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Augmented Reality in Education and Educational Games-Implementation and Evaluation: A Focused Literature Review

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ABSTRACT

Studies on augmented reality (AR) in education and in particular AR games in education are gaining impetus worldwide. This area has been actively developing over the past decades relative to the dawn of the 4th industrial revolution and the rapid growth of digital technologies. The present review in the field of educational AR consists of a focused literature review on specific research questions regarding the effective utilization of AR in education and AR gaming applications in the everyday classroom. Moreover, the review studies knowledge and skills' enhancement, teachers' roles, relevant theories, and evaluation techniques. From the analysis of 78 selected articles, specific conclusions are drawn and a proposition of a series of recommendations and future research in certain areas of educational AR is portrayed. Respectively, considered, several acknowledged issues and limitations regarding the research and the subject area such as infrastructure, curriculum correspondence, AR games in classroom instruction and evaluation as well as the educators' acceptance and contribution.

Keywords: augmented reality, augmented reality in education, augmented reality educational games, instruction, evaluation, focused literature review

INTRODUCTION

In todays' 21st century world, humanity is progressing through the period of the so-called 4th industrial revolution, the technological revolution, and the dawn of the virtual worlds. The present revolution is offering multiple technological achievements especially through the last 20 years, where smart devices are constantly integrated into the everyday lives of people and students (Ometov et al., 2021). Typical examples of similar devices are the smartphones and tablets, while great emphasis is sited on the possibility of virtual transfer of users into digitally enhanced or virtual environments, the so-called mixed reality environments (Costanza et al., 2009). The utilization of these ecosystems entails the simultaneous adoption of digital identities through the possibility of employing a virtual protagonist (avatar) (Slater & Sanchez-Vives, 2016). Thus, we have the emergence of augmented reality (AR) environments as well as the design and creation of corresponding educational games (AR serious games) with the purpose to enhance specific knowledge and skills by the students (Serino et al., 2016). According to Squire and Jan (2007, p. 6), "AR games are those played in the real world with the support of related digital devices (PDAs, smart phones, tablets, etc.), which create an imaginary overlay layer above the real environment."

Today one can assertively voice that the evolution of these applications combined with the multiple technological achievements of the high-tech revolution have profoundly transformed the way societies operate, communicate, and learn. Through the literature review we noted that previous studies (Brower et al., 2014; Efstathiou et al., 2018; Fotaris et al., 2017; Melanie & Hughes, 2020; Saltan & Arslan, 2017; Sommerauer & Müller, 2014) focused on a variety of aims and objectives such as design, subjects, in class implementation, evaluation modes as well as infrastructure, learning issues, and students' participation. However, in the associated literature there seems a lesser focus on AR game effectual implementation in class practices, effective cognitive approaches as well as specified and context-oriented fruitful evaluation techniques. Koutromanos et al. (2015) focused on literature review regarding the use of AR games in education and specifically the use of those games through mobile devices in the context of formal and informal environments in primary and secondary education. Das et al. (2017) concentrated on the review and commentary of both the benefits and dangers of AR video games for children and adolescents, while Casas et al. (2018), Kari (2016), and Tomi and Rambli (2013) introduced AR game application into learning and interaction.

Thus, it is important to indicate that the present study-focused literature review is more contemporary and reflects on the less studied and specific area of AR gaming applications and evaluation techniques in the everyday classroom. Through a series of solicited research questions, the study aims to illuminate the area of AR in education and educational games evaluation, across

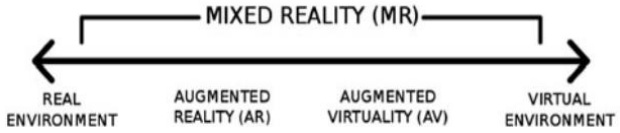

Figure 1. Milgram et al.'s (1994) reality-virtuality continuum

selected criteria such as cognitive areas and skills, the teachers' role, relevant theories, specialized assessment, and distinctive evaluation tools.

Definition and Characteristics of Augmented Reality

AR derived from the expansion of the field of virtual reality, where computer systems create entirely virtual environments. Virtual reality systems are presented in several forms such as virtual worlds, serious games, and emulators. Unlike virtual worlds, an AR system creates for the user a mixed world, where reality and virtuality are combined. AR is defined as having three main characteristics, as follows:

1. mixture of real and virtual,
2. real-time interactivity, and
3. 3D process (Azuma, 1997).

AR applications supplement the real world by incorporating virtual or computer-generated digital content (Azuma et al., 2001).

In 1995, Milgram et al. (1995) described the "*reality-virtuality continuum*", whereby AR forms a part of a more general category, called "mixed reality" (**Figure 1**). At one end of the mixed reality lies the real environment and at the other the virtual. AR is encountered immediately after the edge of the real world since its concept is based on augmenting it with data from a computer. Augmented virtuality (AV), a term created also by Milgram et al. (1995), is closest to virtual reality and describes systems that present mainly synthetic images with the addition of some elements from the real environment so that they look more realistic.

The difference between AV and AR stands with the concept that AR lies in the surrounding environment. In the case of the first two, the surrounding space is virtual as opposed to AR, which is implemented in a real environment. The upgraded reality according to different conditions (Azuma, 1997; Bimber & Raskar, 2005; Starner et al., 1997; Vallino, 1998) who dealt with this area can be defined as augmenting the real environment perceived by humans through the senses (such as sight, hearing, touch, and smell) with additional virtual information generated through applicable devices. To achieve the coexistence of the two worlds, the real and the virtual, AR needs to have the following three basic singularities (Azuma, 1997, Azuma et al., 2001):

1. Harmonious synthesis of real and virtual objects in a real environment.
2. Production of real-time interaction environment.
3. Registration of real-connecting objects with each other.

AR applications are categorized into two different categories with acknowledgment to technologies that they use:

1. Marker-based and
2. Marker-less (Carrera & Asensio, 2017).

In marker-based AR applications, symbolic figures are perceived by a computer through a marker and a camera in a way that virtual information is portrayed to the users. In marker-less applications, such as in location-based AR applications, user's real-world location is collected through GPS technology and contextually relevant virtual data are provided to the user at geographically pointed locations (Bower et al., 2014).

It is necessary to note at this point that some AR applications instead of augmenting the real world with virtual objects require the removal of real ones. This kind of AR metric, authors call it "*diminished reality*" (DR) (Azuma et al., 2001).

LITERATURE REVIEW METHODOLOGY

Our systematic review was based on a database-driven literature search between May and September 2021, through the scientific databases ERIC IEEE Xplore, ScienceDirect, Directory of Open Access Journals (DOAJ), and JSTOR. As well as certain journals from SAGE journals like New Media and Society and Sage Open; Springer journals like International Journal of Computer-Supported Collaborative Learning, Virtual Reality, and Springer Open as well as specific e-books such as the Handbook of Research on Educational Communications and Technology, Handbook of Mobile Teaching and Learning, the Augmented Reality and Virtual Reality. Also, from Taylor & Francis journals such as the Educational Media International and the European Journal of Special Needs Education; and Elsevier journal like Computers and Education. The search continued also through Google Scholar. Our review is based on 78 selected and relevant journals linked to the subjects under study. We followed the stages provided for systematic reviews by Gough et al. (2017), consisting of the following four key activities, as follows:

1. Propose a research question.
2. Ascertain and qualify relevant research.
3. Critically evaluate research articles using a systematic and comprehensible process.
4. Run a conclusive analysis and draw a final claim.

Table 1. Augmented reality literature review criteria

Exclusion criteria	Inclusion criteria
Not a relevant academic source	Article was peer-reviewed
Not in English language	Article was original research in English language
Missing empirical and theoretical foundation	Article refers to a learning theory and practices
Not related to augmented reality	Article focuses on augmented reality development
Purely abstract paper	Article entails practical use of augmented reality
Do not incorporate any evaluation	Article contains evaluation of augmented reality in instruction

In our focused literature review, we aimed at finding and analyzing research articles that

1. portray and analyze empirical studies in which AR applications and AR serious games were utilized for reinforcing teaching and learning,
2. are grounded in specific learning theories, and
3. provide evaluation modes and tools.

The paper aims to respond, through the review of the literature, to the existing research activity in the field of educational AR applications and serious games as well as to acknowledge and define the framework for the creation of a scale of graded criteria (rubric) concerning their evaluation and effective application in the daily educational process addressed on the subsequent augmented reality literature review criteria table (**Table 1**). The following questions are incited to elicit the appropriate answers regarding the subject under study:

1. RQ-1. What cognitive areas and skills with the use of AR does the existing research focus on?
2. RQ-2. Which is the role of the teachers in educational AR implementation as well as their stances?
3. RQ-3. Which are the relevant theories as well as educational environment on which AR in education could be effective?
4. RQ-4. What kind of assessment is relevant and appropriate?
5. RQ-5. What are the axes on which stands the creation and application of the scaling of graded evaluation criteria?
6. RQ-6. How AR games are effectively utilized and evaluated in the classroom?

Furthermore, the exclusion and inclusion criteria on the selection of the relevant papers are portrayed on **Table 1**.

Augmented Reality in Education and Subject Areas

Answering the first RQ-1 on cognitive areas and skills with the use of AR we have identified several relevant papers. Numerous educational utilizations of AR have already been documented in the literature. AR has been employed to enhance students' learning of science, including environmental science (Hsiao et al., 2016; Squire & Klopfer, 2007), microbiology (Chen, 2006), and biomedical science (Rasimah et al., 2011). Mathematical thinking skills through simulations (Dunleavy & Dede, 2014; Mitchell, 2011). Serious games and role play-based AR has been applied to enhance interest, participation, and motivation in medical science (Rosenbaum et al., 2007). Creative writing and literacy (Billinghurst et al., 2001) as well as visual poetry (Lin et al., 2013). Environmental education such as the virtual life cycle of a variety of butterflies (Tarng & Ou, 2012). Furthermore, there is reference of learning through the authorship of AR applications such as specific serious games (Klopfer & Sheldon, 2010) and enhancing geography skills through the participation of students as digital creators, building Google Earth models using AR sights (Thornton et al., 2012). The use of AR applications is believed to improve students' cognition and interaction with outcomes of a more successful learning (Lu & Liu, 2015). Whereas the motivation or accomplishment of specific skills is identified as an important rationale for the development of teaching tools (Ferrer-Torregrosa et al., 2015),

According to the 2012 horizon report (Johnson et al., 2016), AR by leveling information into three-dimensional (3D) space, creates new experiences of the world. The report suggested that AR should be formally adopted in education in the upcoming years to offer new opportunities for teaching, learning, research, and creative discovery in instruction and knowledge creation. AR provides the advantage of portraying virtual objects or information that overlap physical objects or environments, resulting in the experience of a mixed reality, in which virtual objects and real environments coexist in a meaningful way to enhance learning and knowledge experiences.

According to Chen and Wang (2015), who have studied the relevant literature from the years 2011-2016, they reported that there is a large volume of published studies stating advantages, limitations, and effectiveness of AR in education. However, since AR is an emerging technology, it is important to study the progress and the actual impact of its use in educational settings, defining how it is utilized to effectively design and implement relevant learning scenarios with a focus on learning issues and the students' participation and engagement.

Thus, in this review, we look empirically at studies that have utilized AR technology in education, through certain games and applications, the analysis of which will be able to assist constructing a framework that asserts the actual current state of the specific technology in education.

According to studies by Chen and Tsai (2012), it is recorded that 40% of the 55 scientific journals surveyed disclose relevant references to the educational field of "sciences", (science), which is the most widespread area in the use of AR by any field in education. This may be because AR has proven to be effective when adopted in laboratory experiments and specific educational environments (Akcayir & Akcayir, 2017; Wojciechowski & Cellary, 2013) as in mathematics, geometry (Bujak et al., 2013; Sommerauer & Müller, 2014), geography and environmental studies (Chen & Wang, 2015; Hsiao et al., 2016). Consequently, the studies concluded that AR is effective for specific activities where students acquire knowledge about certain thematics and

concepts that they would not be able to see in the real world or without a specialized device, and thus recruit abstract or complex concepts. In addition, 16.36% of AR studies focus on social science subjects. Studies in this area also focus on language learning (Liu & Tsai, 2013; Yang & Liao, 2014), visual art and painting (Chang et al., 2014; Ibáñez et al., 2014). AR has been widely used in the social sciences due to the ability to augment information and combine it with facts to provide new experiences. Also, there are research studies of the effect of AR on engineering (14.55%), health (7.27%), and education services (7.27%).

The most important advantages of AR according to the relevant studies are the cognitive effects and the motivation of involvement in the teaching and learning process. In these 55 articles, most of the studies reported that AR leads to better learning performance as it promotes learning motivation, since AR provides a particularly attractive graphic and virtual study environment as well as specific conditions of authentic interaction by the students with the subject. Also, active participation of students, improved perceptual correlation and playful interaction as well as positive attitudes of students regarding the tools and educational applications of AR, cited as effective parameters of the use of AR in everyday teaching reality.

Through our studies with AR education systems, it is important to evaluate the impact of these learning applications and the feasibility of integrating them into classrooms and everyday teaching and learning. Many factors are involved in this process that varies from cost to teacher accreditation and acknowledgement. The evaluation process of a specific technology is an important step for pedagogical planning and instructional design. A process according to which applications and learning experiences are designed, delivered, and implemented educationally. It is also necessary to properly and accurately evaluate the specific AR applications and AR games so that teachers are confident with their positive or non-positive results. It is also important to consider the views of both teachers and students as these may differ (da Silva et al., 2016; Santos et al., 2019). Until now there are no specific studies on evaluation criteria in education. Hence, the proposal to evaluate educational game-applications is prevalent due to the increasing use of commercial applications (apps) on smart phones and tablets as well as the increasing number of users and choices of these applications (Green et al., 2014; Koutromanos et al., 2015; Ok et al., 2016; Papadakis et al., 2017). Therefore, the main research purpose of the evaluation concept is to design and implement a scale of graded criteria or rubric assessment (Kouloumbaritsi & Matsagouras, 2004; Petropoulou et al., 2015). The concept focuses on criteria for the selection, instruction modes, of educational AR games and on the methodology for the formulation of a scale of classified criteria for specific characteristics of AR related to the promotion and educational utilization of AR objects and worlds, which enhance the participation, motivation, and engagement of the students and form a playful and pleasant learning climate.

Teachers and Augmented Reality

Regarding RQ-2, the role of the teacher as a designer, implementor, and facilitator appears to be a critical element. Jerry and Aaron (2010) through their research to track objects and graph vertical and horizontal velocity and displacement, discovered that the teacher's use of thinking questions and their facilitation skills were quite critical to motivate students and cultivate forms of challenge that lead to knowledge gain and skills enhancement from the activities. Teachers in many cases and research findings state that they are not well equipped or trained to effectively solve the technical issues and problems that may arise when AR fails to function as intended (Billinghurst & Duenser, 2012; Rakes & Rakes, 2004). As such, teachers need constant and effective support by specialists to guarantee a positive stance and effective utilization of AR educational applications (Dede, 2009). It is decisive that teachers acquire the necessary competences and skills to integrate AR effectively into their classes to avoid learning with AR solely from IT teachers who are mostly focused on technical issues and with less effective pedagogy (Billinghurst & Duenser, 2012).

Regarding the potential of AR in education, there has been relatively little integration of AR games and practices into the classroom, suggesting that there are only a few best practices to inspire and motivate teacher practice (Johnson et al., 2012). For an effective implementation of educational AR game technology, teachers need to believe that it is a valuable tool in enhancing engagement, participation, and motivation of students as well as an effective pedagogy where teaching and learning strategies are most suited to the specified and practiced curriculum (Overbay et al., 2010). A major barrier to the effective integration of AR technology by the teachers seem to be their lack of a sited conceptual framework regarding the successful implementation of AR instruction modes and uses (Rasimah et al., 2011). Without such contexts, the application of these specific technologies within the classroom becomes sporadic, individualistic, superficial, and unproductive (Ertmer et al., 2012). According to the study of Tzima et al. (2019), the most significant factors for the effective use of AR technology in education are the enrichment of collaboration among teachers of different specialties and a more flexible curriculum. Furthermore, the endorsement and coordination by the central educational services is also of high importance.

THEORIES AND MODELS

In our endeavor to answer RQ-3, which are the relevant theories as well as proper educational environment on which AR in education could be effective, we have identified and note the following theoretical fundamentals. The relevant literature points out that AR technology in education can adopt and integrate a diversity of certain pedagogical approaches (Johnson et al., 2010; Shelton, 2002). Learning theories can be portrayed from a cognitive, behavioral or constructivist perspective, establishing the cognitive and social aspects of learning (Illeris, 2018, p. 8). Specific pedagogical theories on AR integration in education as well as the relevant references and research articles, as follows:

1. **Constructivist instruction and learning:** knowledge through utilizing AR in promoting engagement, motivation, and participation. Connecting new knowledge and experiences to the previous (Kerawalla et al., 2006).
2. **Situated learning:** Centripetal, authentic, and contextualized learning is enhanced by implanting learning experiences through the AR and real-world environment and by bringing the everyday world into the classroom (Chen & Tsai, 2012;

Dede, 2009; Dunleavy & Dede, 2014; McLellan, 1996; Rasimah et al., 2011). The specific theory is studied through the AR prism on how to promote intentional deep learning in the review of augmented reality in education chapter (Wen & Looi, 2019).

3. **Game-based learning:** According to particular related research studies, AR tools can be utilized to create ubiquitous and immersive game-based learning through game like digital learning experiences and participation (Dunleavy & Dede, 2014; Hirumi et al., 2010; Kiili, 2005; Klopfer & Squire, 2008; Prensky, 2001; Squire & Jan, 2007; Van Eck, 2006). Using AR tools can promote certain real world alike missions and learning situations such as programming, pattern analysis, visual content analysis, and storytelling (Brom et al., 2010).
4. **Enquiry-based learning:** Through data collection and analysis (Dunleavy & Dede, 2014), real-world context models and situations that can be modified for study purposes (Kaufmann & Schmalstieg, 2003). According to recent research, AR assists in inquiry-based learning through context and data easily modified and distributed (Johnson et al., 2010).
5. **Mobile learning instructional design:** According to Radosavljevic et al. (2020) and Sharples (2009), mobile learning instructional design model through the implementation of AR exhibited that AR and mobile learning support learners' collaboration in order to construct common knowledge, use technology to enrich learners' collaborative knowledge building with other learners and teachers as well as shortens the time of realizing a task and the efficacy of solving a task is higher as opposed to the traditional methods.
6. **Experiential learning:** As Kolb's (2014) cycle pointed concrete experience, reflective observation, active experimentation, and abstract conceptualization using instruction techniques and practices which associates to real-world. Benefits of experiential learning in AR include immediate application of knowledge, motivation, reflection, real world practice, and teamwork enhancement (Huang et al., 2016).
7. **Cognitive theory of multimedia learning (CTML):** It is further acknowledged as the "*multimedia principle*", expresses the concept that students acquire knowledge more authentically from both text and images than from text alone (Mayer, 2009, 2017; Sorden, 2013). According to one study, museum visitors who participated in CTML education experiences performed significantly better on knowledge acquisition as well as assessments related to augmented displays than non-augmented displays, and they perceived AR as a valuable and necessary add-on for museum exhibitions (Sommerauer & Müller, 2014).
8. **Just-in-time teaching effectively and actively involves students in the learning practice (JiTT):** JiTT is an instructing and learning approach, intended to support the utilization of the in-class time frame for a more dynamic and connecting learning experience. JiTT dwells on a criticism circle between computerized learning, instructive materials, and classroom guidance (Novak et al., 1999). Applicable studies focus on comparative ways that educators can best utilize AR for altering their instructing methods as debated by (Reilly & Dede, 2019).
9. **The technology acceptance model (TAM):** TAM is a concept in information systems' that models how students understand and use technology. Davis (1989) first proposed the TAM. The model provides a traditional view of technology acceptance from the students' perspectives, such as ease of use, system quality and functionality as well as interactivity. Arbaugh (2004) detected that between the first and subsequent online course practices, the perceived usefulness and ease of use of the blackboard e-learning tool (e-learning software platform) increased dramatically. Recent and relevant research highlights the importance of providing continuous professional development (CPD) and technology support for teachers in order to encourage the use of AR and VR in the classroom (Jang et al., 2021).

EVALUATION

We focused on the assessment criteria and setting for an effective AR deployment in education regarding RQ-4 and RQ-5. It is critical to develop certain concepts and indicators in order to appropriately evaluate new educational technologies. Dexter et al. (2002) identifies two criteria for effective technology integration and application in K-12 classrooms:

1. the teacher must perform as an instructional designer, planning the use of technology to aid learning and also act as a facilitator of learning and
2. teachers must be supported in their position by schools.

According to Crompton (1996), evaluating a certain computer technology in seclusion will likely focus on different features of the same technology such as screen design and text arrangement. Conversely, evaluating curricular resources allows for the investigation of other factors that will lead to the product's successful integration into the course:

1. Educational background,
2. Course goals and objectives,
3. Teaching style,
4. Learning methodologies,
5. Evaluation methods, and
6. Implementation tactics are some of these traits.

Moreover, formative evaluations, as stated by Scriven (1991), seem essential during the development or enhancement of a project, or student, and it is organized with the intent to progress. On the other hand, summative evaluation is characteristically quantitative, using numeric scores or letter grades to assess knowledge gain and quality learning outcomes. Consequently, an

inclusive evaluation containing both types of assessment techniques is important in order to achieve a complete picture of the implementation process of AR technology in education. It is important to acknowledge and point that still evaluation is a new and undocumented field in AR utilization in education that need further research and studies.

Augmented Reality Games

In attempting to answer RQ-6, we detected a small number of related papers. Relatively, it is emphasized that AR games promote specific student behavior in certain settings. According to Kari (2016), in a study on Pokemon Go-AR game, the specific AR game can be implemented in a school or an educational setting to encourage students to participate in a physical activity and substitute passive-screen based learning. There were also significant occurrences when the game was played for entertaining and physical activity purposes. According to Anneta et al. (2012), students will acquire 21st century skills through AR game-based teaching and learning. Benford et al. (2003) identify four educational applications for mobile AR: information services and guides, games, field trips, and field science. As previously stated, games are tending to become the most compelling and commercially promising of the four options (Benford et al., 2003). Furthermore, in terms of allowing users to handle real objects of varying shape and weight, an AR world offers students the prospect to develop high-quality motor skills that may be more conveyable to daily living events than other techniques (Burke et al., 2010). According to Das et al. (2017), the blending of virtual and real-world elements creates exciting new possibilities not just for immersive gameplay, but also for increased socialization and exercise. However, mental health and safety could be in danger if gameplay becomes an addiction or players become targets for cyberbullying. Regarding limitations and challenges we noted that another main challenge for serious-games and gamification, involves user-performance metrics, characterization of the player's activity and better integration of assessment and user analytics in AR educational games (Bellotti et al., 2013).

Constraints of the Implementation of Augmented Reality Technology in Education

We state the belief that, AR in education, as a novel technology and instruction method, has many characteristics that need to be explored and many future research studies also remain to be performed in this relatively new field. Several limitations exist related to the educational implementation of AR. According to Hsu et al. (2013), numerous students in an AR learning exercise consented of the quality of the AR tools but most of them did not regard the tools to be as effective as the traditional textbooks. They found difficulties in utilizing AR tools to obtain information due to infrastructure and technology issues. Accordingly, since technology is rapidly improving and 5G connectivity is introduced and applied to more and more countries, it is suggested that more researchers in the education field should investigate the potential of AR to effectively incorporate into the everyday educational settings through the advancement in teaching methods and the enhancement of competences and knowledge of the participating students (Haus et al., 2019). Thus, results and discussion are limited to the specific resources. Future studies could lead to different results and conclusions.

Additionally, pedagogical issues should be addressed when AR systems are implemented in education environments, (Potkonjak et al., 2016). Primary, in the learning design based on AR technologies, how should the information be disseminated between two realities and among different devices. This requests to balance decentralized information flows with supervised educational activities. To resolve these tensions, learning theories such as situated learning (Wegner, 1998) and inquiry-based learning (Johnson et al., 2010) could provide useful design guidelines for educators and learning designers.

Moreover, certain drawbacks as stated in the papers mostly highlight issues related to the technical aspects of utilizing AR in the learning process. Other issues regard training of the teachers and their acceptance of the effectiveness of AR in education. Teachers should be highly valued in terms of successfully adopting and implementing AR tools and games in education.

Further shortcomings suggest the appropriateness of educational models and instruction theories that need to be adopted by the teachers as well as the evaluation criteria and forms. There seems to appear a need for a common framework of specific theories, instruction modes and evaluation methods that ascertain effectiveness in the education field. These suggestions provide the potential to make AR a powerful learning tool that can assist students to gain content knowledge and maintain that knowledge through their interactions with various learning activities, tools, games, and projects.

DISCUSSION

This study examined 78 educational AR articles indexed in specific scientific databases such as ERIC IEEE Xplore, ScienceDirect, Directory of Open Access Journals (DOAJ), and JSTOR. As well as certain journals like SAGE journals, Springer, Springer Open, and Taylor & Francis. Selected articles were analyzed and coded according to the following headings: year of publication, method, research topic, sample level, sample size, data collection tool, AR type, and delivery technology. Data analyses set out to acknowledge and portray trends, adoption methods, educational modes, and evaluation techniques in educational AR studies.

As it is widely recognized, teachers play an important role in the adoption of new technologies in schools. Accordingly, it is principally significant that the involvement of teachers in the evaluation of new technology applications through a more active and creative stance should and need to be supported. It is beneficial for teachers to have at their disposal, flexible enough tools, to facilitate them in the educational utilization and pedagogical use of instructive content and knowledge sources. Main purpose is the effective and seamless application of new technologies into everyday teaching and learning practices.

In addition, through the literature review, we noted that there is a tendency for these educational applications-AR games to relate, in the majority, to specific topics such as science, technology, mathematics and engineering, i.e., belong to the field of STEM education (science, technology, engineering, mathematics) (NSB, 2007). Accordingly, it is expected that the future thematic

direction of the AR applications will follow the previous finding as well as prevail in the contemporary educational reality. Relative to this argument it is suggested the review of the current curriculum so as to include more subjects that could be taught through AR tools, as well as a flexible instruction policy that promote the autonomy of teachers to utilize tools and resources that they believe are appropriate to their students' needs.

Moreover, it is important to state that very few systems have considered the special needs of students in AR. Wu et al. (2013) state that few systems have been designed for students with special needs. Likewise, and according to Lindsay (2007), the prospects for children with special needs and disabilities can be developed by a specific policy such as inclusive education schemes.

We cannot isolate children from technology, but we should, on any occasion, ensure that they are not unfavorably affected by it (Ebbeck et al., 2016). As Parette et al. (2010, p. 2) state regarding the escalating technological applications available to children: The question is not only whether the technology should be properly evaluated and utilized in educational settings, but also how it can make a difference in effective learning, skills development, knowledge acquisition as well as the wider development of personalities and talents of these children in today's rapidly evolving societies of the 21st century.

CONCLUSIONS

The number of educational AR studies has rapidly increased over the years. It seems that educational AR will be more widespread in the future along with modern advances in mobile technologies. The importance of AR utilization in the everyday instructional practices and the escalation in the number of AR studies would prolong in the forthcoming years.

Regarding the educational community, results derived from the literature review, portray that the most important factors for the effective use of AR technology in education are the development of collaboration between teachers as well as the establishment of a new and flexible curricula moving towards the enhancement of specific competences such as problem solving, critical thinking, creativity, and experiential learning. Emphasis should also be given to the support and coordination by the central educational directorates through continuous quality training and infrastructure.

AR in education characteristically engulfs "the potential to both engage and excite" (Thornton et al., 2012 p. 18) cited by Wu et al. (2013). Conferring to recent research from the literature review we documented that, AR could enable learning content in 3D experiences, ubiquitous learning, collaborative and situated learning, multiple senses provocation, immediacy, and immersive learning engagement, visualizing the invisible, and associating formal and informal learning (Wu et al., 2013, p. 43).

Regarding the relevant theories, constructivist theories emphasize learning through active engagement (Comstock, 2013). AR tools and educational games could be considered constructivist in type due to their ability to grant students collaborative action and knowledge construction (Bower et al., 2014; Kerawalla et al., 2006; Teichner, 2014). Other theories include social engagement and cooperation such as social learning theory by Bandura (1977), game-based learning by Salomon and Perkins (1998), JITL, just in time learning and support by Novak et al. (1999), self-directed learning by Knowles (1970), and personalized learning by Campbell et al. (2007). AR educational environments provide data and information that converts into knowledge through a fun way via multiple portrayal of data, multi-sensory provocation, such as auditory, visual, and spatial, hence affording a diversified learning environment that could suggest greater motivation and engagement resulting in knowledge and skills enhancement and deeper-longer understanding.

Limitations and Future Research

There is a limited number of articles related to AR games' evaluation and implementation in education. That could be due to the fact the area is fairly new and not a plethora of associated AR educational applications are present and functional. However, every day, new and interesting AR educational tools are emerging, connected to novel and immersive technologies as well as linked instruction models and lesson plans that could change completely the educational scene as we know it. Thus, although the limited studies in the field, the importance of AR game implementation and evaluation in education is affirmed in the literature.

Drawing from the focused literature we could suggest that future research should study the importance of a flexible and diversified curriculum in education so as to provide affordances to entail AR educational tools and games through utilizing a multimodal portrayal of data and an active-experiential learning. AR technology software designers should also collaborate with teachers so as to design and create learning-friendly experiences that could be effectively integrated into the everyday classroom pedagogy, such as AR content, games and environments that match the subjects and knowledge needed to be transferred to the students. Further a student-friendly and fully functional AR environment that pupils can collaborate, reflect on their achievements and progress, understand the topics and the tasks, assist each other, and enhance problem solving and critical skills. Additionally, designers should grant perceptive applications that monitor and adapt to student progress and can easily and functionally integrate with the existing curriculum such as textbooks and knowledge games.

This study attempted to contribute to the current knowledge in AR and AR games educational setting by providing a focused and contemporary state of research in this topic. Although the limited literature in the field of AR games the study endeavored to illustrate specific fields of merit that could benefit of further research such as AR games and evaluation techniques in education so as to pinpoint the value of this technology to the learning processes of today's challenging world of "meta-education".

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