

# Reinforce Context Awareness in Augmented Reality-based Learning Design

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**Abstract:** This paper provides a systematic review of Augmented Reality (AR) in education, by focusing on exploring how and why AR technology can be used to promote learning effectively. Through discussing the learning theories and pedagogies adopted in existing empirical studies, this study underlines the necessity of context-aware design in the use of AR. On that basis, we put forward two suggestions for future educational AR design in collaborative settings.

## Introduction

The major distinction between traditional instructional design and constructivism is that the former focused on designing instruction that has predictable outcomes, while the latter focuses on learning environment and experience design (Jonassen, 1994). The use of Augmented Reality (AR) in education can be considered as one of the natural evolutions because it combines virtual and real objects in a real setting, that provides a bi-directional interactive learning environment. A large and growing body of literature has reported affordances and effectiveness of the use of AR in different scenarios and a series of studies has demonstrated that cognitive and affective effects of AR on learning (e.g., Liu, 2009; Yoon et al., 2017). However, after analysing 32 studies published in 6 indexed journals between 2003 and 2013, Bacca et al., (2014) pointed out that the major learning effectiveness was reported by focusing on learning gains in terms of pre-and post-test results or learning motivations. Instead of merely providing novel and interesting approaches to convey information, the real value of AR-based learning should be uncovered through investigating how and why AR should be used to promote learning effectively. To find out these how and why questions, we conducted a systematic review study, paying attention to those studies in which theoretical foundations of learning and AR-based learning processes were discussed. The review concentrates on these two questions: (1) what are the learning theories that are used to inform the design and to predict learning effectiveness in an AR environment; and (2) what pedagogies are integrated with AR to improve learning in existing empirical studies?

## Review methods

We selected scientific articles on the educational uses of AR, published in journals that indexed in the SSCI database. We used two well-known online research databases related to education and technology (ERIC and ACM Digital Library), searching with the query string: (“AR” OR “mixed reality”) AND (education), and then obtained a total of 356 journal papers. We eliminated studies that did not involve a concrete intervention (e.g., technical development papers or literature reviews) and the papers from similar authors discussing the same application in similar settings and excluded the studies that only provided users’ perceptions towards the system use without a discussion about learning effect. In this process, we also added 8 more relevant papers via scanning references cited in the previously selected papers. As a result, 57 papers were identified as eligible articles for further analysis.

## Findings and suggestions

The results showed that of the 57 papers that we identified and analyzed, only 11 provided an explicit theoretical framework. These theories and frameworks, and the referenced studies were presented below. These references studies were further categorized into **context-independent** and **context-aware** design. Taking into account the education levels and the subject contents, the main fields of studies in which AR are applied to were classified into seven categories (see Table 1).

Findings from this review showed that those context-independent AR applications focused more on conveying content information in an alternative approach but paid less attention to the pedagogical design. The context-aware AR applications, however, underlying the learning theories, such as situated learning and distributed cognition, tended to have more holistic learning environment designs by integrating diverse pedagogical approaches and strategies. Moreover, the majority of the context-aware AR applications worked on taking use of AR to increase collaboration and knowledge transfer in the different scenarios, beyond multimodal or multimedia content presentations.

Table 1: The pedagogical approaches or strategies used

Fields	No.	Context-independent	Context-aware
Kindergarten	3		Dramatic play (Han et al., 2015)
K12_Math	6		
K12_Science	23	Game-based learning (Lu & Liu, 2015)	Digital storytelling (Laine et al., 2016) Inquiry-based learning (Bressler & Bodzin, 2013; Chiang et al., 2014; Kamarainen et al., 2016) Game-based learning (Hwang et al., 2016; Squire & Klopfer, 2007) Collaborative problem-based learning (Tolentino et al., 2009; Liu et al., 2009)
K12_Language learning & other social studies	5	Game-based learning (Tobar-Muñoz et al., 2017)	Digital storytelling (Sugimoto, 2011) Inquiry-based learning (e.g., Chang et al., 2013) Game-based learning (Dunleavy et al., 2009) Task-based collaborative learning (Liu, 2009)
University	12		Historical reasoning through inquiry (Harley et al., 2016); Experiential learning (Yin et al., 2013)
Workplace	5		Peer assessment (Chao et al., 2016)
Special education	1		
<b>Total</b>	<b>57</b>	<b>33</b>	<b>24</b>

The findings suggest further studies of AR applications in teaching and learning are needed to study context-aware learning designs. Two concrete suggestions are pinpointed and summarized. They are:

- **Foregrounding design of human-context interactions:** It has been noted that AR not only provides each individual with a new interactive approach to realize human and computer interaction but also integrates human-computer-context interactions. Hence, in addition to providing rich content via 3D models or environments, future studies should pay more attention to enhancing the interactions between learners and the contextual information through pedagogical content design. The link between virtual information and authentic environments should be emphasized. As Klopfer and Squire (2007) pointed out in their early study, successful AR applications require learners to solve complex problems in which they have to use a combination of real collected evidence and virtual information. One mechanism for achieving this is to design context-aware applications on mobile devices. Meanwhile, the integration of pedagogical designs (such as collaborative problem solving or task-based inquiry learning) with AR also can help to create authentic learning contexts where participants need to solve problems or complete tasks together.
- **Designing immersive learning experience to achieve collaborative distributed cognition:** One of the most significant affordances of AR is providing an immersive hybrid learning environment that combines virtual and physical objects. Nevertheless, the purpose of using AR in education is not to replicate or replace real-world interactions with highly immersive environments. As Lindgren and Johnson-Glenberg (2013) stated that AR environments may be particularly well aligned with collaborative activity as social interactions typically involve the physical interplay between participants, and the structure of AR can facilitate and enhance these interactions. AR designers can focus on the use of AR to enable learners to build up common ground for shared understanding.

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