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## Using pervasive games as learning tools in educational contexts: a systematic review

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**Abstract:** Technology is now a vital part of our society and with such a significant impact on the educational system, information and communication technologies (ICT) cannot be dissociated from the educational process (Ramos and de Andrade, 2016). While the implementation of digital technologies in society and more specifically among young people represents a challenge for teachers, it might also provide the opportunity to improve academic performance. In this context, pervasive games have established a new trend and present a new way for people to interact with each other in a real environment by means of virtual worlds and the elements they bring to the table. Students are therefore able to enjoy a learning process with fun graphics on their mobile devices, as well as stories or other features common to pervasive games. In this paper, we focus our attention on the results of pervasive learning games, results which we had previously obtained from a systematic literature review (Arango-López et al., 2017a), as well as from a review of specific literature to identify different research projects for improving the learning process.

**Keywords:** pervasive games; learning games; education; systematic review; mobile learning.

## **1 Introduction**

Every day, more and more games are available on our mobile devices but mostly all of them have similar environmental features. The only game environment proposed by most games is the virtual world inside it, with its own rules, challenges, scenarios and characters. People spend much of their leisure time involved in these virtual environments and this often results in reduced physical activity and less social interaction with others.

In this way, mobile devices have come to play a rather fundamental role in our lives by enabling many of our everyday activities to be associated with the context in which they are performed. Due to the wide availability of personal communication devices, there has been an increase in the demand for location-based mobile services (Ahmadi et al., 2014).

We use mobile devices to communicate with friends and family, for work or even to play games for entertainment, but we can also use them in other activities such as sightseeing, to purchase goods or services, to obtain information about something using its QR code, or in the learning process at school (Moreira and Ferreira, 2015; Moreira et al., 2016). In the case of entertainment, applications contain virtual worlds and users are invited to be a part of said worlds. As the game progresses, players become more and more immersed and as they do, they disconnect from the real world.

Much is to be gained by taking advantage of these technological capabilities in the educational process, and by allowing students to use their devices and knowledge and by integrating technology in a learning activity, we posit homework will become more enjoyable and there will be better communication between teachers and their students as a result of these pervasive games.

This paper considers pervasive games to be a ludic form of mixed reality (i.e., real and virtual reality) entertainment with goals, rules, competition and attacks, based on the use of mobile computing and/or pervasive computing technologies (Hinske et al., 2007). This is possible through the use of the device's sensors (Viana et al., 2014). Such games are a recent form of entertainment that takes the game experience out of the device and brings it into the physical world, integrating both virtual and physical realms (Valente et al., 2015). It also proposes a new way to play a game wherever and whenever the user wants, combining real and virtual elements, places and people, and including everyday

life events. In this way, pervasive games break the boundaries of the circle surrounding classic games (Montola, 2005).

We want to know how these games can improve the results of students in learning activities. In addition, taking into account another previous research (Arango-López et al., 2017c), where we defined that some theoretical subjects are boring to learn for students, we want to know if pervasive games can empower students to change their thinking about these subjects, and also, to know if the application of these games can increase the students' motivation to learn.

This paper is structured as follows: Section 2 provides an overview of games in general and pervasive games in particular, and describes how they can help in an educational context and how they are involved in the learning process; Section 3 presents the methodology used to conduct the systematic literature review; Section 4 shows the results obtained during data extraction and analysis; Section 5 presents the current and future trends; Section 6 outlines our conclusions and lines of future work.

## **2 Background**

One specific problem of the pervasive game definition is that there is no general meaning for every context; therefore, different definitions for the term have been presented within the scientific community such as healthcare, education, tourism, arts, etc. However, for ease of understanding in this paper, we can present some definitions of it. Firstly, pervasive gaming is a genre of gaming that systematically blurs and breaks traditional game boundaries. The limits of the magic circle are explored in spatial, temporal, and social dimensions (Montola, 2012). Secondly, pervasive games can be a valuable and enjoyable way of bringing people back to the physical world and can play a key role in motivating people to interact offline (Caon et al., 2013). Thirdly, a digital pervasive game can be defined as a game in which the gaming experience is extended to the real world (Viana et al., 2014). Finally, a perspective of pervasive games from the point of view of the player's experience is presented by Arango-López et al. (2017b), where they explain how the user experience is enriched through the evolving of the game world and its components.

These definitions reveal an interesting research field to explore and figure out how this type of game can support the learning process by providing a more realistic experience and increasing motivation both in the classroom and at home by means of ludic activities through pervasive games.

### *2.1 Related work*

From the moment we are born, we play, and playing facilitates learning; hence the term edutainment (Nemec and Trna, 2007; Moreno-Ger et al., 2008). Developments in technological devices, communication networks, etc. are therefore being used to take advantage of their potential in the field of education. However, many of these projects have failed in several circumstances (Valente and Feijó, 2014), because there is no model for building technological tools that focus on pervasive games and their special features. As a result, there has been new research into the design models, showing a new perspective of these applications. Various studies have been conducted on pervasive

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games, researching their scope and application in different fields such as education, learning, training and evaluation.

Angelo et al. (2016) have based their work on traditional teaching methodologies and have managed to create models for the development of mobile applications and various features have been added to address the concept of pervasive computing.

Various applications have also been developed to answer the call from educational institutions for technological tools that can be implemented in the teaching process, but not all have the same aims. For example, mixed systems are controlled by a central server, and client terminals (represented by mobile devices) capture environment data while showing information to the player (Ferreira et al., 2015; Lemcke et al., 2015). More specifically, we discovered an interesting app in the field of evaluation that enables the teacher to assess students and track their improved performance.

There are also native applications that only run on a mobile device and take advantage of the device's special features. The first example (Frias-Martinez et al., 2012) shows how the application named 'EducaMovil' can help to improve knowledge acquisition in the classroom. The second is an experiment presented by Nordby et al. (2016), which consists in giving tools to students to create an overarching pervasive game on a blackboard; through it, children help prevent climate change with various small actions and must solve problems around the school. These applications generally facilitate collaborative work, which is important for enabling students to acquire new knowledge and special skills as a team.

Some other published projects and prototypes will be reviewed in Section 3.

### *2.2 Games*

In the pre-computer age (Miller, 1969), games were designed and played out in the physical world with the use of real-world properties, such as physical objects, our sense of space and spatial relations (Magerkurth et al., 2005). The main objective of such games was entertainment. With technological progress, however, human relationships have migrated from the physical to the virtual world (Caon et al., 2013), and games can currently be designed and used for a wide range of purposes (Sedano et al., 2007), such as individual entertainment (Holleis et al., 2006), as a catalyst for social interaction (Paelke and Reimann, 2005), for teaching-learning (Padilla-Zea et al., 2017), as an experimental platform for new technologies and game design concepts, and as a publicity campaign, to name just a few.

Unlike toys, games have the advantage of being organised and structured: every player is aware of the goal of the game; the rules guarantee fair competition; both the game's current situation and outcome can be measured and compared; the players must make decisions based on available, countable resources. In other words, the rules are the central component of a game and *virtualising* them can yield benefits for the players (Hinske and Langheinrich, 2009). At school or university, games can therefore help students and teachers by making the learning process more interesting and interactive and by providing opportunities for the development of new skills in a motivating way. Students can use their mobile devices for more than just calling or messaging and can take greater advantage of the device's technological capabilities such as geolocation sensors, camera, and data processing power, thereby enabling them to perform better academically, both as individuals and as a group.

### 2.3 *Pervasive games*

Pervasive games represent a radically new game form that relays gaming experiences to the physical world, weaving information and communication technologies (ICTs) into the fabric of the players' real environments (Kasapakis and Gavalas, 2015). Many different forms of gaming have been grouped under the concept, including the massively collaborative troubleshooting games (The A.I. Game), location-based mobile games (Botfighters), games which enhance reality with ludic content (Visby Under), and games which combine virtual and physical elements (Montola, 2005).

Mobile devices are currently the main elements for achieving pervasive game objectives since they are linked naturally and directly. They are the main driving force for fulfilling the promises of pervasive game playing as they are naturally networked, they contain sensors, their use is widespread and they are easily accessible (Valente et al., 2015). Due to the need for a corresponding infrastructure, short-range proximity sensors are not ideal for implementing pervasive games, hence GPS and Wi-Fi form the basis of most recent location-aware games (Magerkurth et al., 2005). Emerging pervasive games use sensors, graphics and networking technologies to provide immersive game experiences integrated with the real world (Sra and Schmandt, 2015).

These games may involve one or more players, who may be distributed or co-located, and game play can take place in a wide variety of locations and contexts where one might expect such mobile devices to be used (Soule et al., 2013). Games have not received full attention of the engineering community's requirements. This scenario is becoming more critical as we move towards newer forms of games, namely pervasive games (Valente et al., 2015); these include different types of games, such as mixed reality games, augmented reality games and geolocated games.

Games have increasingly become a family pursuit that people play together socially, either online or in real spaces (Ariffin and Sulaiman, 2014), absorbing the player in a single reality (virtual or real).

### 2.4 *Pervasive games in education*

Education plays a crucial role in human progress and academic success is one of the factors for improving the quality of life (Anopas and Wongsawat, 2014). The wide use of different digital technologies in daily activities, especially in social interactions has transformed the ways people interact and communicate (Santos-Trigo et al., 2015). The rising popularity of video games has seen a recent push towards the application of video game-based technologies for teaching and learning (Kapralos, 2012).

Along the same lines, children enjoy such stimuli and they can accomplish tasks in an easier and more pleasurable way (Stach and Schlindwein, 2012). Teachers can therefore use these games to introduce new teaching methods in order to improve student performance in the classroom. Other features of pervasive games such as geolocation, graphics and virtual characters can provide students with the opportunity to communicate with each other and to achieve objectives as a team, and improve their social relationships through group work.

Pervasive and augmented learning games address a broad variety of topics, target groups and educational domains (Schmitz et al., 2012). Progress in the field of ICTs and the facilities offered by the digital wave have favoured the renewal of certain innovative teaching methods (Souad, 2016).

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Games will also make the education process more enjoyable and pleasant and will encourage students to be more active in class (Tüysüz, 2009). This is possible because in digitally-told stories, there may be large amounts of real content, as well as completely virtual elements (Jantke and Hume, 2015), and this can improve student motivation. A person's motivation is evidently a key factor in skill acquisition and engages knowledge.

Game-based learning promises to be a new successful approach in university education. Motivating students nowadays with traditional teaching methods such as lectures and written materials proves to be a difficult task and universities are therefore seeking new methods in the changing context of education (Kuk et al., 2012). There are also certain specific kinds of games that are more serious and in addition to the game element also have a more significant purpose, such as, for instance, learning (Palazzi, 2015). Even though serious games are not the same as pervasive games, they share many common features when used in education and learning, thus we have included various results for serious games in our systematic literature review.

### **3 Systematic literature review**

A systematic literature review is a method for analysing, evaluating and interpreting every relevant study to a particular research question, specific area or phenomenon of interest (Paz and Pow-Sang, 2016). This process originated in medical science due to the ever-increasing amount of research into each area (Kitchenham et al., 2009). Consequently, it is necessary to identify and guide research towards a specific, unresearched subject.

Accordingly, the scientific community, and more specifically the area of software engineering, have proposed some steps for the application of these protocols in this area. Kitchenham and Charters (2007) propose a series of phases which are used in this document. The process is described below.

#### *3.1 Need for the literature review*

One consequence of the current wide adoption of mobile computing is the emergence of mobile and pervasive gaming (Soute et al., 2013) and it is necessary to obtain information about the pervasive game tools involved in educational and learning activities. This will enable us to draw some conclusions about the current state of these technologies in the field of education in terms of applications, design models and methodologies that support the implementation of pervasive games in learning and training activities.

#### *3.2 Research questions*

The main objective of this systematic literature review was to obtain important data about scientific production, journal papers or conference proceedings, in order to identify the current state of pervasive games in an educational context. For this purpose, we plan to search different databases for relevant articles and we believe that the following questions are important:

RQ1 What kinds of applications based on pervasive games principles are used in the educational or learning process?

RQ2 Are these pervasive games led by learning techniques or methodologies in the field of education?

Continuing on with the methodology phases proposed by Kitchenham and Charters (2007), we consider applying PICOC (Chamberlain et al., 2013) to define the main concepts. Since the aim of our research is not to compare interventions, the ‘comparison’ criterion was not considered. These concepts are detailed in Table 1.

**Table 1** Definition of concepts using PICOC

<i>Criterion</i>	<i>Description</i>
Population	Researchers, students, and teachers
Intervention	Pervasive games in an educational context
Outcome	List of applications used in training and learning activities and, if possible, the model design or methodology applied for this
Context	Academic level

### 3.3 Search terms

In the PICOC analysis, various terms appear which are associated with pervasive games and their application in an educational context. The terms are as follows:

- 1 pervasive game
- 2 learner
- 3 learning
- 4 education
- 5 training.

### 3.4 Search process

With search terms, we build a query string and this is supplemented with logic operators to improve execution results. We limited the search process to papers that had been published in journals or conference proceedings since 2012. The string was executed on 12<sup>th</sup> February 2017 and we obtained the following result:

**((educat \* OR learn\*) AND (“pervasive” AND gam\*))**

For each database, it was necessary to build a specific string because each has a different syntax. Examples of these resulting strings are shown below.

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*IEEE Xplore string:*

**(((((("Document Title":educat\*) OR "Abstract":educat\*) OR "Document Title":learn) OR "Abstract":learn) AND (((p\_Title:"pervasive" AND p\_Title:gam\*) OR ("Abstract": "pervasive" AND "Abstract":gam\*))))))**

*ACM Digital Library string:*

**(( acmdlTitle:(educat\* learn\*) OR recordAbstract:(educat\* learn\*)) AND (recordAbstract:(pervasive AND gam\*) OR acmdlTitle:(pervasive AND gam\*)))**

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*Science Direct string:*

**pub-date > 2011 and TITLE-ABSTR-KEY((educat\* OR learn\*)) and TITLE-ABSTR-KEY((pervasive AND gam\*))**

In order to obtain the best results, we also applied various filters and these were defined as inclusion criteria and exclusion criteria. The following sections show a list of each criterion type.

### *3.5 Inclusion criteria*

- 1 Paper published between 2012 and current date.
- 2 Paper published as result of conferences, congresses or journals.
- 3 Paper written in English.
- 4 Paper included in databases shown in Table 2.

### *3.6 Exclusion criteria*

- 1 Paper only has a content table or summary.
- 2 Paper is not related to research.
- 3 Paper describes a process with no prototype for validation.

### *3.7 Extracting information*

We considered different databases in order to execute the query string. Access to these databases is private and the database names and links are shown in Table 2.

**Table 2** Databases used in the search with the query string

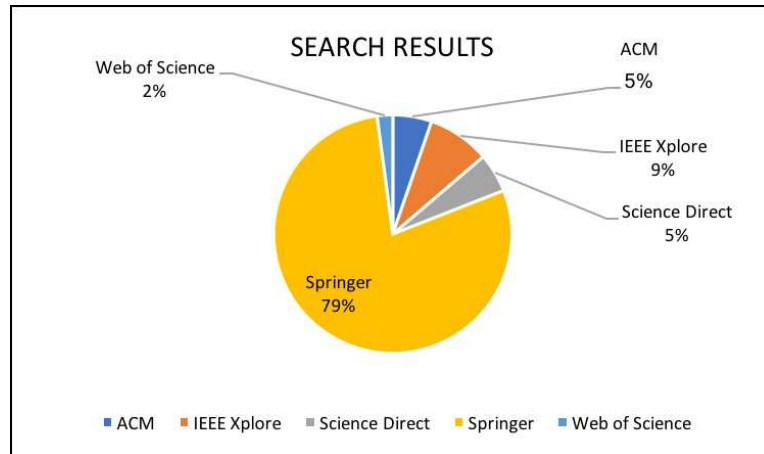
<i>Name</i>	<i>URL</i>	<i>Acronym</i>
Springer link	<a href="http://www.springer.com/">http://www.springer.com/</a>	Springer
Science Direct	<a href="http://www.sciencedirect.com/">http://www.sciencedirect.com/</a>	ScDirect
IEEE Xplore Digital Library	<a href="http://ieeexplore.ieee.org/">http://ieeexplore.ieee.org/</a>	IEEEXplore
ACM Digital Library	<a href="http://dl.acm.org/">http://dl.acm.org/</a>	ACM
Web of Science	<a href="https://webofknowledge.com/">https://webofknowledge.com/</a>	Web of Science

**Table 3** Results of the run query for each database (number)

<i>Database</i>	<i>Results</i>
IEEEXplore	16
ACM	10
Springer	149
Science Direct	10
Web of Science	4
<i>Total</i>	<i>189</i>

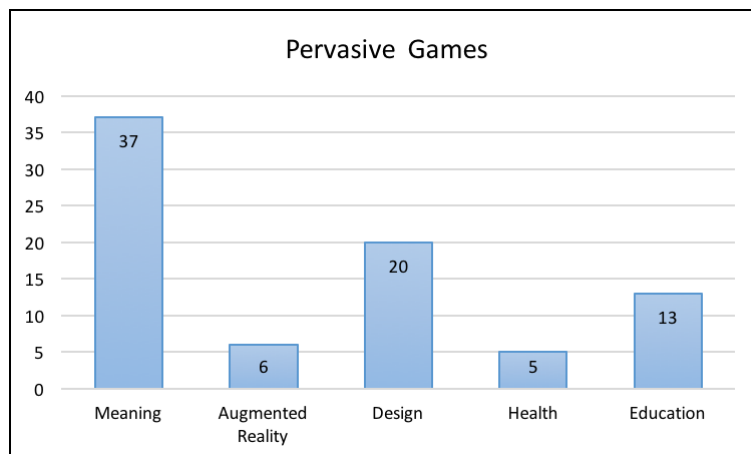
By running query strings for each database, results were obtained for the different topics, papers associated with the search terms were found, and exclusion criteria were also applied on these. Eventually, 189 papers were accepted for analysis and the results are shown in Table 3 and Figure 1.

**Figure 1** Search results for each database (percentage) (see online version for colours)



Using the numbers shown in Table 3, we have created a pie chart to represent the results as percentages (Figure 1). This figure shows the results of the different databases, and Springer is the most representative in terms of the percentage of papers (79%), but this is really due to the limited number of filter options that this database has. In the other databases, there are options that help us filter the search results.

**Figure 2** Search results for the pervasive games category of the previous systematic review (see online version for colours)



Our systematic literature review yielded similar results to those given by Springer and other databases. This information is shown in Figure 2, which displays the results for the pervasive game categories for each subcategory. The education subcategory has 13 related papers, a similar number to our most recent review (as we mentioned in the introduction, we conducted another review of literature relating to pervasive game development last year).

## 4 Data analysis and results

### 4.1 Additional filters

Figure 1 displays the overall results. We analysed and evaluated the title and abstract of each paper to check that they were relevant to the research topic. The results of this process are displayed in Table 3. The table shows the percentages for the analysis results based on total papers for each database, categorised according to type: accepted, rejected (in terms of additional criteria such as title, abstract and full text) and duplicated. However, some papers were rejected (R) and found in different databases (D). For this reason, there is a difference between the total number of papers shown in Table 3 and the total number of papers in Figure 1.

**Table 4** Title, abstract and full-text analysis results

<i>Databases</i>	<i>Total</i>	<i>D</i> <sup>1</sup>	<i>% D</i>	<i>A</i> <sup>2</sup>	<i>% A</i>	<i>TR</i> <sup>3</sup>	<i>AR</i> <sup>4</sup>	<i>FTR</i> <sup>5</sup>	<i>R</i> <sup>6</sup>	<i>%R</i>
IEEEXplore	16	0	0	6	37.5	4	5	1	10	62.5
ACM	10	0	0	5	50	3	1	1	5	50
Springer	149	7	4.7	3	2	133	8	5	146	98
Science Direct	10	1	10	1	10	7	1	1	9	90
Web of Science	4	0	0	2	2	1	0	1	2	50
<i>Total</i>	<i>189</i>	<i>8</i>	<i>4.2</i>	<i>17</i>	<i>9</i>	<i>149</i>	<i>15</i>	<i>9</i>	<i>172</i>	<i>91</i>

Notes: <sup>1</sup>Duplicated: when a paper was included in the results list more than once.

<sup>2</sup>Accepted: a paper meeting exclusion/inclusion criteria requirements.

<sup>3</sup>Title rejected: papers excluded because the title indicated another area of study.

<sup>4</sup>Abstract rejected: papers excluded because the abstract indicated another area of study.

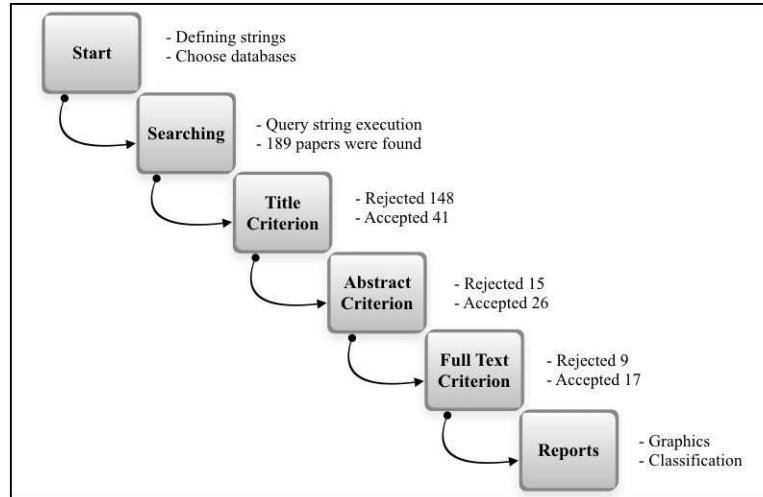
<sup>5</sup>Full text rejected: papers excluded because the content indicated another area of study.

<sup>6</sup>Rejected: papers not meeting exclusion/inclusion criteria requirements (sum of TR, AR and FTR).

### 4.2 Process description

Figure 3 shows the search process description and application of exclusion criteria. Once the first additional exclusion criterion (based on title) had been applied, the number was reduced from 189 to 40 papers. By applying the second additional exclusion criterion (based on abstract), the number of papers was reduced to 25. These 25 papers were then read to achieve the third additional exclusion criterion (based on the full text). Finally, 16 papers were selected to answer the research questions. In this phase, we were sure that each paper was relevant to the research topic.

**Figure 3** Steps of the systematic literature review search



Through this process, we can define that the numbers with the greatest relevance are associated with the acceptance percentage; 8.5 % is a good result and corresponds to 16 papers. The subsequent classification is represented in Table 5. The complete list of papers and codes has been included in Appendix.

**Table 5** Results according to topic category and paper

<i>Category</i>	<i>Subcategory</i>	<i>#</i>	<i>Studies (Appendix)</i>
Academic	Evaluation	6	006, 015, 016, 018, 022, 024, 034
	Individual work	15	005, 012, 014, 015, 016, 017, 018, 021, 022, 024, 031, 034, 038, 176, 179, 182
	Group work	13	005, 012, 015, 017, 018, 022, 024, 031, 034, 038, 176, 179, 182
	Teacher Interaction	3	012, 014, 015, 016, 018, 022, 024, 031, 034, 176, 179
Technological	Prototype	13	005, 014, 015, 016, 017, 018, 021, 022, 024, 031, 034, 038, 176, 182
	Ontology-based	2	006, 017
	Geolocation	4	018, 038, 176, 182
	Related with serious games	3	012, 018, 031
Level	School	10	006, 012, 015, 016, 017, 022, 024, 031, 034, 176, 179
	University	11	005, 006, 012, 014, 015, 017, 018, 021, 038, 179, 182
Methods	Design model	10	006, 012, 014, 017, 018, 024, 031, 034, 176, 179

In order to better explain the results shown in Figure 3, Table 5 presents a general description of the categories found. Efforts have obviously been made to incorporate pervasive games in the learning process to stimulate individual and group work in

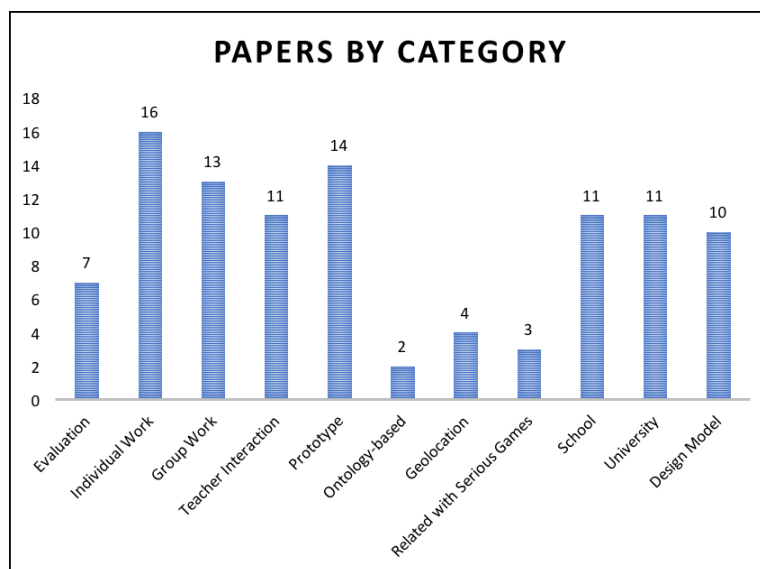
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universities and schools. Figure 4 displays the results and number of papers for each category and it is apparent how activities that are not led by the teacher can lead to self-learning.

Another important characteristic revealed by these results relates to where the learning is taking place, and universities and schools are objective in the application of these games for improving student performance both in and outside the classroom, either with or without a teacher.

Additionally, we can say that a representative number of prototypes present a design model for development and new frameworks for this.

**Figure 4** Results of papers found according to category (see online version for colours)



### *4.3 Results*

The benefits of using serious games in an educational environment have been recognised. Although this type of game does not belong in the category of pervasive games, both have common features which enable us to take advantage of their strengths in order to provide more options for students and teachers and to improve learning activity skills. Figure 4 shows how almost 25% of the prototypes relate to serious games.

On the basis of our systematic literature review and its results, answers are provided to the following research questions.

RQ1 What kinds of applications based on pervasive games principles are used in the educational or learning process?

Figure 4 shows that 14 prototypes were found and these are focused 100% on support education from a technological perspective. However, not all the papers concern the same field. We have identified categories such as applicability (which demonstrates the importance of developing educational skills for individual and group work), interaction

(by maintaining a direct relationship between teacher and student, which is present in 78.5% of prototypes, and also between students), use of technology, and academic levels. These results suggest that pervasive game implementation has been successful since it has led to an increase in student motivation when these games are used in academic activities.

We identify the main objectives in terms of education for each prototype and examples of these are presented below.

- Assessment of knowledge acquired in class (Shih and Chen, 2012; Palazzi, 2015).
- Application of this knowledge (i.e., the theory learned in class) in the real world (Lemcke et al., 2015; Ahmad and Rahman, 2015).
- Interaction between classmates to achieve a common objective, combining and sharing knowledge (Lemcke et al., 2015; Nordby et al., 2016).
- Student support to show them around and help them settle into the academic environment (Köhlmann et al., 2012; Zender et al., 2014; Lemcke et al., 2015).

Unfortunately, the results found in the papers have no detailed information about topics such as age range of students or specific subjects, and this will be a subject for future research. We did, however, find that group work has a positive impact with the application of games in the classroom, by increasing student motivation in certain areas because of student involvement with technology and games. Consequently, relationships between students and their support for each other can improve naturally.

RQ2 Are these pervasive games addressed by learning techniques or methodologies in the field of education?

We identified design models for pervasive games that are associated with the educational context, such as gamist, narrativist and simulationist (GNS) (Shih and Chen, 2012), game theory (Mejbri et al., 2016), dynamic pervasive storytelling (DPS) (Plohn et al., 2015) and instructional design (Ahmad and Rahman, 2015), to name but a few. However, there are no explicit learning techniques within these. It was necessary to analyse each one in order to categorise it into one or many kinds of learning. We took into account six different types of learning and found applications in four of them. The evaluated learning types were: context-based learning (Tessmer and Richey, 1997), meaningful learning (Heinze-Fry and Novak, 1990; Novak, 1990), project-based learning (Kotnour and Vergopia, 2005; Helle et al., 2006), cooperative learning (Oxford and Dean, 1997), social learning (Bandura, 1971) and service learning (Bingle and Hatcher, 1991, 2000). No prototypes are associated with the last two types of learning, but the other types of learning are presented as follows:

- Context-based learning (Frias-Martinez et al., 2012; Köhlmann et al., 2012; Zender et al., 2014; Lemcke et al., 2015; Lamrani and Abdelwahed, 2016).
- Meaningful learning (Shih and Chen, 2012; Ferreira et al., 2015; Ahmad and Rahman, 2015; Lamrani and Abdelwahed, 2016).
- Project-based learning (Chen et al., 2014; Lemcke et al., 2015).
- Cooperative learning (Chen et al., 2014; Ferreira et al., 2015; Lemcke et al., 2015; Gennari et al., 2016).

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It is important to say that a pervasive game can be associated with different kinds of learning. The process for classifying these applications was:

- 1 Completely read the paper.
- 2 Identify how the prototype works and what its field of application is.
- 3 Classify each prototype according to defined variables, such as individual and group work, assessment, interaction with teachers, etc.
- 4 Each learning type has a set of characteristics, and we found relationships between these and identified variables.

To complement RQ1 and RQ2, we want to delve into the areas of engagement and gamification. Although these fields of knowledge are important, each one has its own features and different impact in the educational process. In one hand, we have the gamification, which allows us to introduce a fun component in learning activities. Through gamification and their patterns (Cortizo Pérez et al., 2011; Ašeriškis and Damaševičius, 2014; Gamification Design Elements, 2015; Arango-López et al., 2017c), students are more interested in tasks, which entails an increase in their learning motivation towards them. Students set goals continuously; not learning goals, but game goals, like to become the best in a rank table or to have the best gun in the game. Indirectly, these game goals support the motivation and learning process.

On the other hand, when pervasive principles are applied in the education context, the students present a high level of engagement with the game (Huizenga et al., 2009; Schmitz et al., 2012; Melero et al., 2015), and also with the subject. For instance, a successful pervasive game that captured the attention of players was Pokemon GO; this game engaged a lot of players in few days, the players walked a lot to get more Pokemons, and this is a behaviour that comes from the game. About education, we found several case studies where the relationship between motivation, engagement and the results obtained by students was established. For instance, in Gennari et al. (2016) a case study was conducted, where results assessed whether groups of children continued using gamified probes for cooperating over time. The results were positive, and children showed a greater interest with the gamified activities.

In the next section, we present how the social extension of pervasive games will be applied in order to get information about collaborative learning and group engagement.

## **5 Current and future trends**

Several papers allowed us to find out the current and future trends in pervasive games applied to education and learning. Some of these are:

- 1 The development of pervasive skills in an educational context through implementation of methodologies and new techniques to give the students a set of new learning tools.
- 2 To increase the motivation level of students in the learning process.
- 3 The user experience is a field that researchers want to improve as a new way to increase the learning activity in several knowledge areas.

A collective aim is to provide a fun way for students to play and learn. In addition, a common need expressed in different papers is related to the measurement techniques of the effectiveness of pervasive games in the learning process, in both isolated and collaborative environments.

The majority of the prototypes presented in the papers found are physical games; for instance, in Gennari et al. (2016) cards are used as stimulus for creating stories in a game. In fact, the pervasive narrative is one of the main topics to work on in the future, to engage the students in each learning activity through a story. On the other hand, the technologies are not necessarily implemented in pervasive games; therefore, generating technological tools is a way to contribute to learning based on games, especially, when technological devices are part of our daily life, including the interaction with games.

Researchers proposed that pervasive computing contributes immensely to making our lives simpler, more accessible, easier, and any object ahead can become more useful. However, most widespread devices have made an impact in a variety of areas. That is why, it is necessary to continue with the design of pervasive games, taking advantages of their features. Actually, the target has been extended to people with special conditions like blind and deaf people because they are a crowd with serious limitations in the education field.

## **6 Conclusions and future work**

The main objective of this article was to research the applicability of pervasive games in an educational context and identify the type of game used to improve the student learning process. Our second objective was to examine the application of these games both in and outside the class. It was also important to identify student interaction with the game, either on their own or with others.

The researchers and teachers implemented the pervasive games in schools and universities using tests and experiments to improve student performance. The researchers implemented prototypes, which were then tested together with the students. They reported a significant increase in student concentration and motivation in academic activities.

Pervasive games have a greater impact on more theory-based academic areas due to the dynamics and ludic activities provided by these games. This is a good way to increase the student's knowledge acquisition, irrespective of their age, as the research was conducted in both schools and universities.

Viviers et al. (2016) state that the students said that they would recommend educational games to fellow students and that similar teaching methods should be applied to develop pervasive skills. They are also endorsed by teachers who would then recommend them to their peers, so that these methodologies and tools can be applied to enhance class content. Accordingly, pervasive games offer a new way of teaching certain topics that is more successful than traditional methodologies. Thanks to the experience gained during the game, users can interact with real objects and people and can apply their acquired knowledge in real-life activities, enabling them to retain this knowledge for longer.

### *Using pervasive games as learning tools in educational contexts*

Although, the identified papers described design methods for pervasive games, we were interested in learning techniques that could be applied to these games. It was therefore necessary to classify the prototypes by identifying and associating their features with already known educational techniques.

In conclusion, this paper enables progress to be made in an educational context through the use of pervasive games with an enhanced user experience, which will improve the student learning process and lead to a greater acquisition of reasoning skills by incorporating real and virtual world elements. It is important to highlight the fact that the implementation of these games must always be supplemented with traditional learning techniques to provide the necessary academic balance.

At present, there is no guideline for pervasive games development and even less so in the academic context. A pervasive game development methodology is therefore needed to consider and address each of the games' different features.

By way of future research, we will consider student groups that have been classified according to age and subject in order to evaluate the theoretical and practical components. We believe that not only is it important to create or apply metrics to measure progress in the teaching and learning activities, but also to consider a process to compare the effectiveness of pervasive games, serious games and traditional activities in the classroom. Within the JUGUEMOS project (see Acknowledgements) there are aims specifically for these points, and several doctoral and master theses are focused on evaluating the user experience from an educational point of view.

In a previous research (Arango-lópez et al., 2017c), we have had experiences with school students evaluating the motivation through gamification patterns, both individually and in collaborative ways. Now, we want to do experiments applying pervasive games in the same context, thus, we could have a comparison between traditional methodologies, gamification patterns and pervasive games. We keep in mind metrics for each process, and in this case we consider measuring the game playability (Sánchez et al., 2012) and students' motivation (Tondello et al., 2016). The objective group is the same used previously to compare the performance for each technique. Thus, we want to know how can pervasive games really impact and enhance the education and learning process, considering the pervasive context presented by Söbke et al. (2017).

Along the same lines, we consider proposing, in a doctoral thesis, for a software process that develops pervasive games to be created; also, we want to consider certain special features that aim to extend the playability metrics proposed by Sánchez et al. (2012) and can be applied in different contexts. In addition, in an undergraduate degree project, we are working to build a tool to edit and create game experience based on pervasive narrative that can be a way to improve user experience, which could generate an increase in the level of engagement and motivation.

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## Appendix

File with complete results is available here: <https://goo.gl/DW2Zuh>

Accepted papers are related as follows:

<i>Code</i>	<i>Journal</i>	<i>Paper title</i>	<i>Year</i>
005	IEEE	FreshUP: implementation and evaluation of a pervasive game for freshmen	2012
006	IEEE	Personalisation of gamification in collaborative learning contexts using ontologies	2015
012	IEEE	Learning through play in pervasive context: a survey	2015
014	IEEE	Approaching M-learning with the application of instructional pervasive game	2012
015	IEEE	A mobile serious game for computer science learning	2015
016	IEEE	AKAMIA – chemistry mobile game-based tutorial	2014
017	ACM	Analysis of pervasive games-based learning systems requirements using game theory	2016
018	ACM	RouteMe: a multilevel pervasive game on mobile ad hoc routing	2015
021	ACM	Mystery at the library: encouraging library exploration using a pervasive mobile game	2015
022	ACM	Mobilising education: evaluation of a mobile learning tool in a low-income school	2012
024	ACM	Geometry in the real world: mobile image processing for educational games	2015
031	Springer	Visual novels: a methodology guideline for pervasive educational games that favours discernment	2014
034	Springer	Gamified probes for cooperative learning: a case study	2016
038	Springer	HiNTHunt – a pervasive game to support and encourage desired activities for new students	2014
176	WoSc	The art of gamification; teaching sustainability and system thinking by pervasive game development	2016
179	WoSc	Dynamic pervasive storytelling in long lasting learning games	2015
182	ScDirect	FreshUP: a pervasive educational game for freshmen	2014