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Review

Literature Review of Location-Based Mobile Games in Education: Challenges, Impacts and Opportunities

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Abstract: With the universal use of mobile computing devices, there has been a notable increase in the number of mobile applications developed for educational purposes. Gamification strategies offer a new set of tools to educators and, combined with the location services provided by those devices, allow the creation of innovative location-based mobile learning experiences. In this literature review, we conduct an analysis of educational mobile location-based games. The review includes articles published from January of 2010 to October of 2020, and from 127 records screened, 26 articles were analysed in full-text form. This analysis allowed us to answer the following six predefined research questions: Who are the target audiences for location-based games? In which subjects are location-based games most used? Which strategies are implemented with mobile devices to improve the student's learning process? What are the main impacts of location-based games on students' learning? What are the main challenges to the development of location-based games for education? What future tendencies and research opportunities can be identified from the analysis of the current state of the art?

Keywords: game-based learning; location-based games; mobile games; mobile learning

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1. Introduction

The widespread use of mobile devices, with great processing and communication capacity, has boosted the development of new applications that have been changing the way we teach and how we interact with students. Its versatility, and the possibility of being used anywhere at any time, has allowed the development of new learning approaches. Perhaps the most common has been the use of mobile applications to create learning experiences that emphasize the importance of the context where learning takes place. These applications are often combined with gamification strategies, making them more appealing to students, by involving them in interesting activities and leading them to learn in a more motivated and amusing way. These strategies, using mobile location-based games (LBG) in education, have offered new learning opportunities in authentic environments, but they have also posed new challenges for education professionals, which are related to the underlying technological advances and the need to adapt the traditional pedagogical practices. LBG support a wide range of learning experiences in different areas (e.g., history, math, music, natural sciences, geography, etc.) that can benefit from location-based mechanics. They allow students to complete challenges, answer surveys, or interact with virtual contextualized objects, which enrich their learning experience. At the same time, they are also a useful tool for educators, since they give them feedback of the students' performance (their actions and answers throughout the proposed activities). However, for LBG applications to be useful and fulfil their objectives, their contents and activities need to be closely aligned with the learning objectives and educational strategies. Additionally, educators may need pedagogical and technical support so that they can successfully adapt the use of these applications to their teaching strategies.

This work aims to review the literature on LBG for education, so that their main impacts on students' learning, the main strategies that are used to increase the students' motivation, and the main challenges when developing these types of games for education purposes, can be identified. Thus, the primary research questions defined for this review were as follows: (RQ1) Who are the target audiences for location-based games? (RQ2) In which subjects are location-based games most used? (RQ3) Which strategies are implemented with mobile devices to improve the student's learning process? (RQ4) What are the main impacts of location-based games on students' learning? (RQ5) What are the main challenges to the development of location-based games for education? (RQ6) What future tendencies and research opportunities can be identified from the analysis of the current state of the art?

2. Related Work

In the last years, several studies have been conducted that reviewed works related to the use of LBG in education, but normally with a reduced scope, in the following ways: focused on a specific type of application, addressing the issues associated with pedagogical aspects or the student learning outcomes, evaluating the impact of LBG in the student's motivation and performance, etc. These studies are also quite different regarding the number of works analyzed and the period under analysis. Table 1 summarizes some of their characteristics.

Table 1. Studies reviewing location-based games for education.

Review	Year	Focus	Studies	Timespan
[1]	2019	Trends in mobile game-based learning	113	2007–2016
[2]	2018	Augmented reality LBG: pedagogical, technological, and gaming aspects	31	2012–2017
[3]	2017	Augmented reality LBG: impact on students' motivation and performance	17	2012–2017
[4]	2017	Augmented reality LBG: efficacy, effects on students learning outcomes and social interactions	26	2006–2016
[5]	2015	Augmented reality LBG: outcomes regarding student learning	7	2000–2014
[6]	2012	LBG: narrative structure and interaction modes	15	2004–2010

A brief analysis of the literature reviews on mobile location-based games for learning allowed a characterization of their objectives, and the identification of some shortcomings that still need to be better studied. Some of these shortcomings justify the significance of this new review, namely, reduced focus on the particularities of mobile location-based games in general; a lack of a systematic analysis of the studies related to mobile location-based games for education, published in the last ten years; and a lack of a comprehensive overview of mobile location-based games for education, including technologies, strategies, and covered subjects. Other studies have addressed the use of mobile learning in teacher education (e.g., [1,7]). However, these studies analyzed mobile applications that are used in education in a comprehensive, generic way, and without focusing on the analysis of the importance and implications that localization can assume in this type of application. The systematic review described in [1] is one of the most complete reviews of this area, with some similarities with this work. Its focus is more generic and addresses the use of game-based learning applications, with the aim of highlighting the research domain and issues of promoting game-based learning in future mobile technology. The work presented here focuses on location-based games in education, the importance of location or situated learning, strategies, challenges, and their impacts on students' learning.

3. Methodology

This systematic review was organized according to the eight-step guide to conduct a systematic literature review of information systems research [8]. This process includes the following steps:

1. Identifying the purpose and intended goals of the review (Section 3.1);
2. Meetings and discussions to define the procedure to be followed;
3. Searching for the literature (Section 3.2);

4. Screening for inclusion (Section 3.3);
5. Screening for exclusion (Section 3.4);
6. Data extraction (Section 4);
7. Analysis (Sections 4 and 5);
8. Writing the review.

3.1. Purpose of the Review

The main goal of this review was to answer the 6 research questions identified in the first section. Additionally, results of the review were used to identify opportunities for using mobile location-based games in education and to make recommendations for future research.

3.2. Searching for the Literature

The search for literature was performed using the Scopus database. Scopus is the largest abstract and indexing database of peer-reviewed scientific journals, books, and conference proceedings. It covers more than 40,000 sources and provides impact and citation information over the indexed material that greatly helps in the identification and selection of the most relevant contributions in a given field. Since the covered sources span a large number of individual databases, it is usually more effective, depending on the research field, to search Scopus directly instead of a handful of smaller databases. To perform the search, a set of search terms related to the usage of mobile location-based games in education were identified. Thus, after some initial experiments, and considering an initial analysis of some literature studies, 4 groups of terms were identified that should be considered in the research. First, terms related to location-based games should be included since they represent the type of applications considered in the study. Second, terms related to games and gamification. Thirdly, terms related to "education" and "learning" were added to the search terms, as this review specifically focuses on the education area. Finally, terms related to mobility, navigation, and the use of personal smartphones were also included. The objective is to analyze works in which learning takes place in situ, regardless of the type of interaction with the point of interest (e.g., AR, sound, video, web quiz, QR code, etc.).

The complete string for the search is as follows:

(location OR locative OR situated) AND (game OR gamification OR lbg) AND (learning OR education OR students) AND (mobile OR smartphone OR navigation OR outdoor).

The database search was carried out in October 2020 and resulted in 126 studies.

Additionally, one more study was identified through other sources.

3.3. Screening for Inclusion

In this screening, we considered that studies should only be included in the review if they met the following criteria: (1) studies that presented different approaches relative to location-based games for education; (2) studies where the proposed approach is based on the use of mobile devices; (3) studies published since 2010; (4) studies that were published in peer-reviewed journals and conferences; (5) studies that were written in English; and (6) studies with full text available. Studies that did not meet all these criteria were excluded. After applying criteria 3–6, 108 studies remained.

Four reviewers then examined the obtained set of studies by title and, when necessary, reading the abstract, to decide whether, for the purposes of the review, they were worth reading further or if they should be excluded. At this stage, the reviewers did not judge the quality or evaluate the information found in each study. Criteria (1) and (2) were determined merely by reviewing the title and, when necessary, the abstract. Some duplicated studies were also removed. After this, 71 studies were excluded, and 37 studies remained.

3.4. Screening for Exclusion

The final list of studies was assessed by the four reviewers to determine whether they should be included in the quantitative and qualitative analysis. At this stage, each reviewer analyzed the full text of each study to assess in detail the purpose, strategy, and outcomes of each study. Only studies focusing on the use of mobile location-based games for education, and presenting their design methodology and experiment results, were considered. Studies that did not included this information were excluded. At this stage, only the 37 previously selected studies were analyzed. After analyzing the full text of each study, a further 11 were excluded. This process resulted in a final selection of 26 studies to be fully reviewed.

3.5. Results Summary

As presented in Figure 1, after searching for the literature 127 studies were obtained, and after applying the inclusion criteria identified in Section 3.3 "Screening for Inclusion", 19 studies were excluded, resulting in 108 studies. These studies were evaluated in terms of title and abstract resulting in the exclusion of 71 studies. The main criteria for excluding the papers were because these studies were not related to the use of a mobile app to play location-based games for education, or in some cases the full text was not available. The full-text evaluation of the remaining 37 studies was performed, excluding 11 studies that did not match the defined inclusion criteria. The remaining 26 studies were presented in the qualitative and quantitative analysis.

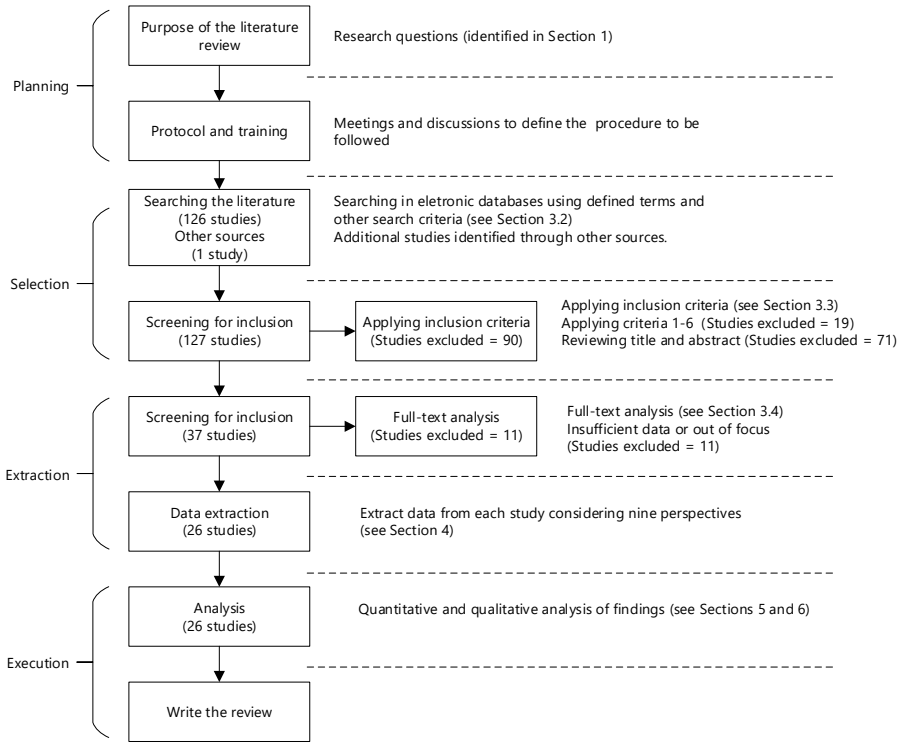

Figure 1. Flowchart of the systematic review process.

Following the inclusion criteria, the studies analyzed were published between 2010 and 2020. Considering the 26 selected studies, there is a predominance of studies in the years 2016 and 2017. Only 4 of the analyzed studies were published in 2020. However, it must be considered that the database search was carried out in October 2020 and, therefore, most of the 2020 studies had not yet been published.

4. Data Extraction and Data Analysis

Each study was then reviewed and analyzed, based on ten items, as described in Table 2. These items were selected for their relevance in providing information to answer the research questions identified in Section 1.

Table 2. Type of data to be extracted.

Item	Description
Year of publication	Year of publication
Main purpose	What is the main purpose of the game and what are its main goals?
Target population	What is the target population of the application?
Target subject	What is the main subject for which the game is intended?
Playing modes	How is the game played? What requirements need to be met by participants to win the game?
Development	How was the game developed? Was it developed using an existing framework or was it fully developed?
Customization	What types of customization are supported?
Activities	What kind of activities are available?
Impact	What are the main impacts of the game in the learning process?

Following the methodology described in the previous sections, and represented in Figure 1, 26 papers were identified and will be subject to a more detailed analysis in this section, starting by a brief description of each work. The data regarding the items identified in Table 2 are extracted from each paper and presented in Tables 3–5.

"The buildings speak about our city" [9] combines location-based and marker-based augmented reality to motivate primary school students to learn history, discovering the buildings of tobacco warehouses, and exploring their relationship with the economic and cultural development of the city. "QuesTInSitu: The Game" [10] is an LBG that uses elements of games (e.g., hints, feedback, bonus, etc.) and puzzles (meaning that the students have different attempts to solve the questions). The authors describe four learning contexts in which secondary education teachers at different schools were involved in the design of their own location-based learning games. The SmartZoos toolkit [11] allows not only teachers, but also students, to design location-based games, adventure trails and other challenges (quizzes, assignments, etc.), with their personal mobile devices. It provides an online tool for creating location-based interactive assignments, and for composing and playing location-based quiz games. Igpaw Intramuros [12] is a virtual tour game that encourages players to navigate through several historical markers within a city, to learn about their historical significance. Along the way, players can provide "help" to troubled historical characters in a traditional adventure-game setting, enhanced with augmented reality. The purpose of "The Heraklion Fortification Gates" game [13] is to teach the history of the Venetian walls of the city of Heraklion. The game locates the player's position using GPS and then gives them instructions on how to get to a specific location. The work presented in [14] discusses the usage of LBGs for informatics education of pupils in primary and secondary schools. They selected some LBG from the set of games published on the Wherigo website. One game was to familiarize students, from primary and secondary school (from 5th to 9th grade), with the basic concepts of Wherigo games. In the other game, the task was to draw the figure of a house, created by physical movement of the player and scanned by GPS technology, in one stroke. Using LBG to support orientation and mobility training for visually impaired students was investigated in [15]. They implemented a prototype for a scavenger hunt-like mobile game. To play the game, players need to scan the NFC tag with a mobile phone at a certain location, and the game event is read to the user by text-to-speech. No additional indoor tracking or localization technique was used.

Table 3. Purpose and goals of the studies (n = 26).

Study	Year	Goal
[9]	2015	Motivate primary school students to learn history.
[10]	2017	Create or adapt educational games to teachers' requirements depending on their particular situations and evaluate the impact of the designed games in students' satisfaction.
[11]	2017	Help students in their biology course in a zoo.
[12]	2016	Encourage players to navigate through several historical markers of a city to learn about their historical significance.
[13]	2018	Teach the history of the Venetian walls of the city of Heraklion.
[14]	2013	Introduce students to underlying concepts of informatics.
[15]	2018	Support orientation and mobility training for visually impaired students.
[16]	2012	Support outdoor learning activities about history and geography as part of the curriculum for elementary schools.
[17]	2011	Serve as a project-based learning tool for undergraduate students in business and related disciplines.
[18]	2017	Teach mobile technology to the elderly.
[19]	2020	Promote learning on basic astronomy.
[20]	2017	Promote learning experiences for different subjects.
[21]	2013	Promote autonomously travelling ability.
[22]	2016	Develop young children's spatial ability.
[23]	2019	Support learning in the context of field trips.
[24]	2014	Contribute to a road safety campaign targeting Flemish adolescents.
[25]	2014	Transform orientation events in higher education institutions in a mobile location-based game.
[26]	2017	Discuss the advantages of both learning by playing and learning by designing games.
[27]	2016	Motivate university students to increase physical activity.
[28]	2020	Introduce more complex mechanics (e.g., ecological simulation) in mobile location-based games.
[29]	2020	Allow teachers to build applications from high level components through an authoring tool for mobile learning games.
[30]	2020	Allow youngsters to explore their surroundings based on their interests or needs.
[31]	2015	Divulge and teach design culture.
[32]	2016	Compare active and passive approach to mobile location-based games in the school curricula.
[33]	2012	Provide a learning path in the library by enticing students to challenge the game and learn new things.
[34]	2010	Introduce various biology-related topics including genome manipulation, access to nature and nature preservation.
[35]	2016	Studies the effectiveness of using an AR gaming-based approach on students' learning outcomes in comparison with a conventional AR-based mobile learning approach.

Table 4. Location-based games for education (n = 26).

Study	Target Population	Target Subject	Modes	Development	Customization	Activities
[9]	Primary students	History	Find specific locations Complete activities	Existing framework (the FreshAiR and Layar Creator platforms)	Locations Activities	AR visualizations and other information such as text, images, videos, audio Answer quizzes
[10]	Secondary schools' students	Math, music, natural sciences, geography, and art history	Find specific locations. Complete activities	Authoring framework	Locations Activities Hints	Answer quizzes
[11]	5th grade students	Biology	Find specific locations Complete activities	Existing framework (SmartZoos toolkit)	No	Answer quizzes Image-matching Solve puzzles
[12]	General	History	Find specific locations Complete activities	Existing framework (MAGIS framework)	No	AR visualizations Answer quizzes
[13]	-	History	Find specific locations Complete activities	Full development	No	AR visualizations in the form of text, mini-videos and sound Answer quizzes
[14]	Primary and secondary school students (5th to 9th grade)	Informatics	Find specific locations	Full development	No	Visit locations in a pre-defined order
[15]	Visually impaired students	Orientation and mobility training for visually impaired students	Find specific locations Complete activities	Full development	No	Listening information from a virtual game character Solve puzzles Collect items
[16]	Elementary school students	History and geography	Find specific locations Complete activities	Full development	Locations Clues Activities	Identify and reach the specific locations according to a set of clues Complete a set of tasks related with the specific location
[17]	Undergraduate students in business	Business and related disciplines	Find specific locations by moving around an AR environment Complete activities	Full development	No	Interviews Analyze documents Design solutions
[18]	Elderly	Mobile Technology	Find specific locations Complete activities	Full development	No	Taking pictures Scanning QR codes Answer quizzes
[19]	Primary school students	Astronomy	Find specific locations Complete activities	Full development	Activities	Answer quizzes
[20]	K-12 school students	Multidisciplinary	Find specific locations Complete activities	Full development	Activities Locations	Answer quizzes
[21]	People with intellectual disabilities and additional sensory impairments	Travel ability	Find specific locations Complete activities	Full development	Locations Activities	Answer quizzes
[22]	Pre-school children	Spatial ability	Find specific locations Complete activities	Existing framework (TaleBlazer)	No	Puzzles/challenges Answer quizzes
[23]	Children of 7th and 8th years of the 3rd cycle of basic education	Science	Find specific locations Complete activities	Full development	Activities Locations	Answer quizzes Taking photos Collecting data

Table 4. *Cont.*

Study	Target Population	Target Subject	Modes	Development	Customization	Activities
[24]	Teenagers from 15 to 18 years old	Road safety	Find specific locations Complete activities	Full development	No	Mini games Virtual item collection
[25]	First year students in higher education institutions	Orientation events	Find specific locations Complete activities	Existing framework (Treasure-HIT development system)	No	Answer quizzes Activities aiming to provide campus information
[26]	Higher education students	Business and society and several others	Find specific locations Complete activities	Existing framework (Mobile Learning Academy)	No	Answer quizzes Taking photos Item identification
[27]	Higher education students	Motivating physical exercise	Find specific locations Complete activities	Full development	No	Physical activities collecting clues
[28]	Secondary school students	Ecology	Find specific locations Complete activities	Full development	No	Exploration and decision-making tasks related to wildcat life preservation
[29]	Students from different education levels	Multidisciplinary	Find specific locations Complete activities	Authoring framework	Activities Locations	Answer quizzes and others
[30]	Youngsters	Multidisciplinary	Find specific locations Complete activities	Full development	Activities	Physical activities Answer quizzes Taking photos Small games Traditional learning assignments Among others
[31]	High school students	Design	Find specific locations Complete activities	Existing framework (Mobile Learning Academy)	No	Answer quizzes
[32]	Elementary school classes	undefined	Find specific locations Complete activities	Full development	No	Multimedia content triggered by locations or QR codes Interactive interviews Answer quizzes
[33]	Students with different knowledge level	Wireless technologies	Find specific locations Complete activities	Full development	No	Read documents Answer quizzes
[34]	Children aged 13 and up	Biology	Find specific locations based on audio information Complete activities	Full development	No	Collect snippets of audio
[35]	Fifth graders (average age of 11)	Ecology	Find specific locations Complete activities	Full development	Activities	Multiple-choice questions Mini games (matching game or AR-based shooting game)

Table 5. Impact and challenges of location-based games for education (n = 26).

Study	Evaluation Population	Identified Impacts on the Learning Process
[9]	5 teachers and 21 students.	The impact of the game on the students' learning was not assessed.
[10]	253 students from the 4 secondary schools.	The impact of the game on the students' learning was not assessed.
[11]	Not evaluated.	-
[12]	Not evaluated.	-
[13]	Not evaluated.	-
[14]	Two groups of 6 and 7 students (primary and secondary school students, from 5th to 9th grade).	Helps students to understand a stack structure during the final discussion.
[15]	6 visually impaired students.	Supports orientation and mobility training for visually impaired students.
[16]	Not evaluated.	-
[17]	A group of business students.	The impact of the game on the students' learning was not assessed.
[18]	30 (15 two-person teams).	Increases the technical skills of the elderly, improves their physical activity, and enhances positive intergenerational interaction.
[19]	251 students and 22 teachers.	Promotes students' interest to learn about the solar system and promotes physical activity and social interaction.
[20]	6 teachers of a K-12 school and their students.	Promotes students' interest in learning.
[21]	12 people aged 15–32 years, with a range of disabilities.	Promotes autonomously travelling ability.
[22]	Two groups of two children.	Develops spatial and map skills in young children.
[23]	Not evaluated.	-
[24]	41 students aged 15–18 years.	The impact of the game on the students' learning was not assessed.
[25]	41 first year higher education institutions students.	Increases familiarity with the campus, giving an acquainted feeling with their peers so they are less alone.
[26]	More than 500 students played the games, 209 students participated in game design.	The impact of the game on the students' learning was not assessed.
[27]	12 university students.	Promotes more enjoyment and potentially increased adherence to physical activities.
[28]	329 secondary school students.	Promotes more enjoyment.
[29]	More than 1500 students from different education levels.	The impact of the game on the students' learning was not assessed.
[30]	Several groups in different evaluations and phases.	Preliminary evaluations show that the app is usable for youngsters and able to engage them. They also suggested that it may be able to increase the intrinsic motivation and learning capacity of youngsters.
[31]	No formal evaluation.	Preliminary evaluations suggest satisfactory results in terms of social engagement.
[32]	27 students aged 14–15 years.	The impact of the game on the students' learning was not assessed.
[33]	20 students in the experimental group and 19 students in the control group.	Improves proficiency in the course material.
[34]	Two groups of players (27 nature guides and 16 students aged 18–20 years.	The impact of the game on the students' learning was not assessed.
[35]	Two classes of students with an average age of 11 years old (taught by the same teacher)	Significantly improves the students' learning achievements and learning attitudes.

The Treasure-HIT [16] is a treasure hunt game aimed to support outdoor learning activities about history and geography, as part of the curriculum for elementary schools. A pervasive location-based game is presented in [17] for undergraduate students in business. The game aims to be a project-based learning tool, and its main goal is to offer an experience of business consulting that is more engaging than the usual web simulation. The university campus is augmented so that it can represent a virtual company. This game was part of a simulated consulting project by the University Business School. The game "Stroll Around Yesterday" [18] is a mobile location-based game designed for mixed-age teams of the following two players: a senior and a junior. The aim of the game is to teach the elderly how to use mobile devices, such has tablets and smartphones, with the help of young volunteers with a better knowledge of how to use these technologies. PlanetarySystemGo [19] is a mobile augmented reality platform for learning purposes, which includes a location-based game, developed to encourage learning about the universe. The game takes place in the real environment, captured by the mobile phone camera. Celestial bodies, such as stars or planets, are added to this environment as virtual objects. The game may be played in online or offline mode. An internet connection is only necessary to download the event and to send data from the game to the database, through web services.

Avastusrada [20] is a tool that allows teachers to define learning activities outside the classroom, by creating location-based learning tracks. A track comprises a set of location points that students must reach. They can visit location points randomly or in a predefined order, depending on how the track is defined. Regardless, when reaching one of those points, students must do an activity defined by the teacher.

Route Mate [21] is a location-aware application that is designed to help people with intellectual disabilities and additional sensory impairments to travel, independently, to work or other destinations. It aims to promote a feeling of independence for its users, who are usually overprotected by their parents or caregivers. The tool allows the users to plan a route in advance, alone or with the help of their caregivers. The game presented in [22] is a treasure hunt mobile game for young children, designed to develop their spatial ability. A fictional story, using familiar characters, is used as the game storyline. A digital video with voiced over static images is used to tell the story. The goal of the game is to find a coin in the school yard. Trilho Verde [23] is a mobile location-based application designed for support learning in the context of field trips. In its first version, Trilho Verde presents only one field trip itinerary, designed for science classes of 7th and 8th years of the 3rd cycle of basic education. This itinerary is made of a set of interesting spots that the students must visit. When starting a field trip with Trilho Verde, the students will be guided through the respective itinerary in one of two different ways, so if they are too far away from the next spot, a map is presented to show the spot's location. In [24], the development of City Jam is described, a location-based mobile game with the purpose of contributing to a road safety campaign targeting Flemish adolescents from 15 to 18 years old. The game was played in a digital map of the city of Ghent and included several location-aware mini games, as well as discovery and virtual item collection activities. In [25], the authors present an approach to orientation events in higher education institutions, using a mobile location-based game called Welcome game. The game was developed using the Treasure-HIT development system and transformed the welcome event into a team-based competition. In [26], the advantages of learning by playing and learning by design are discussed, when integrating location-based mobile learning games in higher education courses. The games developed using Mobile Learning Academy (MLG) included an urban game about the story of businesses in Adelaide's West End, and a second approach that investigates the advantages of MLG design and implementation by the students themselves. In [27], the use of gamification is explored, in the context of location-based mobile applications targeted at motivating university students to increase their physical activity. A fitness application prototype named LOOP was developed, implementing the following two game modes: chasing and treasure hunting. The work described in [28] combines simulation mechanics with location-based mobile games. Its main contribution to the field is the proposal of

an approach to introduce more challenging game mechanics, which in this case is an ecological simulation in the game flow of location-based games. JEM Inventor [29] is an authoring tool for mobile learning games, including location-based games. It proposes a three-layer architecture, corresponding to three different design modes. The standard mode allows teachers to build applications from high-level components. The intermediate mode is similar, but introduces additional features. The expert mode allows access to algorithmic blocks. TICKLE [30] is a mobile location-based system that offers youngsters an interactive environment with which they can explore their surroundings, based on their interests or needs. The environment offers cards that the youngsters can collect by performing small challenges. The players collect points based on the performed challenges. Two mobile location-based urban games to divulge and teach design culture are presented in [31]. The goal is to promote the culture of design among high school students, using mobile gaming, providing an informal way of learning, valorizing and contextualizing Italian and Milanese design across the city. The work presented in [32] compares two kinds of educational processes within a location-based game approach for elementary school classes. The 'designers' class took part in the whole process of game design, except the technical part (programming and content implementation). The 'players' class did not get any special treatment, but played the game made by their fellow students. An RFID-based game-guided learning system is described in [33]. At a predefined stage, students answer questions that are automatically selected by the system, and the system indicates the RFID guide path when the answers are wrong. The students follow the path in search of books to learn new topics. A location-based game, called Klintespillet [34], is presented as an educational game, with an interface mostly centered around audio content. The game follows a narrative based on folklore, and on special features of the site where the game should be played. The goal of the game is to introduce various topics, including genome manipulation, access to nature and nature preservation, to children aged 13 and upwards. The objective of the players is to collect snippets of audio at specific locations in the woods, where the narrative is supposed to have taken place. The game is played by listening to the audio content, without the use of the smartphone screen. Augmented reality (AR) is used in [35] to support learning activities in real-world contexts. The authors presented an AR-based gaming approach for supporting in-field mobile learning activities. An experiment was conducted in an elementary school natural science course, to compare the students' learning outcomes using the AR-based gaming approach and a conventional AR-based mobile learning system. The results show that the AR-based gaming approach has significant positive effects on the students' learning achievements and learning attitudes.

As previously mentioned, complementarily to the previous short description of each of the 26 works, Tables 3–5 list additional items, defined in Table 2, that will be relevant for the global discussion presented in the next section.

5. Discussion

In this section we will synthetize and discuss the data and results presented in the previous sections. This discussion will then be used as the basis for the answers to the research questions initially proposed in this review. Those answers are summarized in Table 6.

Location-based mobile learning has been applied in many different contexts, targeting a diverse set of audiences. Work has been conducted for every education level, from 5th grade students to university students. Some work has also been orientated towards teachers, namely, to provide them with tools to develop their own games for their specific contexts. It is important to stress that there is an evident tendency to apply LBG to new contexts and audiences. Some of the games analyzed were designed to improve the abilities of a particular group of the population with specific needs, imposed by some type of impairment, or for the elderly. Educational applications for the general public are also being introduced. This shows that location-based games can prove valuable in different

contexts besides academic education, and can be extended to accommodate many distinct types of learning.

Table 6. Answers to the research questions.

(RQ1) Who are the target audiences for location-based games?	Essentially students from all education levels, but location-based mobile learning seems to be also trying to reach new audiences, including older generations and people with disabilities.
(RQ2) In which subjects are location-based games most used?	History, mathematics, biology, informatics, geography, ecology, astronomy, business, design, sciences, music, orientation disabilities, technology. New areas such as physical exercise, tourism and learning activities for the elderly or people with disabilities are also being considered.
(RQ3) Which strategies are implemented with mobile devices to improve the student's learning process?	Inclusion of competitive mechanisms between individuals or groups, connection to social networks, integration of technical environment-enriching elements such as augmented reality, innovative game modes (simulation, adventure), integration of diverse physical activities.
(RQ4) What are the main impacts of location-based games on students' learning?	Positive effects are generally present, including an increase in interest, motivation and improved learning outcomes. Other positives aspects include feeling more involved in the learning process, increased physical activities and social interactions. However, there is a lack of formal quantitative evaluation of the reported results.
(RQ5) What are the main challenges to the development of location-based games for education?	Most difficulties seem to be related to the cost of full development of this type of application or the lack of software development skills by educators interested in creating their own games for specific subjects. Although not technical, there is also a difficulty with the definition of evaluation mechanisms to objectively evaluate the results of LBG in the learning outcomes.
(RQ6) What future tendencies and research opportunities can be identified from the analysis of the current state of the art?	Easier-to-use development frameworks could allow a larger adoption of LBG. These frameworks should facilitate content addition/update and the inclusion of important technologies such as augmented reality. Integrating elements from different game genres that are heavy location-dependent could lead to new avenues of development in LBG. There are new contexts to explore, such as physical exercise and gamification of touristic and other cultural activities, as well as new audiences to reach, including the elderly and the people with disabilities. Many contexts in LBG learning can be easily connected with social networks, increasing game visibility and user satisfaction.

We can also find a lot of variety regarding the subject matter for the location-based mobile games. This includes subjects as diverse as history, math, biology, informatics, geography, ecology, astronomy, business, design, etc. History is particularly popular among developers, as visiting historical places seems to synergize particularly well with the mechanisms of location-based learning. Additionally, many games are oriented to complimentary aspects of students' lives, including dealing with disabilities, improving cognitive abilities, facilitating social connection and integration, and even promoting healthier lifestyles (practicing exercise and dealing with burnout).

Most game modes included in the analyzed articles involve some form of treasure hunt or trail following. This aligns to the normal expectations of location-based mobile games. Typically, the games include some form of educational activity at specific trajectory locations or points of interest, including multimedia visualizations, answering quizzes, gathering data, taking pictures or videos, virtual item collection, or some kind of mini game. Besides this more standard approach to game-based mobile learning, many applications apply innovative strategies to capture the student's attention and improve their motivation. A popular approach is to include competitive mechanisms between individuals or groups playing the game simultaneously. Virtual or augmented reality elements are used to enrich the perceived environment. Some games include decision making in simulated scenarios, to increase and diversify the challenges proposed to students. Social networking elements, as expected, are becoming more popular, since not only can they be integrated into the gaming experience, but they can also act as free publicity for the game. Another extension to location-based mobile learning includes the addition of physical activity elements, such as pursuit between players, to the gaming experience. This might lead to new applications in the fitness and physical education areas.

A large majority of the analyzed games were fully developed by the works' authors, or software companies associated with the project. This has obvious development costs that can act as a barrier to a wider adoption of LBG. However, a new trend in the area seems to be the use of tools or frameworks (smartzoo toolkit, tale-blazer, Mobile Learning Academy, JEM inventor...) that allow an easy and faster development cycle, as well as the

creation of new games or content by a larger public, without specific skills in software development. Another relatively recent trend is the possibility of content customization in some of the analyzed games. This mainly includes the addition of new points of interest in a new or pre-exiting trail, and the creation and association of activities to these points of interest. These customization possibilities, often associated with a back-office-type application, specifically developed to allow game customization, can be a powerful factor in the dissemination of location-based gaming, by allowing the reutilization of existing games in new contexts with minimal effort.

Most (but not all) of the analyzed works included some form of evaluation by the target group of users, including teachers and educators, where appropriate. These evaluations allowed a high number of authors to conclude that the gaming experience had some form of positive impact towards the initial goals of the work. The positive effects include an increase in interest by the students, which was also reported in several studies, to feel more motivated. The students also felt more involved in the learning process, especially when they were included in the game design or content development. Improved social interaction and an increase in physical activities are also positive results reported in several works. A few approaches specifically affirm that the game improved the learning outcomes, but it is hard to find quantified, statistically significant values to support these assertions, with some notable exceptions, such as [35], where a formal comparison shows that an LBG gaming approach has significant positive effects on students' learning achievements and learning attitudes, when compared with a control group.

Overall, however, the evaluation process appeared to be difficult, with many papers failing to present a concrete evaluation result or mentioning it just as a task to include in future work. The evaluation process is mostly seen as a tool to obtain feedback to improve the application, and there is a lack of quantitative studies in the analyzed works that support and quantify the impact of the described applications in the learning processes.

After this analysis, it seems clear that, while the use of LBG is gaining wider acceptance, there are still many opportunities for innovation and expansion to new audiences. The addition of some form of physical exercise to some games can allow the hybridization of learning and physical activities, reaching newer audiences and providing benefits in both areas. New applications connecting learning with tourism, including the gamification of museum tours for the younger or even the general public, also indicate that many new areas can benefit from this kind of approach. As older generations become more technologically adept, new opportunities for LBG also emerge. One of the analyzed applications proposes intergenerational learning to ease this adoption. Applications to help people with some form of disability to acquire new abilities or recover lost ones can also be integrated in this area, when location is used as mechanism to improve learning.

From a technological viewpoint, progress can still be made in the development of more complete and easier-to-use frameworks to facilitate the development of this type of game, especially by users with no formal skills in software development. Educators, as particularly important stakeholders in this area, are often interested in applying this new tool to their learning activities. However, full game development is not an option, so the availability of easy-to-use frameworks for LBG development could allow a much easier adoption of these games as educational tools. These frameworks should also include tools to update the game content, so that existing games could easily be repurposed in new contexts and subjects. The use of augmented reality is an important new addition to this type of game, so these frameworks should include a straightforward way for users to integrate this type of functionality into their games. Although there are already some frameworks that help with the development of location-based games, we believe there are still opportunities for innovation in this area. Finally, there also seems to be a possibility to integrate elements from more game's genres into LBG. Some attempts have already been made to include elements from simulation, adventure and even card-collecting games. Extending this process to other classical game types, such as role-playing games, first-person shooters, strategy games, and others could offer interesting innovative ideas and

mechanisms for location-based games, since all these genres heavily depend on the concept of location.

Following the above discussion, we can now answer the original research questions proposed for this review. These answers are presented in Table 6, and the first four follow factually from the articles' review and summary. The answer to RQ5 results from the authors' interpretation and discussion of the particular difficulties described in the reviewed articles. Finally, to answer RQ6, we built on the novel ideas, suggestions and proposals for future work described in the reviewed papers, adding our own opinions on where this research field may be headed.

6. Conclusions

In this article we presented a systematic review of the literature that discusses location-based games for education. We started by defining six research questions that we intended to answer at the end of the review, and defined the criteria that would be used to select articles to include in the review. From the initial search results, 26 articles were selected for in-depth analysis. The work presented in these articles was briefly described in Section 4, and for each article we collected information relevant for the posterior discussion and summarized it in Tables 3–5. The data collected were discussed in detail in Section 5, leading to our answer to the research questions, presented in Table 6.

This review allowed us to confirm that mobile location-based games are being widely used in education, at all levels from the 5th grade up. Interestingly, it was also found that other less academic learning environments were also reported to be experimenting with LBG, including new learning approaches for both the elderly and people with several types of disabilities. We found that game-based learning is being used as an educational tool not only in many of the common school subjects, but could also be found in new contexts more loosely related with education, such as helping people to do physical exercise, overcome disabilities, or better enjoy touristic experiences. These facts suggest that mobile-based game learning could become much more pervasive, and it is now extending to different areas and target audiences, as many other forms of mobile gaming have already done.

We also found that many different strategies have been attempted to help improve the students learning outcome, as well as keeping them focused on a medium where distraction is readily available. New technologies, such as augmented reality, are being adopted fast, as they are found to be useful in this particular context. The reviewed papers usually reported positive outcomes from the performed evaluations, but we found that these evaluations are usually not quantitative or statistically relevant, which, on one hand, underscores the difficulty in evaluating the results of game-based learning and, on the other hand, suggests the opportunity for designing and applying more formal evaluation methods for LBG.

Finally, where we found that there are still technical barriers to a wider adoption of LBG in education, many opportunities for innovation and further work still remain in the area. New frameworks and libraries to facilitate development and content creation by users that have no formation in the area can still be created or improved in usability and technologies included. New strategies, possibly borrowed from other popular mobile game genres, can be applied to make location-based game learning more appealing. Expanding LBG to new domains and targeting new audiences also opens wide avenues of expansion and diversification of these types of games. When synergized with the omnipresence of social networks, the opportunities for growth and innovation opportunities of socially connected LBG-based learning seems limitless.

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