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Current status, opportunities and challenges of augmented reality in education

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ABSTRACT

Although augmented reality (AR) has gained much research attention in recent years, the term AR was given different meanings by varying researchers. In this article, we first provide an overview of definitions, taxonomies, and technologies of AR. We argue that viewing AR as a concept rather than a type of technology would be more productive for educators, researchers, and designers. Then we identify certain features and affordances of AR systems and applications. Yet, these compelling features may not be unique to AR applications and can be found in other technological systems or learning environments (e.g., ubiquitous and mobile learning environments). The instructional approach adopted by an AR system and the alignment among technology design, instructional approach, and learning experiences may be more important. Thus, we classify three categories of instructional approaches that emphasize the "roles," "tasks," and "locations," and discuss what and how different categories of AR approaches may help students learn. While AR offers new learning opportunities, it also creates new challenges for educators. We outline technological, pedagogical, learning issues related to the implementation of AR in education. For example, students in AR environments may be cognitively overloaded by the large amount of information they encounter, the multiple technological devices they are required to use, and the complex tasks they have to complete. This article provides possible solutions for some of the challenges and suggests topics and issues for future research.

1. Introduction

Bridging virtual and real worlds, augmented reality (AR) creates a reality that is enhanced and augmented (Bronack, 2011; Klopfer & Squire, 2008). New possibilities for teaching and learning provided by AR have been increasingly recognized by educational researchers. The coexistence of virtual objects and real environments allows learners to visualize complex spatial relationships and abstract concepts (Arvanitis et al., 2007), experience phenomena that is not possible in the real world (Klopfer & Squire, 2008), interact with two- and three-dimensional synthetic objects in the mixed reality (Kerawalla, Luckin, Seljeflot, & Woolard, 2006), and develop important practices and literacies that cannot be developed and enacted in other technology-enhanced learning environments (Squire & Jan, 2007; Squire & Klopfer, 2007). These educational benefits have made AR one of the key emerging technologies for education over the next five years (Johnson, Levine, Smith, & Haywood, 2010a, 2010b; Martin et al., 2011).

Although AR has garnered much research attention in recent years, the term AR was given different meanings by researchers. Additionally, AR could be created by utilizing and connecting various innovative technologies (e.g., mobile devices, wearable computers, and immersion technologies). However, like many innovations, the educational values of AR are not solely based on the use of technologies but closely related to how AR is designed, implemented, and integrated into formal and informal learning settings. To provide insights into opportunities offered by AR, therefore, the purpose of this article is to present current status, opportunities, and challenges of AR in education.

To achieve the purpose of this article, we sought empirical studies and theoretical papers that addressed questions of how AR could be designed for educational purposes and how AR could be incorporated into educational settings. Articles and book chapters published from

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January 2000 to October 2012 in the database of Educational Resources Information Center (ERIC), Social Science Citation Index (SSCI) journals were included in our literature search. We chose keywords including: augmented reality, mixed reality, and education and obtained over 70 citations. We also searched for conference papers from the IEEE database, particularly those published in International Symposium on Mixed and Augmented Reality (ISMAR), for relevant papers. After the searches, we selected only those that focused on AR and related educational issues. This left us with a total of 54 citations. We then read these articles and chapters, discussed major findings, generated guiding questions for in-depth reading, and took notes on how the questions were answered in the papers. The guiding questions included: How does the paper define augmented reality? What are the functions and affordances of AR in education identified in the paper? Is there any framework, theory, or principle guiding the design of AR in the paper? How is AR integrated into learning or teaching (e.g., any associated learning or teaching activities)? What learning outcomes are promoted by AR? Several temporary themes emerged from our notes. After another round of reading and discussion, we summarized and analyzed the statements and arguments in the papers to support the themes and to accomplish our purpose.

In the following sections, we start with an overview of definitions, taxonomies, and technologies of AR. We argue that viewing AR as a concept rather than a type of technology would be more fruitful for educators, researchers, and designers. Then we identify features and affordances of AR systems and applications. Yet, these compelling features may not be unique to AR applications and can be found in other technological systems or learning environments (e.g., ubiquitous and mobile learning environments) with similar technologies. The alignment between technology design, instructional approach, and learning experiences may be more important when AR is implemented in classrooms. Thus, we propose three major categories of instructional approaches that have been employed in AR learning environments and discuss what and how AR helps students learn. While AR offers new learning opportunities, it brings challenges as well. We outline technological, pedagogical, and learning issues related to the implementation of AR in education and discuss possible solutions for some of the issues. Finally, based on our analyses and discussions of research in AR, directions for future research are suggested.

2. Definitions, taxonomies and technologies

2.1. Definitions of AR

Researchers in computer sciences and educational technology have defined AR diversely. Milgram, Takemura, Utsumi, and Kishino (1994) defined "augmented reality" by two approaches: a broad approach and a restricted approach. In the broad sense, AR refers to "augmenting natural feedback to the operator with simulated cues" (p. 283). On the other hand, the restricted approach emphasizes the technology aspect and is defining AR as "a form of virtual reality where the participant's head-mounted display is transparent, allowing a clear view of the real world" (p. 283). There were also researchers defining AR based on its features or characteristics. For example, as proposed by Azuma (1997), AR can be defined as a system that fulfills three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects.

Klopfer (2008) indicated that the term AR should not be defined restrictedly. This term could be applied to any technology that blends real and virtual information in a meaningful way. According to Klopfer and Squire (2008), AR could be broadly defined as "a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information" (p. 205). In this situation, AR could provide users technology-mediated immersive experiences in which real and virtual worlds are blended (Klopfer & Sheldon, 2010) and users' interactions and engagement are augmented (Dunleavy, Dede, & Mitchell, 2009).

For educators and designers, defining AR in a broad sense would be more productive because such a definition suggests that AR could be created and implemented by varied technologies, such as desktop computers, handheld devices, head-mounted displays and so on (Broll et al., 2008; Johnson et al., 2010b; Liu, 2009). That is, the notion of AR is not limited to any type of technology and could be reconsidered from a broad view nowadays. AR exploits the affordances of the real world by providing additional and contextual information that augments learners' experience of reality (Squire & Klopfer, 2007). AR might be based on and accompany with technology, but it should be conceptualized beyond technology only.

2.2. Taxonomies of AR

As being defined as a situation, AR signifies a variation of virtual reality, and plays a supplemental role rather than a replacement of reality (Azuma, 1997; Martin-Gutierrez et al., 2010). To describe to what extent reality is supplemented or augmented, previous research has been developed several taxonomies of AR. Milgram et al. (1994) proposed a so-called Reality–Virtuality continuum, ranging from a completely real environment to a completely virtual one. Within this continuum, mixed reality can be defined as a situation where real world and virtual world objects are presented together. Moreover, mixed reality consists of two main ideas: augmented reality and augmented virtuality (AV). According to Milgram et al., AR is a combination of the real and the virtual and contains more real than virtual, whereas AV refers to adding elements of reality to a virtual environment and includes more virtual information. For example, virtual objects could be added to a real environment in AR, and a real object could be projected into a virtual environment in AV. Their differentiation might rely on whether reality or virtuality is being enhanced (Liu, Cheok, Mei-Ling, & Theng, 2007). Although the immersive learning environment, where virtual and real objects coexist in a seamless way, is advocated, the differentiations between AV and AR still need to be noticed. AR, therefore, can be regarded as mixed reality, which perhaps contains more real than virtual materials and information.

In addressing the issue of distinction between AV and AR, Klopfer (2008) further used a spectrum to emphasize the weight of the augmentation provided in AR. How much virtual information provided to the users determines the weight. A lightly augmented reality refers to a situation in which users utilize a large amount of information and physical materials from the real world, and have access to relatively little virtual information. On the other hand, a heavily augmented reality contains frequently accessible virtual information. This spectrum suggests a possible role of technology in augmented reality. In a heavily augmented world, most immersive technologies, such as head-mounted displays, are implemented. For lightly augmented reality, users mainly interact with physical materials and objects, and occasionally manipulate and access the virtual information. The mixed reality created by location-awareness mobile devices is one typical example (Klopfer & Yoon, 2005).