The Application of Augmented Reality in Online Education: A Review of Studies Published in Selected Journals from 2003 to 2012

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ABSTRACT
In this paper, the authors reviewed the empirical augmented reality (AR) and online education studies, and those focused on designing or development of AR to help students learn, published in SSCI, SCI-EXPANDED, and A&HCI journals from 2003 to 2012. The authors in this study found that the number of AR and online education studies has significantly increased since 2009. Based on this review, it is found that contributors from Spain, Romania, Taiwan, and Germany had the most publications on AR and online education during 2003 to 2012. Moreover, the analysis of these selected papers reveals that most empirical AR and online education studies were conducted at universities, as well as in computer science courses. Furthermore, the quantitative research method was used more in the reviewed papers. The findings and analysis from this review may provide potential directions and insights for future AR and online education research.

Keywords: Augmented Reality, E-Learning, Online Education, Research Trends, Students

INTRODUCTION
The beginnings of augmented reality (AR) date back to Sutherland’s (1968) work in the 1960s, which used a see-through head-mounted display (HMD) to present 3D graphics (Azuma, Bailot, Behringer, Feiner, Julier, & MacIntyre, 2001). AR is defined as the technology of including virtual objects in real scenes through enabling the addition of missing information into real life (El Sayed, Zayed & Sharawy, 2011). It is a variation of Virtual Environments (VE), or Virtual Reality, as it is more commonly called (Azuma, 1997). AR provides huge opportunities...
for online education, especially in disciplines that place emphasis on practical training and are unsuited to completely non-classroom training (Andújar, Mejías, & Márquez, 2011). It is revealed that insufficient communication and ineffective course facilitation result in the unfulfilled promises of online learning, and students may consequently feel unmotivated (Blignaut & Nagel, 2009). The application of AR could help students to visualize different learning objects, deal with the information and interact with theories in an innovative, interactive, and effective approach (El Sayed, Zayed & Sharawy, 2011).

This application of AR in education enables the learners to read a book through a display and see, not only the pages of the book itself, but also virtual content associated with related pages. These techniques are used in social science teaching. The Massachusetts Institute of Technology (MIT) created AR simulation games that integrate PDA-provided real with virtual content (Andújar, Mejías, & Márquez, 2011). The application and development of AR could solve many problems in teaching. For example, it is indicated that AR brings new opportunities for teaching and education, as students experience various difficulties with learning and understanding subjects such as Chemistry (Iordache, Pribeanu, & Balog, 2012). In Medina, Chen, and Weghorst’ study (2007), it is reported that AR could facilitate students’ biochemistry learning, while students also enjoy the process of interacting with AR.

In recent years, AR has also been applied in the online education field. For example, Lee, Choi, and Park, (2009) propose an interactive e-learning system using AR and recognition algorithms, and provide learners with realistic audio-visual contents according to the recognition results. Moreover, it is reported that student learning performance is significantly enhanced by using an AR library instruction system (Chen & Tsai, 2012). It is believed that AR should be an important technology and approach to facilitate students’ learning in online learning environments. This study aims to review AR studies published in influential international journals from 2003 to 2012. The research questions of the current study are:

1. What is the status of AR studies published in selected journals from 2003 to 2012? Is the amount of AR studies increasing or decreasing?
2. Which sample groups were selected in AR studies published in selected journals from 2003 to 2012?
3. What subject domains were involved in AR studies published in selected journals from 2003 to 2012?
4. What research methods were applied in AR studies published in selected journals from 2003 to 2012?
5. What regions were major contributors in AR studies published in selected journals from 2003 to 2012?

METHOD

In order to conduct a systematic review of AR and online learning research, the authors used the Social Science Citation Index (SSCI), Science Citation Index Expanded (SCI-EXPANDED), and Arts & Humanities Citation Index (A&HCI) database to search for and collect the literature for review in this study. In addition, the authors set the time period from 2003 to 2012, and the keywords for the topical search in SSCI, SCI-EXPANDED, and A&HCI publications were “augmented reality”, “online education”, and “e-learning”. Moreover, the authors only collected and reviewed journal papers. Based on the topics and the principle of journals only, 19 papers (excluding a duplicate) were selected for review in this study.

To confirm that the selected papers were related to AR research in online education, the authors in this study manually and systemati-
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