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## Augmented Reality Trends in Education: A Systematic Review of Research and Applications

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### ABSTRACT

In recent years, there has been an increasing interest in applying Augmented Reality (AR) to create unique educational settings. So far, however, there is a lack of review studies with focus on investigating factors such as: the uses, advantages, limitations, effectiveness, challenges and features of augmented reality in educational settings. Personalization for promoting an inclusive learning using AR is also a growing area of interest. This paper reports a systematic review of literature on augmented reality in educational settings considering the factors mentioned before. In total, 32 studies published between 2003 and 2013 in 6 indexed journals were analyzed. The main findings from this review provide the current state of the art on research in AR in education. Furthermore, the paper discusses trends and the vision towards the future and opportunities for further research in augmented reality for educational settings.

### Keywords:

Augmented reality, Systematic review, Trends of AR, Personalization, Inclusive learning in augmented reality

### Introduction and definitions

In recent years, technology-enhanced learning (TEL) research has increasingly focused on emergent technologies such as augmented reality, ubiquitous learning (u-learning), mobile learning (m-learning), serious games and learning analytics for improving the satisfaction and experiences of the users in enriched multimodal learning environments (Johnson, Adams Becker, Estrada, & Freeman, 2014). These researches take advantage of technological innovations in hardware and software for mobile devices and their increasing popularity among people as well as the significant development of user modeling and personalization processes which place the student at the center of the learning process. In particular, augmented reality (AR) research has matured to a level that its applications can now be found in both mobile and non-mobile devices. Research on AR has also demonstrated its extreme usefulness for increasing the student motivation in the learning process (Liu & Chu, 2010; Di Serio et al., 2013; Jara et al., 2011; Bujak et al., 2013; Chang et al., 2014).

An AR system allows for combining or "supplementing" real world objects with virtual objects or superimposed information. As a result virtual objects seem to coexist in the same space with the real world (Azuma et al., 2001). However, AR is not restricted only to the sense of sight; it can be applied to all senses such as hearing, touch and smell (Azuma et al., 2001). AR allows for combining virtual content with the real world seamlessly (Azuma, Billinghurst, & Klinker, 2011). This differs from the notion of a Virtual Environment (VE) where the user is completely immersed inside a synthetic environment. In this sense, "AR supplements reality, rather than completely replacing it" (Azuma, 1997). The Reality-Virtuality continuum (Milgram, Takemura, Utsumi, & Kishino, 1995) clearly shows the relation between a real environment, AR and a virtual environment.

As an example of the current AR applications in education, Ibáñez, Di Serio, Villarín, & Delgado Kloos (2014) created an AR application for teaching the basic concepts of electromagnetism. In this application students can explore the effects of a magnetic field. For that purpose, the components used in the experiment (cable, magnets, battery, etc.) can be recognized using the camera of a mobile device like a tablet. As a result students can see superimposed information such as the electromagnetic forces or the circuit behavior using the tablet. The results of this research show that AR improved academic achievement and provided instant feedback.

Some researchers have proposed different definitions of AR. For example, El Sayed, Zayed, & Sharawy (2011) assert that AR enables the addition of missing information in real life by adding virtual objects to real scenes. Supporting this definition, Chen & Tsai (2012) point out that AR allows for interaction with 2D or 3D virtual objects

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In recent years, there has been an increasing interest in applying Augmented Reality (AR) to create unique educational settings. So far, however, there is a lack of review studies with focus on investigating factors such as: the uses, advantages, limitations, effectiveness, challenges and features of augmented reality in educational settings. Personalization for promoting an inclusive learning using AR is also a growing area of interest. This paper reports a systematic review of literature on augmented reality in educational settings considering the factors mentioned before. In total, 32 studies published between 2003 and 2013 in 6 indexed journals were analyzed. The main findings from this review provide the current state of the art on research in AR in education. Furthermore, the paper discusses trends and the vision towards the future and opportunities for further research in augmented reality for educational settings.

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**Keywords** Augmented reality, Systematic review, Trends of AR, Personalization, Inclusive learning in augmented reality. Introduction and definitions. In recent years, technology-enhanced learning (TEL) research has increasingly focused on emergent. These researches take advantage of technological innovations in hardware and software for mobile devices and their increasing popularity among people as well as the significant development of user modeling and personalization processes which place the student at the center of the learning process. In particular, augmented reality (AR) research has matured to a level that its applications can now be found in both mobile and non-mobile devices. Educational Technology & Society seeks academic articles on the issues affecting the developers of educational systems and educators who implement and manage such systems. The articles should discuss the perspectives of both communities and their relation to each other. The aim of the journal is to help them better understand each other's role in the overall process of education and how they may support each other. Coverage: 1998-2018 (Vol. 1, No. 1 - Vol. 21, No. 4). Moving Wall: 0 years (What is the moving wall?) Augmented Reality Trends in Education: A Systematic Review of Research and Applications (pp. 133-149). Jorge Bacca, Silvia Baldiris, Ramon Fabregat, Sabine Graf and Kinshuk. <https://www.jstor.org/stable/jeductechsoci.17.4.133>. Save. Cite this Item. (2014). Augmented reality trends in education: a systematic review of research and applications. Educational Technology & Society, 17(4), 133–149. Google Scholar. Badia, A. (2015). Evaluation of eLearning usage in South African Universities: a critical review. International Journal of Education and Development using Information and Communication Technology, 11(2), 168–183. Google Scholar. Bates, T. (2011).