Digital Game-based Pedagogical Activities in Primary Education: A Review of Ten Years' Studies

Liping Sun
University of Lapland
Xiaojun Chen
St. John's University
Heli Ruokamo
University of Lapland

In primary education, digital games give students the opportunity to explore and participate in digital learning environments. Several researchers have found that digital game-based learning in primary education has many benefits. However, studies have also identified certain problems related to the use digital games in learning. This paper presents the findings of a systematic review of empirical studies published between May 2009 and May 2019 focusing on students' learning outcomes and teachers' pedagogical activities in digital game-based learning in primary education. The results indicated that support, guidance, and interaction are the most frequently used pedagogical activities during gameplay sessions in primary education and that teachers' most significant concern with regard to learning outcomes is knowledge acquisition, followed by attitude and motivation, skill outcomes, and behavior change. The findings will be useful for enabling researchers and teachers to integrate effective pedagogical activities into digital game-based learning strategies. Further studies are proposed to explore teachers' competencies in relation to digital learning environments in primary education.
Keywords: digital game-based learning, learning outcomes, pedagogical activities, primary education

INTRODUCTION

For several decades, researchers have examined the use of a variety of digital games in primary classrooms (e.g., Lotherington & Ronda, 2009; Warren, Dondlinger, Stein, & Barab, 2009; Fogel, Miltenberger, Graves, & Koehler, 2010; Bragg, 2012; Vélez-Agosto & Rivas-Vélez, 2018; Wong, Looi, & Boticki, 2017; Baytak & Land, 2011), and their efforts make a good case for using digital games in primary education. Hwang and Wu

Liping Sun is Ph.D. Candidate in Media Education Hub, Faculty of Education, University of Lapland, Finland. Xiaojun Chen, Ph.D., is Associate Professor and Chair of Department of Curriculum and Instruction, School of Education, St. John's University, USA. Heli Ruokamo, Ph.D., is Professor in Media Education Hub, Faculty of Education, University of Lapland, Finland. Ms. Sun can be reached at liping.sun@ulapland.fi

(2012) reviewed the trends in digital game-based learning research between 2001 and 2010, and reported an increase in research papers on implementing digital game-based learning for young students (i.e., primary school students). Recent analyses of the effectiveness of digital game-based learning in primary education have indicated that digital game-based learning has many potential benefits for both learning and teaching in the following subjects: mathematics (Kyriakides, Meletiou-Mavrotheris, & Prodromou, 2016; Bragg, 2012; O'Rourke, Main, & Hill, 2017), second language learning (Lucht & Heidig, 2013; Vélez-Agosto & Rivas-Vélez, 2018), science (Fokides & Chachlaki, 2019; Pareto, Haake, Lindström, Sjödén, & Gulz, 2012), physical education (Hansen & Sanders, 2010; Yüksel & Tuncel, 2017), geography (Lotherington & Ronda, 2009), writing (Warren et al., 2009), and programming (Asad, Tibi, & Raiyn, 2016).

While digital games give students and teachers the opportunity to explore and participate in the digital learning environment, using digital games in learning presents certain problems related to aspects such as knowledge acquisition (Lucht & Heidig, 2013), behavior regulation (Chen & Law, 2016), time management (Watson, Mong, & Harris, 2011), and technical difficulties (Vandercruysse, Vandewaetere, Cornillie, & Clarebout, 2013; Watson et al., 2011). Despite these difficulties, many researchers regard the use of teachers' pedagogical activities to supplement digital games as promising (Nousiainen, Kangas, Rikala, & Vesisenaho, 2018; O'Rourke et al., 2017; Barab, Sadler, Heiselt, Hickey, & Zuiker, 2010; Yeh, Cheng, Chen, Liao, & Chan, 2019; Kyriakides et al., 2016; Warren et al., 2009). To understand how digital game-based methods are being implemented in primary education, this systematic review is not only timely but also contributes to the literature by offering a broader view of the subject to assess how teachers' pedagogical activities support digital game-based learning in primary education.

PURPOSE OF THE REVIEW AND LIMITATIONS OF PRIOR REVIEWS

We began the investigation by synthesizing the literature on the use digital games in education. While prior reviews of the literature offer useful evidence regarding the use of digital games, limited attention has been paid to the role of teachers' pedagogical activities in digital game-based learning in primary classrooms. Dicheva, Dichev, Agre, and Angelova (2015) examined the use of game elements including digital games in the educational system, and Mora, Riera, González, and Arnedo-Moreno (2015) reviewed gamification design frameworks and their main features. Other researchers have focused on the design aspects of learning with digital games (Ke, 2016) and the impacts and outcomes of using computer games for learning (Hainey, Connolly, Boyle, Wilson, & Razak, 2016). A recent review by Kangas, Koskinen, and Krokfors (2017) focused on understanding the pedagogical aspect of game-based learning across different education levels. However, a gap still exists with regard to understanding how pedagogical activities are integrated into digital game-based learning in primary education with respect to students' learning outcomes.

DIGITAL GAME-BASED LEARNING IN PRIMARY EDUCATION

Primary education is the first phase of students' education and provides them with the fundamental knowledge and skills that they will use for the rest of academic careers (Hainey et al., 2016). Researchers have indicated that if a student is unable to understand the basic knowledge they are taught in primary education, their secondary level education becomes more difficult, which may and have a negative effect on their future academic lives and career expectations (Hainey et al., 2016; Kiili, Devlin, & Multisilta, 2015).

Therefore, appropriate teaching methods, including the use of digital games, are needed to enhance students' engagement in primary education.

A number of studies have identified that game-based learning in primary education has many benefits, such as enabling students to take pleasure in learning (Kyriakides et al., 2016), enabling teachers to provide students with immediate feedback (Bragg, 2012; Beserra, Nussbaum, Zeni, Rodriguez, & Wurman, 2014), enhancing students' participation, and encouraging them to explore the unknown (O'Rourke et al., 2017; Lotherington & Ronda, 2009). Digital game-based learning is an interactive learning experience that integrates educational contents into game activities and can be used in almost all subjects (Siew, 2018; Lucht & Heidig, 2013). With integrated educational content, digital game-based learning captures students' attention, fosters a positive attitude to learning, increases students' interest and engagements, and contributes to the development of thinking skills related to problem solving (Kyriakides et al., 2016; Lotherington & Ronda, 2009; Bragg, 2012; Beserra et al., 2014). Furthermore, digital games offer a non-threatening environment in which inaccurate answers are not regarded as mistakes but as steps in obtaining a better understanding of problems and concepts (van den Heuvel-Panhuizen, Kolovou, & Robitzsch, 2013; Lucht & Heidig, 2013; Fokides, 2018). In this sense, researchers have clarified that, in addition to providing enjoyment, digital games can also accelerate the achievement of learning outcomes in primary education (Kyriakides et al., 2016; Lucht & Heidig, 2013; Vélez-Agosto & Rivas-Vélez, 2018; Siew, 2018).

LEARNING OUTCOMES IN DIGITAL GAME-BASED LEARNING

Researchers have identified various categories for the classification of learning outcomes. For example, a study by All, Nuňez Castellar, and Van Looy (2015) distinguished three categories of outcomes to assess the effectiveness of digital game-based learning: learning, motivation, and efficiency outcomes. *Learning outcomes* are correlated with increased interest in the subject matter, improvements in objective performance, and the transfer of knowledge or skills to real-world situations. *Motivational outcomes* include the enjoyment of learning and increased motivation to participate in digital game-based learning, and *efficiency outcomes* include improved time management and cost-effectiveness (All et al., 2015). In another study, Hainey et al. (2016) reviewed empirical evidence of the outcomes of game-based learning in primary education from 2000 to 2013 and categorized learning and behavioral outcomes as knowledge acquisition and content understanding, affective and motivational, perceptual and cognitive, behavior change, and social/soft skill outcomes. They identified that the most frequent purpose of using games in primary education was knowledge acquisition and content understanding. The present review analyzes how learning outcomes are categorized and addressed in previous research with the aim of clarifying and assessing how teachers' pedagogical activities can support a digital game-based learning environment in primary education.

GAME-BASED PEDAGOGICAL ACTIVITIES

The inclusion of digital games in lesson plans is becoming more and more common among teachers in primary education (Siew, 2018). According to Kangas et al. (2017), in a game-based learning environment, teachers' pedagogical activities include planning game-based learning, taking part in the game session, and evaluating and reflecting on the gameplay session. Integrating teachers' pedagogical activities into digital game-based learning can effectively improve students learning experience and enhance their learning outcomes (Bragg, 2012; Lotherington & Ronda, 2009; Siew, 2018). When learning with

digital games, students like to play, experiment, and learn (Asad et al., 2016; Yüksel & Tuncel, 2017; Pareto et al., 2012; Beserra et al., 2014). At the same time, a teacher's pedagogical activities can motivate students to become interested in the target subject. Researchers have claimed that teachers' pedagogical activities can encourage students to become active learners, solve problems, and develop knowledge and skills (Lotherington & Ronda, 2009; Siew, 2018; Warren et al., 2009; O'Rourke et al., 2017; Barab et al., 2010; Beserra et al., 2014). Active learning has been shown to increase students' knowledge acquisition, motivation, and engagement in primary education (Yüksel & Tuncel, 2017; Beserra et al., 2014; Yeh & Lan, 2018; Fokides & Chachlaki, 2019; Baytak & Land, 2011).

METHODS

PURPOSE AND RESEARCH QUESTIONS

The purpose of this systematic review is to investigate teachers' pedagogical activities in digital game-based learning environments in primary education. The present review focuses on gameplay sessions in primary education, since it is during gameplay sessions that students' learning outcomes are influenced most significantly and it is then that teachers' pedagogical activities can influence those learning outcomes (Tropper, Leiss, & Hänze, 2015; Makar, Bakker, & Ben-Zvi, 2015). The following question is addressed in the systematic review: What pedagogical activities affect students' learning outcomes in digital game-based learning in primary education?

SEARCH PROCEDURE AND INCLUSIONG CRITERIA

A systematic review of the multidisciplinary literature on digital games was conducted using the search terms "digital game" OR "mobile game" OR "video game" OR "gamification" AND "pedagogy". The electronic datasets consulted for this review include ABI/Inform Global (ProQuest), Eric (ProQuest), Academic Search Elite (EBSCO), ScienceDirect (Elsevier), and SpringerLink.

A number of further criteria were specified to select suitable studies for inclusion in the review. To be included in the present review, papers had to
   a. include empirical evidence relating to the use of games in the learning environment,
   b. have a publication date between May 2009 and May 2019,
   c. be a journal article or book chapter,
   d. be peer-reviewed, and
   e. be written in English.

The initial online searches of the aforementioned datasets identified 5,064 papers. An initial screening of papers was performed by reading the titles and abstracts, after which 324 papers were retrieved. Next, we read and reviewed all these papers (N = 324) and narrowed the selection to include only empirical studies of digital game-based learning in primary education. Finally, 22 papers were coded and included in the final literature synthesis.

CODING PROCEDURE AND ANALYSIS

In the data-coding stage, information was extracted from the selected papers (N = 22) and evaluated. The information was coded on the basis of learning outcomes and pedagogical activities in the digital learning environment with a focus on gameplay sessions. Information about learning outcomes included types of learning outcomes, school

subjects, and games used in the classroom. Information about pedagogical activities consisted of teachers' activities during gameplay sessions. A content analysis approach was used to code both learning outcomes and pedagogical activities (Seuring & Gold, 2012; Borrego, Foster, & Froyd, 2014; Mayring, 2000). The learning outcomes and teachers' pedagogical activities were identified and defined according to the descriptions provided in the papers. Examples of information items related to the digital game-based learning processes include the kinds of digital games used in primary education, the purpose of digital game-based learning, the expected learning outcomes in various subjects, how teachers support students to achieve learning outcomes during gameplay sessions, and the frequency of each pedagogical activity related to the various learning outcomes. To identify the teachers' pedagogical activities that related to the various learning outcomes in the digital game-based learning environment, we analyzed the expected learning outcomes and the teachers' activities during the gameplay session and grouped short-answers items into defined categories.

RESULTS

The systematic review uncovered 22 papers centered on implementing digital game-based learning in primary education. This section presents an overview of the selected papers (N = 22) and then addresses the research question. Analyses were conducted on 22 papers to answer the research question identified above.

LEARNING OUTCOMES IN DIGITAL GAME-BASED LEARNING IN PRIMARY EDUACTION

Table 1 shows the frequency (f) of various subjects and learning outcomes addressed when teaching with digital games in primary education. Table 1 shows the frequency (f) of that digital games were used in the primary education subjects including geography (f=1), writing (f=1), physical education (f=3), mathematics (f=8), second language (f=4), programming in computer science (f=1), and science (f=4). The results show that digital game-based learning was most frequently applied in mathematics in primary education. Table 1 (see next page) also shows the numbers of papers that address the various learning outcomes related to digital game-based learning. The most frequently purpose of using digital games in primary education was knowledge acquisition, followed by attitude and motivation, skill outcomes, and behavior change.

Knowledge Acquisition. Twelve studies were identified in this category and more than half of these 12 studies concentrated on the acquisition of specific knowledge. This finding was consistent with a study by Vélez-Agosto and Rivas-Vélez (2018) which found that the purpose of using the video game My English Coach in the classroom was to facilitate sixth-grade students' learning of English vocabulary. Another study by Barab et al. (2010) employed a multi-user virtual environment "Quest Atlantis" to support fourth-grade students in learning scientific concepts, including erosion and water quality.

The results also show that digital games are more frequently used to teach mathematics than to other subjects. One study described a digital game played in pairs by third-grade students during mathematics lessons with the purpose of evaluating how students' conceptual understanding is affected by digital games (Pareto et al., 2012). In a recent study by Fokides (2018), a series of digital games were developed using Microsoft's Kodu Game Lab and were used to teach mathematics to primary school students; the results indicated that students who played digital games outperformed those who did not in understanding mathematical concepts.

Table 1. *Purpose of Game with Respect to Learning Outcomes*

Study Number	Subject	Learning outcomes			
		Attitude and motivation	**Behavior change**	**Knowledge acquisition**	**Skills outcomes**
1	Geography				✓
2	Writing	✓			
3	PE	✓	✓		
4	PE		✓		
5	Mathematics		✓		
6	Second language	✓		✓	
7	Programming	✓			✓
8	Mathematics			✓	✓
9	Mathematics				✓
10	PE				✓
11	Second language			✓	
12	Mathematics	✓		✓	
13	Second language		✓		
14	Science	✓		✓	
15	Science			✓	
16	Mathematics	✓		✓	✓
17	Second language			✓	
18	Mathematics	✓		✓	
19	Science			✓	
20	Science			✓	
21	Mathematics			✓	
22	Mathematics	✓			
Frequency (f)		**9**	**4**	**12**	**6**

Attitude and Motivation. Nine studies were identified in this category involving different subjects. For example, 24 fourth- and fifth-grade students were taught programming in a visual and interactive environment and were found to have positive attitudes and motivation toward programming after participating in the course (Asad et al., 2016). Moreover, a courseware application called DigiGEMs (Digital Games for Education in Mathematics) was used to teach mathematics to teach first- to third-grade primary school students in Malaysia to examine whether games fostered a positive attitude toward learning mathematical concepts among students (Siew, 2018).

It should be pointed out that the learning outcome of improving attitude and motivation was usually related to knowledge acquisition. For example, HOPSCOTCH, an exer-learning game was used in English lessons to facilitate students' vocabulary acquisition and to promote a positive attitude to learning English as a second language (Lucht & Heidig, 2013). In another case, a 3D multi-user virtual environment (MUVE) was employed in a science class to examine whether MUVE had a positive impact on students' attitude and knowledge acquisition   concerning the protection of endangered species (Fokides & Chachlaki, 2019).

Skills Outcomes. Six studies were identified in this category, and the skills involved were literacy skills, problem-solving skills, movement skills, and arithmetic skills. For instance, an educational puzzle game A.L.E.X., which was available on iPads or Android tablet devices, was used by fifth-grade students in a mathematics class. One of the goals was to explore the game's potential for enhancing students' problem-solving skills (Kyriakides et al., 2016). Moreover, in a study by Yüksel and Tuncel (2017), twelve fifth-grade students participated in physical education lessons taught using the digital SMART Trainer system, and their fundamental movement skills were assessed during the process. In another study, Yeh et al. (2019) examined a game-based learning environment called Math Island, which was used as a learning tool to teach second- and third-grade students. The study found an increase in students' arithmetic and word problem-solving skills.

Behavior Change. Four studies were identified in this category; these related to the subjects physical education, mathematics, and second language learning. For example, Fogel et al. (2010) examined a new video gaming technology called "exergaming", which was employed in a regular physical education classroom. The study found that exergaming provided fifth- grade students with more time and opportunities to engage in physical activities. In another study, Yeh and Lan (2018) examined a 3D virtual learning platform named Build & Show, on which 29 fifth-grade students participated and worked collaboratively. They found that students' autonomy in English language learning was enhanced in the 3D virtual world of Build & Show.

LEARNING OUTCOMES IN DIGITAL GAME-BASED LEARNING IN PRIMARY EDUACTION

Table 2 (see next page) provides a detailed overview of teachers' pedagogical activities during gameplay sessions related to students' learning outcomes in primary education. Table 2 shows the frequency (f) of seven categories of pedagogical activities related to students' learning outcomes during gameplay sessions in primary education: support, encouragement, interaction, guidance, classroom management, feedback, and assessment. The pedagogical activities integrated into gameplay sessions in each of the studies considered in the review are presented.

The results show that support (f=11) and guidance (f=11) were the most frequently used pedagogical activities during gameplay sessions in primary education and were often associated with the four main learning outcomes identified in this review: knowledge acquisition, attitude and motivation, skills outcomes, and behavior change. (a) *Knowledge*

acquisition: For example, in a Science Spots AR (SSAR) game-based learning platform (Laine, Nygren, Dirin, & Suk, 2016), the teacher made observations and provided support if fifth-grade students had problems during gameplay, which was helpful for improving students' understanding of scientific concepts. In another study, teachers' offered guidance to fifth-grade students using Scratch to design and develop computer games about environmental science (Baytak & Land, 2011). (b) *Attitude and motivation*: For example, one teacher gave guidance to fourth-grade students' on how to collaborate with their peers in order to solve problems when playing in an online MUVE called Anytown to practice descriptive writing (Warren et al., 2009). (c) *Skills outcomes*: For instance, Lotherington and Ronda (2009) designed and explored four online games to facilitate fourth-grade students' learning of digital literacy skills. The teacher supported students when they needed help. (d) *Behavior change*: In a study by Bragg (2012), students played Guestimate and Hone on the Range in pairs with calculators. The teacher guided the students on how to discuss strategies and reflect on their learning with the purpose of increasing their on-task behaviors.

Table 2. *Teachers' Pedagogical Activities in Gameplay Sessions in Primary Education*

Study number	Pedagogical Activities						
	Support	Encouragement	Interaction	Guidance	Classroom management	Feedback	Assessment
1	✓	✓		✓			
2	✓		✓	✓			
3					✓		
4				✓			
5	✓			✓			✓
8	✓					✓	
9			✓	✓			
10	✓			✓			
11			✓		✓		
12				✓	✓		
13	✓	✓	✓				
14			✓	✓			
15	✓		✓	✓			✓
16	✓						✓
17			✓	✓	✓		
18	✓						
19	✓						
20	✓	✓		✓	✓	✓	
21	✓		✓			✓	
Frequency (f)	11	3	8	11	5	3	3

Interaction (f=8) was another pedagogical activity commonly used during gameplay sessions in primary education and was always associated with the learning outcomes of

knowledge acquisition. In a recent study by Wong et al. (2017), a mobile computer-supported collaborative learning game named Chinese-PP was developed to help Singaporean primary students construct Chinese characters from components and teacher–student interaction was observed during gameplay. In another study, various forms of teacher–student interaction was (e.g. one-to-one, one-to-all) examined when students played Quest Atlantis to learn relevant scientific concepts (Barab et al., 2010). Interaction was also correlated with the learning outcome of improved attitude and motivation for learning. This finding is consistent with a study by Fokides and Chachlaki (2019) in which a 3D MUVE was used to teach fifth- and sixth-grade students issues related to the protection of the Mediterranean monk seal. The teachers initiated or joined students' discussion, which had an impact on the students' attitude toward seals and the environment.

Classroom management (f = 5) was a pedagogical activity used by teachers to improve not only students' knowledge acquisition but also their learning outcomes with regard to behavior change and attitude and motivation. For instance, when sixth-grade students learned English vocabulary using the videogame My English Coach in the classrooms, the teacher interrupted the play if classroom organization was needed (Vélez-Agosto & Rivas-Vélez, 2018). In another case, Hansen and Sanders (2010) examined fifth-grade students' experiences participating in active video games during physical education. The study found that the teacher's classroom organization and management in active gaming increased students' engagement in and motivation for physical activities.

Moreover, the results revealed that encouragement (f = 3), feedback (f = 3), and assessment (f = 3) were commonly used and were beneficial for students' knowledge acquisition. For example, Dr Kawashima's Brain Training game was used to improve students' speed and accuracy in mental math functions during a mathematics class (O'Rourke et al., 2017). The teachers encouraged students to share their strategies with their peers during gameplay. Another study (Beserra et al., 2014) described an educational video game played by third-grade students to enhance their arithmetic knowledge. The teacher supported specific students by providing instant feedback via a shared screen. In other studies (e.g. Barab et al., 2010; Yeh et al., 2019), teachers used assessment to ensure students understood the relevant knowledge.

DISCUSSIONS

In this systematic review, the authors examined students' learning outcomes and teachers' pedagogical activities in digital game-based learning environments in primary education. The findings support the evidence that teachers' pedagogical activities during gameplay sessions have a positive influence on students' learning outcomes in primary education.

EFFECTS OF DIGITAL GAME-BASED PEDAGOGICAL ACTIVITIES ON LEARNING OUTCOMES

The results indicated that the most frequent learning outcome of using digital games for learning was knowledge acquisition, followed by attitude and motivation, skills outcomes, and behavior change respectively. In addition to the acquisition of specific knowledge, it was commonly agreed that attitude and motivation was a significant learning outcome, which received extensive attention in digital game-based learning in primary education. Digital games were used to foster a positive attitude and motivation among students in various subjects including writing (Warren et al., 2009), physical education (Hansen & Sanders, 2010), second language learning (Lucht & Heidig, 2013), programming (Asad et al., 2016), mathematics (Fokides, 2018; Yeh et al., 2019; Pareto et

al., 2012; Siew, 2018), and science (Fokides & Chachlaki, 2019). Moreover, it was found that when designing digital game-based learning classes, more than one learning outcomes were emphasized in primary classrooms. In some cases, two learning outcomes (behavior and attitude and motivation; knowledge acquisition and attitude and motivation; skill outcomes and motivation and attitude; knowledge acquisition and skill outcomes) were addressed and in other cases, three learning outcomes (e.g. knowledge acquisition, skill outcomes and attitude and motivation) were emphasized. It was also found that digital game-based learning was more popular in mathematics classes in primary education and that the main relevant learning outcomes in this regard were knowledge acquisition (conceptual understanding) and skills outcomes (arithmetic skills and problem-solving skills).

Our systematic review advances discussions about how teachers' pedagogical activities during the gameplay sessions support students' learning outcomes in primary education. Considered together, the results indicate that support, guidance, and interaction were the most frequently used pedagogical activities during gameplay sessions in primary education and that teachers were most concerned with the learning outcome knowledge acquisition, followed by improving attitude and motivation, skills outcomes, and behavior change. The pedagogical activities classroom management, encouragement, feedback, and assessment were generally found to be beneficial mainly for students' knowledge acquisition in digital game-based learning. In most of the studies, more than one pedagogical activity was integrated into the gameplay. A reasonable explanation for this is that a single pedagogical activity is not sufficient to provide effective scaffolding to support students' learning outcomes in digital game-based learning environments in primary education (Falloon, 2017; Bernard et al., 2014). Multiple pedagogical activities integrated individually or together into gameplay sessions can be beneficial in stimulating students' knowledge construction and conceptual understanding, facilitating the learning of related skills, and fostering a positive attitude and motivation for the learning process (Barab et al., 2010; Kyriakides et al., 2016; Ke, 2016; O'Rourke et al., 2017; Sun, Siklander, & Ruokamo, 2018; Warren et al., 2009; Yeh et al., 2019).

TEACHERS' CONSIDERATION OF DIGITAL GAME-BASED LEARNING

According to the findings of this review, we suggest that the teachers need to consider the followings when implementing various pedagogical activities during the gameplay session: 1) attitudes toward digital game-based learning, which means it requires both teachers and students to be comfortable to explore and participate in the digital learning environment (Lotherington & Ronda, 2009); 2) beliefs and recognition of pedagogical activities, which can be integrated into gameplay sessions and determine the extent to which these activities improve students' learning outcomes as a result of digital game-based learning in primary education (Warren et al., 2009; Yeh & Lan, 2018; Wong et al., 2017); and 3) the significant role of the teachers themselves, which played in the learning experience of students when digital game are employed in the teaching of various subjects in primary education (Kyriakides et al., 2016; Barab et al., 2010; O'Rourke et al., 2017).

CONCLUSION: LIMITATIONS, IMPLICATIONS AND FUTURE RESEARCH

Although we considered this review carefully, it has certain limitations. The review covers studies from May 2009, so any empirical studies conducted before May 2009 were excluded. Furthermore, the design of digital game-based learning

classes is not addressed in this review. The main reason for this is that the review focuses on teachers' pedagogical activities during gameplay sessions and does not cover their preparation activities.

The review's findings imply that students' learning outcomes in digital game-based learning are closely correlated with teachers' pedagogical activities in primary education. This suggests that the effectiveness of employing digital games to facilitate students' learning outcomes depends on teachers' using appropriate activities in the digital learning environment. This review provides a meaningful repository of empirical proof for researchers and educators that teachers' pedagogical activities during the gameplay sessions may influence the achievement of students' learning outcomes in primary education. Consequently, teachers' pedagogical activities should be considered one of the most significant and effective aspects of digital game-based learning strategies in primary education.

This systematic review reveals the following opportunities for future research. First, further research on the pedagogical benefits of employing digital games in primary education is recommended. It could be meaningful to examine whether teachers find working in digital learning environments effective. Second, further research exploring students' feedback on teachers' pedagogical activities during gameplay could be conducted. It would be useful to explore further the extent to which teachers play an important role in digital game-based learning in primary education. Finally, further research can also be conducted to evaluate the competencies required of teachers in digital learning environments in primary education. This would support teacher education programs in training pre-service teachers and supporting in-service teachers in technology integration centered on pedagogical considerations related to digital game-based learning.

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Appendix: List of papers chosen for the study

Study number	Author details	Year	Title	Subject	Publication title
1	Lotherington & Ronda	2009	Gaming geography: Educational games and literacy development in the Grade 4 classroom	Geography	Canadian Journal of Learning and Technology
2	Warren, Dondlinger, Stein, & Barab	2009	Educational games as supplemental learning tool: Benefits, challenges, and tensions arising from use in an elementary school classroom	Writing	Journal of Interactive Learning Research
3	Hansen & Sanders	2010	Fifth grade students' experiences participating in active gaming in physical education: The persistence to game	Physical Education	Journal of Research
4	Fogel, Miltenberger, Graves, & Koehler	2010	The effects of exergaming on physical activity among inactive children in a physical education classroom	Physical Education	Journal of Applied Behavior Analysis
5	Bragg	2012	The effect of mathematical games on on-task behaviours in the primary classroom	Mathematics	Mathematics Education Research Journal
6	Lucht & Heidig	2013	Applying HOPSCOTCH as an exer-learning game in English lessons: Two exploratory studies	Second language (English)	Educational Technology Research and Development
7	Asad, Tibi, & Raiyn	2016	Primary school pupils' attitudes toward learning programming through visual interactive environments	Programming	World Journal of Education
8	Kyriakides, Meletiou-Mavrotheris, & Prodromou	2016	Mobile technologies in the service of students' learning of mathematics: The example of game application A.L.E.X. in the context of a primary school in Cyprus	Mathematics	Mathematics Education Research Journal
9	O'Rourke, Main, & Hill	2017	Commercially available digital game technology in the classroom: Improving automaticity in mental-maths in primary-aged students	Mathematics	Australian Journal of Teacher Education
10	Yüksel & Tuncel	2017	Experiences of 5th grade students participating in active gaming-assisted physical education lessons	Physical Education	Journal of Education and Training Studies
11	Vélez-Agosto & Rivas-Vélez	2018	Benefits and meanings of educating with videogames in a Puerto Rican sixth grade public school classroom	Second language (English)	International Journal of Educational Technology
12	Fokides	2018	Digital educational games and mathematics. Results of a case study in primary school settings	Mathematics	Education and Information Technologies
13	Yeh & Lan	2018	Fostering student autonomy in English learning through creations in a 3D virtual world	Second language (English)	Educational Technology Research and Development
14	Fokides & Chachlaki	2019	3D multiuser virtual environments and environmental education: The virtual island of the Mediterranean monk seal	Science	Technology, Knowledge, and Learning

Study number	Author details	Year	Title	Subject	Publication title
15	Barab, Sadler, Heiselt, Hickey, & Zuiker	2010	Erratum to: Relating narrative, inquiry, and inscriptions: Supporting consequential play	Science	Journal of Science Education and Technology
16	Yeh, Cheng, Chen, Liao, & Chan	2019	Enhancing achievement and interest in mathematics learning through Math-Island	Mathematics	Research and Practice in Technology Enhanced Learning
17	Wong, Looi, & Boticki	2017	Improving the design of a mCSCL Chinese character forming game with a distributed scaffolding design framework	Second language (Chinese)	Research and Practice in Technology Enhanced Learning
18	Pareto, Haake, Lindström, Sjödén, & Gulz	2012	A teachable-agent-based game affording collaboration and competition: Evaluating math comprehension and motivation	Mathematics	Educational Technology Research and Development
19	Laine, Nygren, Dirin, & Suk	2016	Science Spots AR: A platform for science learning games with augmented reality	Science	Educational Technology Research and Development
20	Baytak & Land	2011	An investigation of the artifacts and process of constructing computers games about environmental science in a fifth grade classroom	Science	Educational Technology Research and Development
21	Beserra, Nussbaum, Zeni, Rodriguez, & Wurman	2014	Practising arithmetic using educational video games with an interpersonal computer	Mathematics	Educational Technology & Society
22	Siew	2018	Pedagogical change in mathematics learning: Harnessing the power of digital game-based learning	Mathematics	Educational Technology & Society