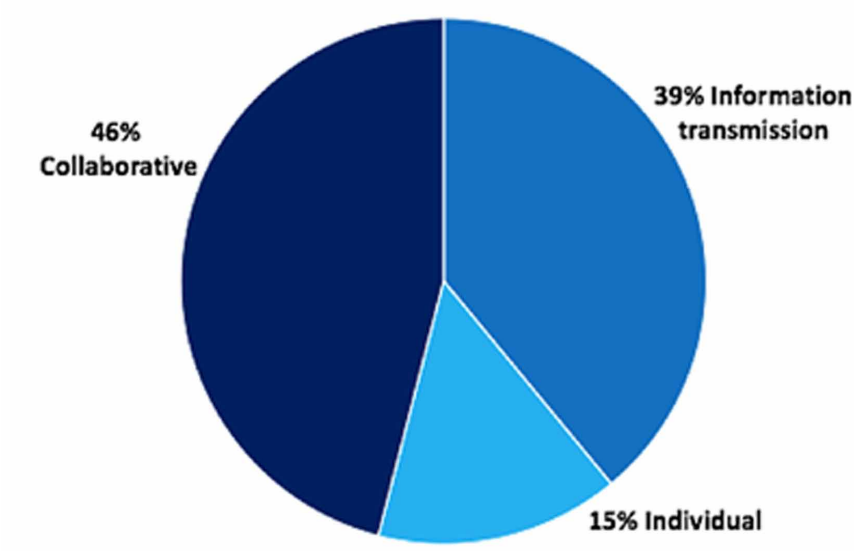


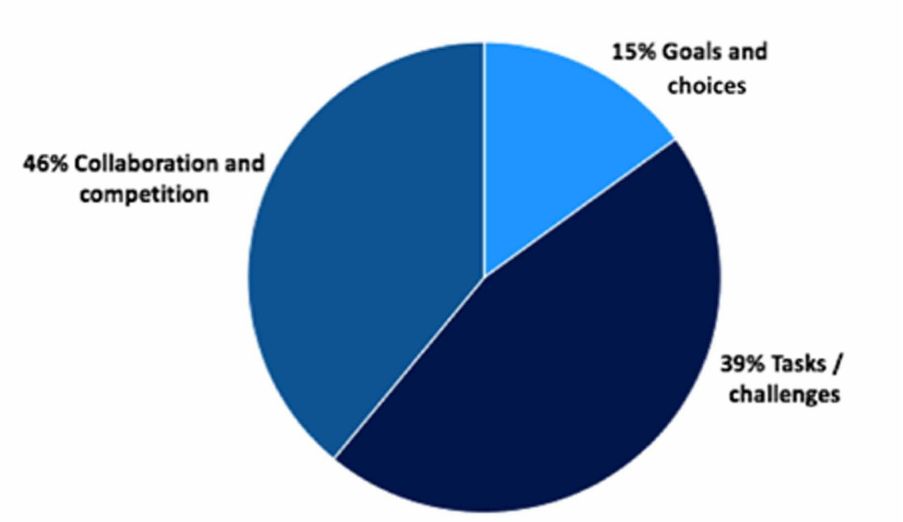
Figure 3. Results of learning attributes review



HTML5-Based Frameworks for Developing Educational and Serious Games

Currently, many HTML5-based frameworks allow for cross-platform game development, and sometimes even from a single platform development (Nagle, 2014). In this sense, this work provides a summary of the most common HTML5-based frameworks used for game development. To select those frameworks, we analyzed their characteristics and identified the largest number of elements supported in each frame-

Figure 4. Results of game category review



work. Analyzed characteristics included support for 2D and 3D graphics, support for audio and video, software license, latest version, whether the framework was a cross-platform engine, and whether it was used in educational applications. As results from the analysis, we found the following ten frameworks as the most commons HTML5-based game engines:

- Construct 2 is an HTML5-based editor using a drag-and-drop functionality that allows users to create complex and engaging games. No programming experience is required, and it is one of the most accessible 2D game development tools (Bura, 2014).
- ImpactJS is JavaScript game engine allowing for the development of stunning HTML5-based games for desktop and mobile browsers (Nagle, 2014).
- Quintus is an HTML5-based framework designed to be modular and lightweight, with a concise JavaScript-friendly syntax. The engine is easy; HTML5 and JavaScript can be used for developing multi-device video games run in a browser (Sonmez, 2016).
- WADE is a Web-based visual editor. It takes care of different resolutions, low-level optimizations, and different input devices, thereby making cross-platform games easy and quick (Chilli, 2016).
- pixi.js is a graphics-rendering engine for websites, games, and mobile applications development. This game engine allows users to create and display interactive graphics, build scenes and animated transitions, and develop cross-platform, responsive games and applications for multiple screen resolutions by using WebGL (Van der Spuy, 2015).
- EaselJS provides a display list allowing users to work with display elements on a canvas as nested objects. It also offers a simple framework for providing shape-based mouse interactions on elements in the display list (Nagle, 2014).
- melonJS is a free, light-weight HTML5-based framework. The engine integrates the tiled map format, thereby making level design easier (melonJS, 2016).
- Three.js is a library that provides a very easy-to-use JavaScript API based on WebGL features. Also, 3D graphics can be created without much WebGL experience (Dirksen, 2014).

- Phaser is a free open source HTML5-based framework that allows for building fully fledged 2D games in a browser with little prior knowledge of either game development or JavaScript for designing for a browser in general (Palef, 2014).
- PlayCanvas is a cloud-based HTMl5-based framework and editor for 3D games, with a focus on real-time collaboration (Eastcott, 2015).

Proprietary Game Engines for Educational and Serious Games Development

A proprietary game engine is a software framework designed for video game creation and development, and many proprietary games engines today allow for cross-platform and cross-browser game development (Martins, Tiago, Carvalho & Soares, 2015). To select the most common proprietary game engines, we analyzed the characteristics like the support of 2D and 3D graphics, the support of audio, video, license, the last version, if the frameworks is multi-platform or not to identify the greatest number of elements supported. However, the main characteristics of proprietary game engines was the programming language used. From this perspective, we found the following eight engines as the most commonly used:

- Unity is a game engine that can handle from a massively-multi player online game all the way down to a simple kart racer (Creighton, 2010).
- CryEngine is a powerful real-time game development tool with scalable computation. It facilitates scripting, animation, and object creation (Corporation, 2016).
- Unreal engine 4 is a complete professional suite offering new workflow features and a deep toolset, empowered with a complete C++ source code (Games E, 2016).
- Cocos2D is an open source cross-platform game framework written in C++/Javascript/Lua (Cocos, 2016).
- Blender is a professional free and open-source 3D computer graphics software product used for creating animated films, visual effects, art, 3D printed models, interactive 3D applications, and video games (Wartmann, 2011).
- BigWorld relies on the Python scripting language and is used for developing game logic and some artificial intelligence (AI) algorithms at the game like scoring systems (Pty B.,2012).
- Leadwerks is the easiest game engine to make 3D games powered by OpenG 4.0 (Corporation V, 2016).
- HeroEngine is a 3D game engine and server technology platform for building MMO-style games (Fabrik, 2016).

Learning Activities on Educational and Serious Games

Gamification is the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals. Its application to real-life tasks influences behavior, improves motivation, and enhances engagement (Burke, 2014). From the innovation perspective, concepts such as serious gaming and gamification are the most interesting and valuable. If the first repurposes a game via different methods in order to offer activities that go beyond mere entertainment, the second uses game design to enhance individual's willingness to participate in originally non-playful experiences. Nowadays, different knowledge fields, such as medicine, entertainment, and education, among others, rely on the gamification approach

Lameras et al. (Lameras, 2015) proposed a classification of serious games based on the game's design features and learning properties. Learning attributes were proposed as collaborative learning, individual, transmission of information, and discussion and argument. The study also proposed various game attributes taken as a basis for establishing the following game categories: rules, goals and choices, tasks/challenges, collaboration and competition, and feedback/assessment.

Learning activities in educational games drive learning outcomes set out by the teacher. Output of some activities is used as input to others, resulting in game flows that can be adapted while the student is executing the learning activity. A game-based learning activity is introduced as distinct from game content; it is the central concern of work within the game-based learning design, which has historical roots in the wider field of instructional design (McLean & Scott, 2011).

In their research, Lameras et al. (Lameras, 2015) conceived in-game learning activities as a situated action, greatly influenced by beliefs and values held by teachers as game designers in specific contexts of practice. Also, authors viewed in-game learning as an emergent iterative process occurring during and also before the orchestration of the learning activity in the game. The study therefore suggested, from the teacher's perspective, two main advantages associated with in-game learning activities design. First, in-game learning activities may provide a framework for linking learning with play for a more creative educational practice. Second, they would offer a context for participation, sharing, and reuse/repurposing of practice within professional communities (see Table 1).

Beetham (Beetham, 2008) defines a learning activity as "specific interaction among students using specific tools and resources, orientated towards specific outcomes." Therefore, the importance of designing learning activities for developing serious games and gamified applications to meet the purpose for which a game was developed. Cook (Cook, 2006) interpreted game attributes from an educational perspective by giving emphasis on feedback properties while acknowledging the relationship between player's rules and attributes. In this sense, game attributes must always be considered in game design to ensure a balance between the challenges to overcome and the skills needed for goals achievement.

Lameras et al. (Lameras, 2015) classified games based on their relevant attributes. In this sense, authors assigned games to categories by understanding that game attributes in a game are used for creating instances of game attributes in the educational practice; for instance, rules are made by scoring. Authors proposed this classification with the aim of helping game designers and supporting instruction, as no other taxonomy had been proposed before. Table 2 provides further details on this classification by identifying for each kind of game its corresponding attributes.

Table 2 classifies games into categories based on their relevant attributes. Lameras (Lameras, 2015) made an attempt to map overarching game categories to game attributes, which can be used to afford the instantiation of game attributes with a focus on educational practice. Lameras works would pave the way for formal support for game and instructional designers when selecting particular types of games that afford distinct mechanisms for supporting certain game categories, thereby aligning specific types of game-play with congruent practices.

LITERATURE REVIEW

Most studies seeking to improve educational games development have discussed gamification in a variety of contexts. In this section, we present a set of works discussing the use of educational games and seri-

Table 1. Types and sub-types of learning activities used in games

Type of learning activity	Learning activities
Information Transmission – Allow students to reflect on information for learning (Beetham, 2008; Gunter, Kenny & Vick, 2006).	– Lectures / lecture notes / slides – Memorizing concepts – Labelling diagrams and concepts – Exampling – Completing incomplete statements – Lecture summaries – Listening
Individual (constructivist) activities – Suggest that learning is more effective when the student is actively engaged in the learning process, rather than when they passively attempt to receive knowledge (Lameras, 2015).	– Web-quest (information search) – Exercise solving – Conducting scientific experiments – Reflecting – Simulations – Modeling – Role play – Inquiring (posing questions) – Determining evidence – Analyzing evidence – Formulating evidence – Connecting explanations to knowledge
Collaborative (constructivist) activities – Stimulate mediated and structured interaction to acquire knowledge (Lameras, 2015).	– Brainstorming – Group projects – Group web-quest – Rank and report – Group of students posing questions to each other – Group simulations – Pair-problem solving – Group data gathering – Group data analysis – Group reflection
Discussion and argumentation activities – Attempt to lead the student through discussions and questions to discover, discuss, appreciate, and verbalize new knowledge (Lameras, 2015).	– Guided discussions (topics provided by the teacher) – Open discussions (topics provided by students) – Choices: data on events and several choices for students to make comments – Debates (justify explanations)

ous games. The following subsections are organized depending on the types of applications discussed: 1) gamification applications, 2) serious games.

Use of Gamification Techniques on Educational Applications

Simões, Díaz-Redondo, and Fernández-Vilas (2013) sought to assist educators and schools with a set of powerful and engaging educational tools to improve student motivation and learning outcomes. Their research intended to develop a framework for the use of these tools to be integrated and tested in an existent social learning environment called schoooools.com. Similarly, Armstrong (2013) defined gamification as a way of tapping into motivational forces to increase individual investment in a system, process, or resource. One way of applying gamification in education is through extrinsic motivation, which comprises external factors unrelated to the nature of the activity itself. From a similar perspective, Lubin (2015) argued that gamification offered a way of minimizing disengagement while actually enhancing learning. In this sense, gamification, if correctly applied, could revolutionize an organization's approach to training, development, and instructing individuals.

Table 2. Game categories and associated game attributes

Game category	Game Attribute	
– Rules	– Scoring – Moving – Timers – Progress bars	– Game instructions, including victory conditions
– Goals and Choices	– Game journal – Missions – Objective cards – Storytelling	– Nested dialogues – Puzzles – NPCs / avatars
– Tasks / challenges	- NPC (non-player character) -based task description – Progress bars – Multiple choices – Major tasks	– Puzzles – Research points – Study – Requirements – Branch tasks
– Collaboration and competition	– Role-playing – Community collaboration – Epic meaning – Bonuses – Contest	– Timers – Coins – Inventories – Leader boards – Communal discovery – Scoring
– Feedback / assessment	– Game hints, NPCs – Game levels – Gaining/losing lives – Progress bars – Dashboards	– Lives/virtual currencies used for buying game items from an online inventory – Progress trees

Kapp (2007) viewed gamification as an instructional design tool that provides the opportunity to re-engage individuals and make the relevancy of the instructional situation more apparent through the implementation of gamification in training and educational settings. Also, Kapp defined gamification as the use of game-based mechanics, aesthetics, and game thinking to engage people, motivate action, promote learning, and solve problems. Also, Robson, Plangger, Kietzmann, MacCarthy and Pitt (2016) introduced and demarcated the principles of gamification, which they defined as the application of game-design principles in order to change behaviors in non-game situations. In addition, Fui-Hoon Nah and others (2014) identified several game design elements used in education, including points, levels/ stages, badges, leaderboards, prizes, progress bars, storylines, and feedback. Authors equally provided examples from the literature to illustrate gamification implementation in the educational context.

De-Marcos (2014) presented results from testing both social networking and gamification in an undergraduate course, comparing them in terms of their impact on students' academic achievement, participation, and attitude. To achieve this, the effects of a gamification plugin deployed in a learning management system were compared to those of a social networking site in the same educational setting. From a similar perspective, Arias (2016) analyzed the entrepreneurial attitude of high school students on the basis of the EAO (Entrepreneurship Attitude Orientation) scale through their participation in a gamified business simulation. On the other hand, Henzi and Alt (2015) applied gamification to leverage the use of information for information-intensive business tasks in the context of corporate intranets. They presented results from an online experiment conducted in the banking industry.

Matallaoui, Herzig and Zarnekow (2015) proposed the Gamification Modeling Language, initially as a formal language adhering to a context-free grammar and based on the current consensus of game

design elements that can be found in gamification. Then, Hamari, Koivisto and Sarsa (2014) defined gamification as an emerged means of supporting customer engagement and enhancing positive patterns in user service by using game mechanics in serious contexts, whereas Ibañez, Di-Serio and Delgado-Kloos (2014) evaluated learning effectiveness and engagement appeal of a gamified learning activity targeted at learning C-programming language. Results from the evaluation showed positive effects of gamified learning activities on student engagement and a moderate improvement in learning outcomes.

Also, Marti-Parreño, Segui-Mas and Segui-Mas (2016) conducted an exploratory study to gain knowledge of teachers' serving in higher education institutions attitude toward gamification. Also, they explored actual use of gamification. Results showed no differences in use of gamification by age, gender, or type of institution (public or private). In addition, Long (2014) designed an Intelligent Tutoring System (ITS) and integrated it with gamification to support students' learning of actionable rules for making problem-selection decisions based on their learning status afforded by the Open Learner Model (OLM), while enhancing both their enjoyment and domain level learning with the ITS. González, Mora & Toledo (2014) proposed a conceptual architecture for an ITS, known as EMATIC (Mathematics Education through ICT), that includes gamification elements as key system components. Finally, Dermeval (2016) sought to contribute to active teacher participation in the use of gamified ITS.

The use of Gamification techniques on educational applications is an important factor to develop gamification applications, the Table 3 shows the related works that have learning activities presents in there without a classification, also this works belongs a game category that is not identified into the work. It is therefore the importance a guide to identified a learning activities classification and game classification.

Use of Serious Games on Educational Applications

In their work, Obikwelu and Read (2012) adopted basic tenets of constructivism for designing learning environments. Authors aimed at ascertaining the extent to which serious games have adopted this pedagogical principle in their approach to facilitating learning. Also, Pereiraa (2012) established a shared vocabulary with the creation of a detailed taxonomy for the field of interest Personal and Social Learning & Ethics. The presented taxonomy worked well for survey purposes, whereas selected representative games exemplified the type of complete categorization that could be achieved with the taxonomy presented. From a different perspective, Carrozzinoa, Evangelistaa, Brondia, and Loren (2012) presented the concept and work-in-progress of SONNA, a research project aiming to analyze the impact of social networks, Web 2.0, and interactive multimedia learning tools.

Raybourn (2010) introduced transmedia learning, a new paradigm for more effective and scalable training and education. In this sense, transmedia learning is defined as the scalable system of messages representing a narrative or core experience that unfolds from the use of multiple media, thus emotionally engaging learners by involving them personally in the story. Likewise, Barbosa and Silva (2010) discussed the importance of Serious Games and their development phases for the Web by using WebGL technology. With this technology, developers can create compelling 3D environments and 3D video games that may be accessed by nearly every person having an Internet connection. In addition, Donovan (2012) provided industry partners with research evidence on the effectiveness of serious games in learning. The author offered examples of serious games usage in the corporate sector, identifying the types of learning content suited to a game-based learning approach and outlining key considerations when designing games for learning. On the other hand, Provelengios and Georgios (2011) discussed utilization

Table 3. Use of Gamification techniques on educational applications

Author	Little	Gamification	Game attribute	Game Category	Learning activities
Simões, Díaz-Redondo, & Fernández-Vilas (2013)	A social gamification framework for a K-6 learning platform	Yes	Yes	No	Yes
Armstrong (2013)	The new engagement game: the role of gamification in scholarly publishing	Yes	No	Yes	Yes
Lubin (2015)	The Gamification of Learning and Instruction Field Book.	Yes	Yes	No	Yes
Kapp (2007)	Gadgets, games, and gizmos for learning	Yes	Yes	No	Yes
Robson, Plangger, Kietzmann, MacCarthy & Pitt (2016)	Game on: Engaging customers and employees through gamification	Yes	Yes	Yes	Yes
Fui-Hoon Nah & others (2014)	Gamification of Education: A Review of Literature	Yes	Yes	Yes	Yes
De-Marcos (2014)	An empirical study comparing gamification and social networking on e-learning	Yes	Yes	No	Yes
Henzi & Alt (2015)	Increasing intranet usage through gamification-insights from an experiment in the banking industry	Yes	Yes	No	Yes
Matallaoui, Herzig & Zarnekow (2015)	Model-Driven Serious Game Development: Integration of the Gamification Modeling Language GaML with Unity.	Yes	Yes	Yes	Yes
Hamari, Koivisto & Sarsa (2014)	Does gamification work? - A literature review of empirical studies on gamification	Yes	No	Yes	Yes
Ibañez, Di-Serio & Delgado-Kloos (2014)	Gamification for Engaging Computer Science Students in Learning Activities: A Case Study	Yes	Yes	No	Yes
Marti-Parreño, Segui-Mas & Segui-Mas (2016)	Teachers' Attitude towards and Actual Use of Gamification	Yes	Yes	No	Yes
Long (2014)	Gamification of Support for Learning Effective Problem Selection Strategies in Intelligent Tutoring Systems	Yes	No	Yes	Yes
González, Mora & Toledo (2014)	Gamification in intelligent tutoring systems	Yes	Yes	Yes	Yes
Dermeval (2016)	Intelligent Authoring of Gamified Intelligent Tutoring Systems	Yes	No	Yes	Yes

of serious games for educational purposes through a case study on the use of Food Force serious game as a learning tool in elementary education.

Boughzala, Michel and De-Freitas (2015) stated that a serious game combines a serious intention with a game's rules and targets. Serious games are often viewed as technological applications using games to engage individuals in an experience through which a learning or professional training aim can be explored. Similarly, Matallaoui, Herzig, and Zarnekow (2015) introduced a model-driven architecture for

designing and generating building blocks for serious games, whereas Sorensen and Meyer (2007) defined serious games as digital games that educate, train, and inform, and are designed for a primary purpose other than entertainment, enjoyment, or fun. In other words, authors claimed that the initial intention of serious games was to combine the serious aspects (learning, instruction, etc.) with the playing aspect of digital games. Meanwhile, Fong-Ling, Rong-Chang and Sheng-Chin (2009) designed the hands-on OS game to introduce learners to common problems associated with computer operating systems. The main goal of this game was to enhance learners' proficiency in certain skills related to computer operating system. Finally, Martins, Carvalho and Soares (2015) argued that one way of helping both professionals and patients was developing serious games oriented to motor rehabilitation in physical therapy sessions. In this sense, authors proposed a modular system of Back Office for centralized management of one or more games targeted for physical therapy.

A serious game is a game designed for a primary purpose other than pure entertainment. It is therefore the importance that the game attributes and game category is necessary were identified in the game. The Table 4 shows the use of serious games techniques on educational applications. The table shows the results of identified a game attributes and a game category in each work that was related.

Table 4. Use of Serious Games techniques on educational applications

Author	Little	Serious games	Game attribute	Game Category	Learning activities
Obikwelu & Read (2012)	The serious game constructivist Framework for children's learning	Yes	Yes	No	Yes
Pereiraa (2013)	Serious Games for Personal and Social Learning & Ethics: Status and Trends	Yes	Yes	No	Yes
Carrozzinoa, Evangelistaa, Brondia, & Loren (2012)	Social Networks and Web- based Serious Games as Novel Educational Tools	Yes	Yes	Yes	Yes
Raybourn (2010)	A new paradigm for serious games: Transmedia learning for more effective training and education	Yes	Yes	Yes	Yes
Barbosa & Silva (2010)	Serious Games - Design and Development of OxyBlood	Yes	Yes	No	Yes
Donovan (2012)	The Use of Serious Games in the Corporate Sector	Yes	Yes	Yes	Yes
Provelengios & Georgios (2011)	Educational applications of Serious Games: The case of the game "Food Force" in primary education students	Yes	No	Yes	Yes
Boughzala, Michel & De-Freitas (2015)	Introduction to the Serious Games, Gamification and Innovation Minitrack	Yes	Yes	No	Yes
Matallaoui, Herzig, & Zarnekow (2015)	Model-Driven Serious Game Development: Integration of the Gamification Modeling Language GaML with Unity	Yes	Yes	Yes	Yes
Sorensen & Meyer (2007)	Serious games in language learning and teaching-a theoretical perspective	Yes	Yes	Yes	Yes
Fong-Ling, Rong-Chang & Sheng-Chin (2009)	EGameFlow: A scale to measure learners' enjoyment of e-learning games	Yes	No	Yes	Yes
Martins, Carvalho & Soares (2015)	Web Platform for Serious Games' Management.	Yes	Yes	No	Yes

EVALUATION AND RESULTS

Kitchenham, Linkman and Law (1997) discuss three methods for software and tools evaluation:

1. **Quantitative Methods:** Quantitative evaluations are based on the assumption that the software product has at least a measurable property that you expect to change as a result of using the methods/tools to be evaluated. Quantitative evaluations can be conducted in three different ways: case studies, formal experiments, and surveys.
2. **Qualitative Methods:** The term Feature Analysis is used in the literature to describe a qualitative evaluation based on (1) identifying the requirements that users have for a particular task or activity and (2) mapping those requirements to features that a method/tool aimed at supporting that task/activity should possess.
3. **Hybrid Evaluation Method:** Finally, the literature describes Qualitative Effects Analysis and Benchmarking as a hybrid evaluation method having both quantitative and qualitative elements.

The evaluation method used in this work was a qualitative method because in the first part the requirements were identified, the requirements was the game attributes used in each game category and in the second part of the analysis, the game attributes were identified the support in each game's engines.

Evaluation Design

This assessment method describes each aspect included in each game category as well as the learning attributes of game categories for serious games and gamification applications development. We thus conducted a qualitative evaluation of the proprietary game engines and HTML5-based frameworks discussed earlier to identify the game attributes present in them. Every subset of attributes supported by each engine was also categorized into a specific a game category.

Evaluation of Games Engines

To conduct the evaluation, we first consulted documentation on each game engine to identify supported attributes, the documentation consulted come from the APIs and Web sites of the games engines, in come case books were consulted like Canvas or Construct 2. Once game attributes were identified, we downloaded the documentation examples, this example consisted in game attributes that the documentation says that the game engine support, the examples were downloaded and tested to verify that each attribute of each engine was truly supported. If an attribute was supported and the example downloaded from the provider, then the result was saved like a result of the analysis. Otherwise, if we did not find a sufficiently stable element, we continued developing examples that fulfilled the objective of the research, following the API documentation or the supplier's practical examples. Results obtained were recorded in tables. Then, the evaluation was performed following three aspects: Aspect 1: games engines selection; Aspect 2: Identification of game attribute; and Aspect 3: Identification of game category. As mentioned earlier, we conducted a qualitative evaluation by (1) identifying the requirements of a game attribute and game category and (2) mapping each game engine and set of game attributes to a game category.

1. **Aspect 1: Selection of game engines**. To select the game engines, we analyzed their characteristics and identified the greatest number of supported elements. Analyzed characteristics included support for 2D and 3D graphics, development language, support for audio and video, software license, latest version, whether it was a multi-platform framework, and whether it was used in educational applications.
2. **Aspect 2: Identification of game attribute**. The evaluation consisted in selecting each game engine and identifying the supported game attribute. As mentioned earlier, we identified game attributes by consulting provider's documentation, downloading examples, and developing examples.
3. **Aspect 3: Identification of game category**. In this section, we assigned a game category to each game engine and game attribute by following the classification proposed by Lameras et al (2015). As mentioned earlier, authors proposed five game categories, including rules, goals and choices, tasks/challenges, collaboration and competition, and feedback/assessment. Results from the evaluation are discussed in the next subsections.

Analysis of Games Engines for Developing Educational and Serious Games

In this section, we present results obtained from the evaluation of game engines. The eight selected proprietary games engines include Unity, CryEngine, Unreal engine 4, cocos2D, Blender, BigWorld, Leadwerks and HeroEngine. The HTML5-based frameworks selected were: Construct 2, ImpactJS, Quintus, WADE, pixi.js, EaselJS, melonJS, three.js, phaser and playCanvas. They all allow for Web-based and mobile applications development, and in some cases hybrid applications. Moreover, they are the most popular game engines among developers, because they all provide a suite of visual development tools and have reusable software components. In this analysis, we rated importance of game attributes for the educational context and determined their availability in every game category, according to selected proprietary games engines. Note that additional attributes may be required depending on the educational game to be developed and the targeted academic level.

The frameworks selected allow for developing Web applications, mobile applications, and in some cases hybrid applications. In this analysis, we rated importance of game attributes for the educational context and determined their availability in every game category according to the selected games engines. Nonetheless, note that additional attributes may be required depending on the educational game to be developed and the targeted academic level.

There are the most popular games engines in use by developers, because every games engine selected provide a suite of visual development tools, in addition to reusable software components. At the end of the analysis process, we have determined the importance of the game attributes for the educational context and the availability of each game attributes on a game categories according to the selected games engines. Nonetheless, it is possible that, according to the type of educational game and the academic level to which this educational game is aimed, some other attributes can be required that they may have been omitted in this evaluation.

Table 5 shows the set of game attributes available in each games engines as well as the game category where it belongs. Note that some attributes appear in two or more game categories.

The objective of this analysis was to obtain a reference to choose a games engine for the development of educational applications, serious games or both. Table 5 shows each one of the attributes supported in each framework and serves as a reference based on what type of application can be developed to choose a framework that meets the game attributes stablished by a developer. The goal of the Table 5 is to provide

Table 5. Analysis of games engines

Game Attribute					
Game engines	**Rules**	**Goals and Choices**	**Task / Challenges**	**Collaboration and Competition**	**Feedback / Assessment**
Construct 2	-Scoring -Moving -Timer levels -Progress bars	-Missions -Avatars -Nested dialogues	-Progress bars -Major tasks -Multiple choices -Branch tasks	-Role-play -Community collaboration -Bonuses -Timers -Communal discovery -Coins -Scoring -Inventories -Leader boards	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards
ImpactJS	-Scoring -Timer Levels -Progress bars	-Puzzles -Storytelling -Missions -Avatars	-Progress bars -Major tasks -Multiple choices	-Role-play -Bonuses -Timer levels -Coins -Scoring -Inventories -Leader boards	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards
Quintus	-Scoring -Moving	-Puzzles -Missions -Avatars	-Progress bars -Major tasks	-Role-play -Timer levels -Scoring	-Game hints -Gaining/ losing lives -Progress bars
WADE	-Scoring -Moving -Timer Levels -Progress bars -Directions	-Missions -Game journal -Storytelling -Nested dialogues -Puzzles -Avatars	-Progress bars -Major tasks -Puzzles	-Role-play -Bonuses -Timer levels -Coins -Scoring -Inventories -Leader boards	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards
pixi.js	-Scoring -Moving -Timer levels -Progress bars	-Missions -Objective cards -Storytelling -Puzzles -Avatars	-Progress bars -Multiple choices -Major tasks -Branch tasks -Puzzles -Research points -Requirements	-Role-play -Bonuses -Timer Levels -Coins -Scoring -Inventories -Leader boards	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards
EaselJS	-Scoring -Moving -Timer levels -Progress bars	-Missions -Objective cards -Storytelling -Nested dialogues -Puzzles -Avatars	-Progress bars -Multiple choices -Major tasks -Branch tasks -Puzzles -Requirements	-Role-play -Bonuses -Timer levels -Coins -Scoring -Inventories -Leader boards	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards
melonJS	-Scoring -Moving -Timer levels -Progress bars -Instructions	-Missions -Objective cards -Storytelling -Puzzles -Avatars	-Progress bars -Multiple choices -Major tasks -Branch tasks -Puzzles -Requirements	-Role-play -Bonuses -Timer levels -Coins -Scoring -Inventories -Leader boards	-NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards
Three.js	-Scoring -Moving -Timer levels -Progress bars	-Missions -Objective cards -Storytelling -Puzzles -Avatars	-Progress bars -Multiple choices -Major tasks -Branch tasks -Puzzles -Requirements	-Role-play -Bonuses -Timer levels -Coins -Scoring -Inventories -Leader boards	-NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards
Phaser	-Scoring -Moving -Timer levels -Progress bars -Instructions, including victory conditions	-Game journal -Missions -Objective cards -Storytelling -Nested dialogues -Puzzles -Avatars	-Progress bars -Multiple choices -Major tasks -Branch tasks -Puzzles -Research points -Requirements	-Role-play -Community collaboration -Bonuses -Timer levels -Coins -Scoring -Inventories -Leader boards	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards
PlayCanvas	-Scoring -Moving -Timer levels -Progress bars	-Game journal -Missions -Storytelling -Nested dialogues -Puzzles -Avatars	-Progress bars -Multiple choices -Major tasks -Branch tasks -Puzzles -Research points -Requirements	-Role-play -Community collaboration -Bonuses -Timer levels -Communal discovery -Coins -Scoring -Inventories -Leader boards	-Game hints -NPCs -Gaining/ losing lives -Progress bars

continued on following page

Table 5. Continued

Game Attribute					
Game engines	**Rules**	**Goals and Choices**	**Task / Challenges**	**Collaboration and Competition**	**Feedback / Assessment**
Unity	-Scoring -Moving -Timer levels -Progress bars -Instructions, including victory conditions	-Game journal -Missions -Objective cards -Storytelling -Nested dialogues -Puzzles -NPCs	-Progress bars -Multiple choices -Major tasks -Branch task -Puzzles -Research points -Requirements	-Role-play -Community collaboration -Bonuses -Contest -Scoring -Timers -Coins -Inventories -Leader boards	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards -Lives
Cryengine	-Moving -Timer levels -Progress bars - Instructions, including victory conditions	-Missions -Objective cards -Puzzles -NPCs/ Avatars	-Progress bars -Multiple choices -Puzzles -Requirements	-Bonuses -Contest -Scoring -Timers -Coins -Leader boards	-Game hints -NPCs -Game levels -Progress bars -Dashboards
Unreal Engine 4	-Scoring -Moving -Timer levels -Progress bars - Instructions, including victory conditions.	-Game journal -Missions -Objective cards -Storytelling -Puzzles -NPCs/ Avatars	-Progress bars -Multiple choices -Major tasks -Branch task -Puzzles -Research points -Requirements	-Role-play -Community collaboration -Bonuses -Contest -Scoring -Timers -Coins -Inventories -Leader boards -Communal discovery	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Progress trees
Cocos2d	-Scoring -Moving -Timer levels -Progress bars - Instructions, including victory	-Game journal -Missions -Objective cards -Puzzles -NPCs/ Avatars	-NPCs-based tasks description -Multiple choices -Major tasks -Branch tasks -Puzzles -Research points -Requirements	-Role-play -Community collaboration -Bonuses -Contest -Scoring -Timers -Coins -Inventories -Leader boards	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards -Progress trees
Blender	-Scoring -Moving -Timer levels -Progress bars -Instructions, Including victory conditions	-Missions -Objective cards -NPCs/ Avatars	-Progress bars -Major tasks -Branch tasks -Puzzles	-Bonuses -Contest -Scoring -Timers -Coins -Leader boards	-Game hints -NPCs -Game levels -Progress bars -Dashboards -Progress trees
BigWorld	-Scoring -Moving -Timer levels -Progress bars - Instructions, including victory conditions	-Game journal -Missions -Objective cards -Puzzles -NPCs/ Avatars	-NPCs-based tasks description -Progress bars -Multiple choices -Major tasks -Branch tasks -Puzzles -Research points -Requirements	-Role-play -Community collaboration -Bonuses -Contest -Scoring -Timers -Coins -Inventories -Leader boards	-Game hints -NPCs -Gaining/ losing lives -Progress bars -Dashboards -Progress trees
Leadwerks	-Scoring -Moving -Timer levels -Progress bars	-Game journal -Missions -Puzzles -NPCs/ Avatars	-Progress bars -Multiple choices -Major tasks -Branch tasks -Puzzles	-Role-play -Community collaboration -Bonuses -Scoring -Timers -Coins -Inventories -Leader boards	-Game hints -NPCs -Game levels -Gaining/ losing lives -Progress bars -Dashboards
HeroEngine	-Scoring -Moving -Timer levels -Progress bars	-Game journal -Missions -Objective cards -Puzzles -NPC	-Progress bars -Major tasks -Branch tasks -Puzzles -Requirements	-Role-play -Bonuses -Scoring -Timers -Coins -Inventories -Leader boards	-Game hints -NPCs -Game levels -Progress bars -Dashboards -Progress trees

a reference for choosing the most suitable games engine for the development of educational or serious games considering learning activities and the game attributes that can be present in the application.

DISCUSSION

This paper presents an analysis of the most used game engines in order to identify game attributes and learning attributes supported in educational and serious games development. Results from this analysis link each set of attributes contained in game engine with a game category and offer a practical guide to identifying those engines that provide the largest support for game attributes. Likewise, results aim at supporting developers in the game development process by helping them identify which attributes will be present in the new game and select the game engine that provides the largest support for game attributes, always considering the game deployment environment.

CONCLUSION

Gamification is the use of game principles in the field of education aimed at increasing student engagement in and enthusiasm for learning. Meanwhile, serious games are virtual environments explicitly intended to educate or train, and they are designed for a primary purpose other than pure entertainment. Fueled by the increasing popularity and advantages of both gamification and serious games across different contexts, in this work we sought to demonstrate both utility and importance of game attributes in the educational environment. As future directions, we will intend to integrate additional framework, such as Cube and Adventure game studio, among others. Also, we will consider the inclusion or approach of a methodology to analysis of games engines for educational and serious games.

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