Augmented Reality Games for Learning: A Literature Review

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Abstract. This study presents a literature review of previous studies of Augmented Reality (AR) games for learning. We classified learner groups, learning subjects, and learning environments mentioned in the literature. From this we conclude that AR games for learning generally have positive effects. We found that the most reported effects for AR learning games were the enhancement of learning performance and the learning experience in terms of fun, interest, and enjoyment. The most commonly used measurements for learning achievements were pre-test and post-test regarding knowledge content, while observations, questionnaires, and interviews were all frequently used to determine motivation. We also found that social interactions were encouraged by AR learning games, especially collaboration among students. The most commonly used game elements included quizzes and goal-setting. Extra instructional materials, 3D models, and face-to-face interactions were most frequently used for AR features. In addition, we came up with five suggestions for the design of AR learning games based on reviewed studies. In conclusion, six interesting findings were discussed in detail in the review, and suggestions for future study were offered to fill the research gaps.

Keywords: Augmented Reality · Education · Learning · Social · Serious games

1 Introduction

Augmented Reality (AR) is the technology that overlaps virtual objects onto the real world objects [1]. It has three main features: the combination of the real world and the virtual world, real-time interaction, and 3D registration [3]. The past few years have witnessed a growing popularity in the research interest for AR since mobile devices such as smartphones and tablets have offered much easier and cheaper access to AR for users than before [1]. Positive effects of AR technology on students' learning were identified in previous studies in the development of skills and knowledge, enhancement of learning experiences, and improvement of collaborative learning [35]. The use of

N. Streitz and P. Markopoulos (Eds.): DAPI 2017, LNCS 10291, pp. 612–626, 2017.
DOI: 10.1007/978-3-319-58697-7_46

AR in education could improve the learning efficiency and provide a more fun experience for students [21].

Serious games can be defined as computer games with educational purposes and see entertainment as an added value. Serious games are gaining increasing importance in education [27], providing an enhanced experience in learning [26]. They were found to be effective with respect to learning and retention [34]. Other frequently reported outcomes included knowledge acquisition and motivational outcomes [9].

AR games refer to the digital games that are played in a real world environment with a virtual layer on top of it [32]. It is possible for players to interact with both the objects in the virtual world and people in the real world, avoiding the social isolation [29]. With the advantages and positive outcomes of AR technology and serious games in the educational field, a growing number of studies focusing on AR games for learning have emerged in the past few years (e.g. studies of EcoMOBILE [11] and study of Mad City Mystery [32]).

1.1 Relevant Literature

The features of AR lead to a variety of positive effects on learning. The interactive 3D models in AR can enhance students' learning experience and collaborative skills; the combination of the real world and the virtual world in AR can support the study of the invisible concept and content; and the rich instructional materials (e.g., text, video, audio, etc.) can attract and immerse students into the learning [35]. In addition to that, some literatures drew attention to the social impacts of AR on students. For instance, the use of AR technology provided more opportunities for students to communicate and collaborate in the real world [20]. The social interactions between students and teachers, students and their parents were also encouraged [33].

Structured literature reviews were found on AR for educational purposes. For example, one systematic review of AR for education investigated 68 AR studies in education and concluded a number of advantages and challenges [1]. In this review, the advantages of AR in educational settings were classified into learner outcomes, pedagogical contributions, interaction, and others. In another review, the definitions, taxonomies, and technologies of AR technology were introduced, and the AR features and their affordances, as well as the solutions for AR challenges, were discovered [35]. Different affordances of location-based AR and image-based AR for science learning were also studied [11]. The review on AR trends in education found the educational field and purposes, target group, advantages, data collection methods, and discussed the trends for AR for educational settings [4].

These literature reviews mainly focused on the advantages and affordances of AR. Moreover, the purposes of using AR were different, such as a practice for lab experiments or an introduction to certain topics [4]. However, the game elements and social factors contained in the AR applications were not addressed enough.

1.2 Purpose of the Study

As can be seen above, numerous studies have been done on the use of AR technology or games in education for students. However, the efficacy of AR learning games as an integrated concept is less well known, let alone what would be successful design strategies for AR learning games. Therefore, the aims of this study is to present a systematic literature review on AR learning games, considering the current state of AR learning games, their effects on students regarding learning outcomes and social interactions, their evaluation techniques, as well as their design principles. To achieve this aim, this study identified and analyzed 26 research articles with the educational use of AR games, published from 2006 to 2016. The research questions are formed as:

RQ1: What learner groups, subjects, and environments are commonly focused on for AR learning games according to the reviewed studies?

RQ2: What are the effects of AR learning games on students in terms of learning achievement and motivation and what are the measurements according to the reviewed studies?

RQ3: What are the effects of social interaction in AR learning games on students according to the reviewed studies?

RQ4: What kinds of elements or features are commonly used in AR learning games according to the reviewed studies?

RQ5: What are the suggestions for the design of AR learning games according to the reviewed studies?

2 Method

2.1 Selection Process

In this study, we first searched via Google Scholar. The search terms we used were "augmented reality" combined with "serious games", "learning and games", and "education and games". Additionally, we investigated the references of previous reviews on AR technology in educational field to find relevant studies. We found 63 studies first. Then we examined the selected studies using a set of inclusion and exclusion criteria (see Table 1) and determined whether they were related to the purpose of this study. After the examination, 26 articles were found to be highly relevant to the purpose of this study.

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Involve AR as primary component	No clear data collection method
Involve game play in the design	Only introduction without evaluation
For educational purposes	For target groups with special needs

2.2 The Data Coding and Analysis Process

The first research question addresses the learner groups, subjects, and environments of AR learning games. The learner groups were divided into kindergarten, primary school students, middle school students, high school students, college students, and not specified in the article. In some studies, more than one learner group was used, then more than one category was applied for the learner group. The subjects of AR learning games were divided by looking for subject-related words in the article. One study might also apply to more than one code for subjects. The environments of using AR learning games were divided into five categories, which were: outdoors, classroom, home, others, and no limits.

The effects and their measurements of AR learning games (RQ2) were coded by reading through the data collection, method, findings, results, discussions, and conclusion sections from the 26 articles. We looked for coding words to identify the effects and measurements. For effects, we used two main categories, learning achievement and motivation. Learning achievement was related to the learning performance, learning effectiveness, and the cognitive load of the knowledge content, while motivation related to a broad view including engagement, interests, fun, satisfaction, and positive attitudes. It should be noted that in some studies, more than one effect could be found, so more than one code might be applied.

As for the effects of social interaction in AR learning games (RQ3), we looked up the coding words: social, collaboration, competition, guide, discussion, communication, reflection, and share from the 26 articles.

To code the elements/features used in AR learning games (RQ4), we read through the design, implementation, and procedure sections from the 26 articles, searching for keywords from the description of the AR games. Sub-categories were classified into two main categories, AR features and game elements.

3 Results and Discussion

3.1 RQ1: What Learner Groups, Subjects, and Environments Are Commonly Focused on for AR Learning Games According to the Reviewed Studies?

Regarding the "learner group", we found that in the past decade, most of the AR learning games focused on primary school students (31%) and middle school students (29%). High school students (20%) followed primary school students and middle school students in popularity (see Fig. 1). Two studies focused on college students (8%). Two studies designed the AR games for college students in the majors of Design [2] and Physics [23]. One potential explanation for this could be that AR learning games can have a positive influence on younger students because they are more evocative and align better to the kind of games they are playing at home [33].

Regarding to the learning "subjects", Science and Biology (38%) were highly focused subjects in the reviewed AR learning games. This might be because the AR technology can provide advantages in reflecting the concept of knowledge in the real world environment, allowing students to observe the objects in real-time. The study of

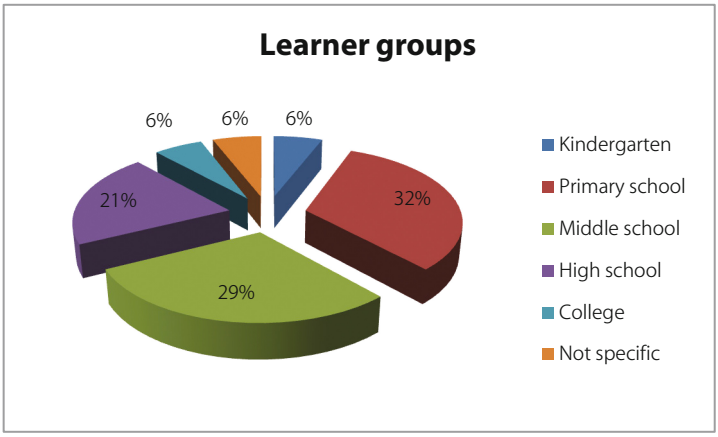

Fig. 1. Learner groups

Physics (12%), History (12%), and Art & Design (12%) were second preferred subjects. The real-time feature of AR enables students to receive feedback or see results immediately, which is favorable for subjects like Art & Design (see Table 2).

Table 2. Subjects of AR learning games.

Subject	Number of papers	Percentage	Sample of research
Science & Biology	10	38%	[6]
Art & Design	3	12%	[2]
Physics	3	12%	[19]
History	3	12%	[32]
Mathematics	2	8%	[9]
Chemistry	2	8%	[33]
Literacy	2	8%	[15]
Others	3	12%	[32]
No specific	2	8%	[12]

We noticed a gap in the subjects of AR learning games. First of all, studies for Literacy (8%), Chemistry (8%) and Mathematics (8%) studying were underrepresented. The uneven situation of subjects should be broken down, which means more attention should be paid to a wider range of subjects [15].

What's more, the existing studies for History learning often made a new game story for students to explore the history of a certain area (e.g. Alien Contact! [11]). The location-based feature of AR technology enhances students' learning experience by allowing them to stand on the historical spots. Other subjects (12%) included culture study [13], 21st century skills [30], and library instruction study [8]. However, we found little focus on the textbook-related content and knowledge, which is also valuable and should be paid attention to.

Regarding to the "environments" to use AR learning games, we saw significant preference from the reviewed studies in using AR learning games outdoors (42%) and in the classrooms (35%). See Table 3. Playing outside is one of the advantages of AR learning games compared to other serious games, which may stimulate interest and excitement in students [6]. On the other hand, it could be difficult for the teacher to control the learning process, and the safety issues should be considered as well. Students might come into dangerous situation, such as car accidents, when they put too much attention to their mobile devices [31]. The AR learning games played in the classroom allowed students to play face-to-face and under the guidance of their teachers. Students could solve problems and collaborate with their classmates [11], and they could immediately get help and feedback from their teachers when they encountered problems or had questions (e.g. AR for preschoolers for Natural Science [7]).

Table 3. Places to use AR learning games.

Subject	Number of papers	Percentage	Sample of research
Classroom	11	42%	[24]
Outdoors	9	35%	[28]
No limits	4	15%	[22]
Home	1	4%	[21]
Others	1	4%	[8]

We found four AR games (15%) with no limits for the environment, and only one AR learning game (4%) was designed specifically for playing at home with the help of parents [2]. Students, especially younger students, spend more time at home than in the classroom, and tend to spend a lot of time playing digital games [25]. Meanwhile, their parents are curious about their learning status. Therefore, it can be effective to design AR learning games that students can play at home. It may encourage them to study more spontaneously and in a more fun way. In addition to that, their safety and communication with parents could also be addressed.

3.2 RQ2: What Are the Effects of AR Learning Games on Students in Terms of Learning Achievement and Motivation and What Are the Measurements According to the Reviewed Studies?

Effects of AR learning games were classified into two main categories in this review, which were learning achievement and motivation (see Table 4).

Regarding to the "learning achievement", half of the reviewed studies reported that AR learning games led to the effective outcomes in achieving learning gains in terms of learning content (e.g. AR for electromagnetism [19] and AR system for library instruction [8]). The positive effects also included the enhancement of learning efficiency (15%) and cognitive skills like problem-solving skills, critical thinking skills, multitasking skills and so on (12%). One study (4%) reported that the use of AR learning game could reduce the cognitive load of students [10], while on the contrary,

Table 4. The effects of AR learning games.

Effects	Sub-categories	Numbers of papers	Percentage	Sample research
Learning achievement	Achieve learning gains	13	50%	[18]
	Enhance learning efficiency	4	15%	[10]
	Enhance cognitive skills	3	12%	[30]
	Decrease cognitive load	1	4%	[10]
Motivation	Enhance fun, interest, enjoyment	16	62%	[1]
	Enhance engagement	12	46%	[6]
	Enhance satisfaction	5	19%	[7]
	Enhance willingness to learn	5	19%	[22]
	Provide positive attitude	4	15%	[16]
	Enhance attention	4	15%	[25]
	Enhance confidence	4	15%	[22]

another study showed that students felt frequently overloaded and confused due to the big amount of materials and tasks during the game play [11]. The rest of the reviewed studies (19%) either found AR games were ineffective in the learning achievement or didn't focus on the learning achievement in their studies.

The motivation aspects involved engagement, satisfaction, fun, enjoyment, interest, attention, confidence and positive attitudes of students (e.g. SysteM [15] and AR-based educational game [18]). Previous studies frequently reported that students described the learning experience with AR games as joyful and playful as they had fun playing AR games to learn school knowledge [25]. We found similar result in our review that most of the students (62%) mentioned AR learning games as fun, interesting, or enjoyable (e.g. AR gaming in sustainable design education [2] and mathematical education game based on AR [21]). Nearly half of the studies (46%) also reported that AR learning games engaged them more than traditional learning methods (e.g. AR system for a visual art course [10]). In addition to these two effects, AR learning games were also evaluated to "enhance satisfaction" (19%), "enhance the willingness to learn" (19%), "enhance attention" (15%), "enhance confidence" (15%), and "enhance positive learning attitude" (15%).

Considerably less well studied were the retention effects. Nearly all studies tested the outcomes immediately after the use of the AR games. In addition, most of the students never used AR games before, so a potential novelty effect of a new technology might influence the research results. Therefore, more research should be done focusing on both short-term and long-term impacts on students after learning with AR games.

Different measurements were used to evaluate the effects caused by AR learning games. The review found that the most frequently (38%) used measurement of learning achievement was a pre-test and post-test knowledge test which examines the improvement of knowledge content learning of students before and after the use of AR learning games (e.g. AR technology in marine education [25]). Three studies (12%)

used post-test in their experiments (e.g. AR for preschoolers for Natural Science [7]). From the result we can see that only 50% studies measured learning achievement in terms of the knowledge content, indicating the rest of studies didn't use a proper test or didn't focus on learning at all.

Regarding to the motivation aspect, most of the previous studies (65%) used observation as the main evaluation methods during students' learning and playing process (e.g. AR for enhancing library instruction [8]). The questionnaire also held a high popularity (58%) in the measurement of motivation (e.g. using AR games to teach 21st century skills [30]). Some studies introduced and explained the questionnaire questions in their studies and Keller's ARCS Motivation Model was frequently adopted as the motivation questionnaire (e.g. AR system for a visual art course [10]), whereas other studies didn't explain how they created and evaluated their questionnaire questions to measure the motivation accurately. Interviews as a way to collect qualitative data was also widely used (42%). Pre-survey and post-survey (15%) were used to investigate the changes of attitudes before and after the use of AR games. See Table 5.

Table 5. Measurement methods of effects.

Effect	Method	Number of papers	Percentage	Sample of research
Learning achievement	Pre-test and post-test	10	38%	[25]
	Post-test only	3	12%	[7]
Motivation	Observation	17	65%	[6]
	Questionnaire	15	58%	[33]
	Interview	11	42%	[11]
	Pre-survey and post-survey	4	15%	[30]

3.3 RQ3: What Are the Effects of Social Interaction in AR Learning Games on Students According to the Reviewed Studies?

Collaboration and interaction have emerged to be the main advantages of AR in education [4], since the technology allows users to work or study face-to-face in real life. Based on reviewed studies, we found three main types of social interactions, which were interactions among students, between teachers and students, and between students and parents. See Table 6.

Most of the social interaction effects were found among students and the main effect was to encourage the collaboration (46%). In some AR games, students were required to work in groups to solve a certain task, while the competition (31%) among groups was also promoted. Evidence was also noted in the desire of sharing experiences with classmates (8%). Unlike the rich social interactions among students, the only social interaction between students & teacher (15%) and students & parents (8%) was guidance.

Table 6. Social interactions.

Type	Effect	Number of papers	Percentage	Sample of research
Student-student	Collaboration	12	46%	[5]
	Competition	8	31%	[18]
	Share	2	8%	[10]
Student-teacher	Guide	4	15%	[33]
Student-parents	Guide	2	8%	[15]

Frequently, little attention was paid to the study of how these social interactions affected the learning achievement or motivation in turn. The attitude from classmates, the feedback from teachers, and the help from parents may all have an impact on children's learning outcomes. In addition, AR games should focus more on the interactions between student and teacher, student and parents.

3.4 RQ4: What Kinds of Elements or Features Are Commonly Used in AR Learning Games According to the Reviewed Studies?

AR learning games include AR features and game elements. Different features or elements may have different outcomes regarding to learning achievement and motivation mentioned above. Therefore, this review sought to identify the frequently used AR features and game elements in AR learning games.

Regarding to the "game elements", we found that time limitation was one of the most commonly used elements (46%) in the reviewed studies, which means students have to finish the game in a certain period of time (e.g. AR science game [6]). One reason to explain this might be because the attention span of students is limited, especially for younger students. Teachers might also find the time limitation helpful for them to control the learning progress, or researchers to control for variables in the experiment. The game elements of quiz-based (50%), inquiry-based (35%), and puzzles (30%) were also preferred by the reviewed studies. Students needed to answer questions or finish tasks in the game to continue. Game story (42%) was also another frequently included element in AR learning game design. Students started the game with story or background information, and some of them might play a role (27%) during the game. Another frequently used game element was "collection" (30%). Players tried to look for different information and collect them in order to achieve the goals. The term "goals" was widely used in the reviewed literature, including the aims to get certain points, rewards, or finish a task (50%). Secret missions or hidden content were also included in some games (15%), the process of looking for the hidden mission might stimulate the interest of the students. The feedback element in the game design was mentioned three times (12%), and two board games (8%) were used. See Table 7.

As for the AR features, 38% of reviewed studies used location-based AR, and the rest used image-based AR (62%). These two forms might have different advantages for learning [11]. Since the visualization of knowledge content can promote to the fun experience of AR learning games for students, more than two third of the studies (77%) included extra instructional materials such as text, video, and audio. The 3D models

Table 7. Game elements.

	Game elements	Number of papers	Percentage	Sample of research
Game	Goals	13	50%	[25]
	Quiz-based	13	50%	[10]
	Time limitation	12	46%	[6]
	Game story	11	42%	[8]
	Inquiry-based	9	35%	[32]
	Collection game	8	30%	[5]
	Solve puzzles	8	30%	[13]
	Role play	7	27%	[32]
	Secret mission	4	15%	[18]
	Feedback	3	12%	[15]
	Board game	2	8%	[21]

were also used frequently in AR learning games (54%). Apart from that, some AR learning games (30%) also used physical objects, allowing students to interact in the game by using physical models. Communication in the real world is the main advantage of AR learning games (as opposed to regular videogames), and half of the reviewed studies encouraged face-to-face interactions in their games. AR presentation avatar (15%) and gesture-based input (12%) were also mentioned in previous studies. See Table 8.

Table 8. AR features.

	AR features	Number of papers	Percentage	Sample of research
AR	Location based	10	38%	[25]
	Image based	16	62%	[8]
	Instructional material	20	77%	[5]
	3D model	14	54%	[15]
	Face-to-face	13	50%	[20]
	Physical model	8	30%	[16]
	AR presentation agent	4	15%	[13]
	Gesture-based input	3	12%	[14]

Although we have found the most commonly used game elements and AR features from previous studies, there is still a lack of research on how different AR features and game elements influenced or supported the positive outcomes mentioned above specifically. Questions like which element or feature in the AR game motivated students most during the learning process and why, which element or feature in the AR game helped students learn better during the learning process and why, which element or feature encouraged students to communicate to each other more and why, needed to be answered.

3.5 RQ5: What Are the Suggestions for the Design of AR Learning Games According to the Reviewed Studies?

According to the reviewed studies, we can discern recommendations for the design of AR learning games that potentially lead to positive effects on students. Generally speaking, during the design process, five aspects should be considered, which are learner groups, learning objectives, AR features, game mechanics, and social interactions.

Involve learners in design process

From the reviewed studies, we found that AR learning games might affect different types of learners in different ways. Some students needed to read the text in the game with assistance, while students with higher level of literacy skills could read the text and play by themselves [27]. This study also showed that most of the students hated the idea of a cookie game because they thought it was for little kids to play. To make the students become more willing to play the game, one of the reviewed studies designed different learning contents and story themes for primary school students, middle school students, and high school students respectively [32]. One advantage of AR learning games compared to traditional learning is that it can provide different learning contents to different students [8]. In the study, results showed that different learning types (i.e. field-independent and field-dependent cognitive styles), students responded differently towards the learning material. In another study, students from a higher educational level benefited more from the use of AR learning game than students from a lower educational level [17]. Players in a game could be classified into multiple player types, such as achievers, explorers, socializers, and killers, thus, finding out the player types might be more effective to motivate students [13].

Therefore, when designing an AR learning game, the designers should always involve the target learner groups into the design process, asking for their preferences and feedback for the game concepts, and taking their player types, learning skills and knowledge level into consideration.

Clear learning objectives

We found a variety of effects of AR learning games, from both learning achievement and motivation aspects. It is hard to achieve all of these effects in one game. Therefore, it is important to have specific and clear learning objectives. Some games focused on the improvement of students' knowledge performance (e.g. an innovative AR educational platform using games [13]), some might just want to make students feel more positive about studying (e.g. EcoMOBILE [20]), while some aimed at the development of cognitive skills, such as investigation and inquiry skills (e.g. ARIES [33]). The clear educational objectives are essential for the design of an effective AR learning game. Only when the educational objectives are clear, the proper game elements and AR features can be selected, and effective AR learning games can be designed.

Identify effects of AR features

AR technology makes AR learning games different from other learning games. A study claimed that the use of AR technology could reveal "hidden" objects to explore, which makes students feel special and excited, seeing "invisible" stuffs [5]. Additionally, AR

superimposed materials like text, pictures, video, and audio into a real time environment [13], which could provide students a more comprehensive understanding of the subject, allowing them to "visualize the spatial structure of a complex model by virtually interacting with it" [13].

AR technology compasses various features, and basically divided into location-based AR and image-based AR. While other forms included the use of an AR avatar, physical objects, extra instructional materials (e.g. video, audio, text etc.), and so on. According to our investigation, most of AR learning applications involved more than one feature in their design, but the specific effects of different kinds of AR features were not well studied. For example, does the AR avatar help students engage in the study, or does it distract the students' attention? Identifying the different outcomes and effects of each feature will make the design of AR technology better help students to achieve their goals.

Study the game mechanics

Like AR features, we also found more than ten types of game elements in previous AR learning games. Designers should study the game mechanics and understand how to use different game elements better to improve the learning achievements and motivation. We found some research already took game mechanics into consideration when they designed the AR learning games. For instance, the digital game-based learning theory was used in the design to enhance the effectiveness of marine education and to establish in children fundamental concepts for environmental conservation [8]. In another study we reviewed, design principles for games on science education were also addressed, such as: "ask students to inhabit roles", "activity is organized around challenges", and so on [32]. The use of flow theory was mentioned in another study, including "clear goals", "equilibrium between challenge and personal skill", "merging of action and awareness", "focused attention", "control", "loss of self-consciousness", "time distortion", as well as "self-rewarding" [13]. What's more, gaming mechanics was used to count the scores of the players based on their gaming status [18]. On the other hand, a big amount of studies ignored the game mechanics or didn't mention it in their research. The study of game mechanics can improve the positive advantages of AR learning games.

Encourage social interactions

From this review we can see that the social interactions such as collaboration and competition in the real world were great advantages of AR learning games. AR also enhanced communication skills, encouraging interactions in the classroom between teacher and students, students and students, students and parents, parents and parents and teachers and teachers [7]. However, few previous AR learning games paid attention to the design of the face-to-face social strategy to encourage social interactions in the real world. We found one study included a chat room in the game in order to encourage social behavior [6]. This function allowed students to talk online with the potential to prevent students from talking to each other in the real world. Some other studies allowed users to share information, solve puzzles together, or exchange game items face-to-face in the real world. The designers should keep the social advantage of AR in the AR learning games, trying to design social functions that can lead to better social effects in real life.

4 Conclusion and Future Research

After the review of previous studies of AR learning games, we have six interesting findings. First of all, the subjects and learning content used in previous studies were too narrow. Studies for Science & Biology attracted most of the attention while there were fewer studies focused on the other subjects, such as Literacy and Mathematics. Secondly, most of the current AR learning games was played outdoors or in the classrooms. However, since students spend a lot of time at home and play digital games, it might be more effective to design AR learning games that can be played at home, which may encourage them to study spontaneously and in a more fun way. Thirdly, a notable gap was found in the retention effects. Nearly all studies tested the outcomes immediately after the use of the AR learning games, and more research should be done on both short-term and long-term effects. As for the measurements in previous studies, some commonly used instruments were addressed, while some studies didn't mention how they created and evaluated their instruments. More attention should be paid to the proper measurements for the effects. Fifth, social interaction effects were found by playing AR learning games, especially among students. However, little research focused on how these social interactions affected the learning achievement or motivation in turn. Also, more social effects were found among students than between student and teacher, or student and parents. The AR games that focus more on the interactions between student and teacher, or student and parents may lead to beneficial results for both sides. Last but not least, we found various game elements and AR features were used in the design of the AR learning games. However, there is a lack of systematic research on how different AR features and game elements influenced or supported the effects specifically.

In addition, we came up with five recommendations for the design of AR learning games in order to maximum the positive effects, which are: (1) involve learners in the design process, (2) always have clear learning objectives, (3) design to encourage social interactions, (4) identify effects of AR features, and (5) study the game mechanics in order to select proper elements in the design.

In summary, though the positive effects of the use of AR learning games were widely recognized in the past decade, more research still needed to be done in the future.

Acknowledgements. The author would like to express special thanks to the China Scholarship Council for supporting this PhD study, thank you for the help from Wenting Du and School of Digital Media, Jiangnan University, and thank you for the help from colleagues at Department of Industrial Design, Eindhoven University of Technology.

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