Educational Research Review 20 (2017) 1–11

Contents lists available at ScienceDirect

Educational Research Review

journal homepage: www.elsevier.com/locate/edurev

Advantages and challenges associated with augmented reality for education: A systematic review of the literature

Murat Akçayır [a], Gökçe Akçayır [b, *]

[a] Kırıkkale University, Faculty of Education, Department of Computer Education and Instructional Technologies, Kırıkkale, Turkey
[b] Gazi University, Faculty of Gazi Education, Department of Computer Education and Instructional Technologies, Ankara, Turkey

ARTICLE INFO

Article history:
Received 2 May 2016
Received in revised form 25 July 2016
Accepted 3 November 2016
Available online 5 November 2016

Keywords:
Augmented reality
Systematic review
Educational technology

ABSTRACT

This study presents a systematic review of the literature on augmented reality (AR) used in educational settings. We consider factors such as publication year, learner type (e.g., K-12, higher education, and adult), technologies in AR, and the advantages and challenges of using AR in educational settings. The full range of SSCI journals was surveyed and a total of 68 research articles were selected for analysis. The findings reveal an increase in the number of AR studies during the last four years. The most reported advantage of AR is that it promotes enhanced learning achievement. Some noted challenges imposed by AR are usability issues and frequent technical problems. We found several other challenges and numerous advantages of AR usage, which are discussed in detail. In addition, current gaps in AR research and needs in the field are identified, and suggestions are offered for future research.

1. Introduction

Augmented reality (AR) can be defined as a technology which overlays virtual objects (augmented components) into the real world. These virtual objects then appear to coexist in the same space as objects in the real world (Azuma et al., 2001). AR was first introduced as a training tool for airline and Air Force pilots during the 1990s (Caudell & Mizell, 1992). Currently, AR is a popular technology that is widely used in educational settings. In this role, AR also has become an important focus of research in recent years. One of the most important reasons that AR technology is so widely used is that it no longer requires expensive hardware and sophisticated equipment, such as head-mounted displays (HMD). The technology now can be used with computers or mobile devices. Thus, using AR technology is not as difficult as it was in the past. It is used today in every level of schooling, from K-12 (Chiang, Yang, & Hwang, 2014b; Kerawalla, Luckin, Seljeflot, & Woolard, 2006) to the university level (Ferrer-Torregrosa, Torralba, Jimenez, García, & Barcia, 2015).

1.1. Relevant literature

Studies have shown that AR technology offers many advantages when used in educational settings (Cheng & Tsai, 2013). For instance, AR helps students to engage in authentic explorations in the real world (Dede, 2009). By displaying virtual elements alongside real objects, AR facilitates the observation of events which cannot easily be observed with the naked eye (Wu, Lee, Chang, & Liang, 2013). Thus, it increases students' motivation and helps them to acquire better investigation skills (Sotiriou &

* Corresponding author.
E-mail addresses: gokceakcayir@gmail.com, gokceakcayir@gazi.edu.tr (G. Akçayır).

http://dx.doi.org/10.1016/j.edurev.2016.11.002
1747-938X/

Bogner, 2008). According to Dunleavy, Dede, and Mitchell (2009, p. 20), AR's most significant advantage is its "unique ability to create immersive hybrid learning environments that combine digital and physical objects, thereby facilitating the development of processing skills such as critical thinking, problem solving, and communicating through interdependent collaborative exercises." A very recent study by Akçayır, Akçayır, Pektaş, and Ocak (2016) revealed that AR technology both improves university students' laboratory skills and helps them to build positive attitudes relating to physics laboratory work.

In the literature, some researchers have drawn attention to limitations associated with AR. For instance, Lin, Hsieh, Wang, Sie, and Chang (2011) stated that students find AR complicated, and that they often encounter technical problems while using it. Without a well-designed interface and guidance for the students, AR technology can be too complicated for them to use (Squire & Jan 2007). The various devices that deliver AR applications may cause additional technical problems (Wu et al., 2013). Additionally, Yu, Jin, Luo, Lai, and Huang (2009) stated that bulky AR technologies such as HMDs are not easy to handle, and that AR technologies should be developed to be smaller, lighter, more portable, and fast enough to display graphics. Aside from technical limitations, Munoz-Cristobal et al. (2015) showed that excessive additional lecture time is required to use AR effectively in education.

A considerable amount of research has been focused on AR usage in educational settings. However, though numerous AR studies have been published, the educational advantages and related utilities of AR have only recently been explored in detail (Cheng & Tsai, 2013; Martin et al., 2011). To date, no comprehensive explication of the educational effects and implications of AR exists (Radu, 2012). Therefore, a review of the advantages and challenges reported in research studies on AR technology in education can usefully suggest both best practices and areas in which to invest future research and development, so that this technology may be employed to its maximum capacity. In the present study, 68 research articles examining educational uses of AR, published up to 2015, were identified and analyzed to fill this need.

1.2. The purpose of the study

Investigating prior research in a field is important, as this reveals the current state of the field and offers guidance to researchers who are seeking suitable topics to explore (Höffler & Leutner, 2007; Karatas, 2008; Seo & Bryant, 2009). Moreover, such systematic reviews provide a concise reference for policymakers, who must make critical decisions regarding funding and applications (Hwang & Tsai, 2011; Shih, Feng, & Tsai, 2008). The examination of prior research in a field also helps researchers to determine which subjects are of continuing importance (Davies, Howell, & Petrie, 2010; Nolen, 2009).

There are many literature review studies in the fields of global education and technology (Hwang & Tsai, 2011; Wu et al., 2012). In these studies, researchers focus on topics such as e-learning (Lu, Wu, & Chiu, 2009; Shih et al., 2008), mobile and ubiquitous learning (Hwang & Tsai, 2011; Wu et al., 2012), blended learning (Drysdale, Graham, Spring, & Halverson, 2013), and educational technologies (Hew, Kale, & Kim, 2007; Kucuk, Aydemir, Yildirim, Arpacik, & Goktas, 2013). But reviews of research on AR technology are less common (Bacca, Baldiris, Fabregat, & Graf, 2014) because AR has only recently become very popular in educational settings. To fill that gap in the literature, in this study we located and then analyzed all of the published studies in the Social Science Citation Index (SSCI) journal database (to the end of 2015) which address educational uses of AR technology. The purpose is to present a systematic review of the literature on AR used in educational settings (e.g., formal learning, informal learning, and training in a workplace). More specifically, the following research questions (RQ) are addressed:

RQ1. What is the distribution over time of the studies published in the SSCI-indexed journals that examine educational uses of AR?

RQ2. What learner types (types of participants) are commonly selected for the research studies published in the SSCI-indexed journals?

RQ3. Which AR technologies are most used for educational purposes within the studies published in the SSCI-indexed journals?

RQ4. What are the advantages of AR in educational settings, indicated in the studies published in the SSCI-indexed journals?

RQ5. What are the challenges imposed by AR in educational settings, indicated in the studies published in the SSCI-indexed journals?

2. Method

2.1. The manuscript selection process

In review studies, various methods are used by researchers to select manuscripts. Examples include selecting a defined set of articles from important journals within the field (Hwang & Tsai, 2011; Nolen, 2009), selecting all articles published within the leading journals of the field (Karatas, 2008; Shih et al., 2008), and using databases in which the studies are indexed – such as ProQuest (Drysdale et al., 2013), Education Resources Information Center (ERIC), and SSCI (Kucuk et al., 2013).

For this review, we selected scientific articles on the educational uses of AR, published in journals that are indexed in the SSCI database. We employed this method because it is easy to access the field tags of SSCI indexed articles, such as topic and research area (Luor, Johanson, Lu, & Wu, 2008). The Web of Science site (WOS) was the point of access. WOS provides a search