A review of using Augmented Reality in Education from 2011 to 2016

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Abstract. In recent years, there has been an increasing interest in applying Augmented Reality (AR) to create unique educational settings. This paper reports a review of literature on augmented reality in educational settings considering the factors include the uses, advantages, features, and effectiveness of augmented reality in educational settings. In total, 55 studies published between 2011 and 2016 in Social Sciences Citation Index database 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, literature review, trends of Augmented Reality

1 Introduction

In the past two decades, the applications of augmented reality (AR) have been increasingly receiving attention. AR was first used in the 1990s, when applications were related to the training of pilots[1]. According to the 2011 Horizon Report, AR, with its layering of information over 3D space, creates new experiences of the world, and suggested that AR should be adopted in the next 2–3 years to provide new opportunities for teaching, learning, research, or creative inquiry. AR takes advantage of virtual objects or information overlaying physical objects or environments, resulting in a mixed reality in which virtual objects and real environments coexist in a meaningful way to augment learning experiences [2][3]. There is a large volume of published studies that report advantages, limitations, effectiveness challenges, etc. of AR in education. However, since AR is an emergent technology, it is important to get an overview of the advances and real impact of its use in educational settings, describing how AR has been used for generate more student-center learning scenarios. In this study, we review empirical

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studies that have employed the augmented reality technology in education. The analysis may help to construct a framework revealing the current state of the augmented reality technology in education.

2 Method

The literature source for this review was the Social Sciences Citation Index (SSCI) database, one of the highly recognized databases indexing core journals in the social sciences. The time span was set from 2011 to 2016, and the document type was limited to journal articles in an attempt to review studies of potentially more consistent quality. We used the keyword "Augmented Reality" for searches, and 55 papers were identified as the research sample pool of this review. Content analysis[4] was applied in order to extract the information of each paper. We analyzed and classified sample groups, major contributing countries, subject domains, type of AR, the research methods involved (qualitative, quantitative, mixed, system design and review paper) and effectiveness of AR in the 55 papers in this study. Two of the authors of the paper manually coded the studies separately according to their characteristics and classified them according to the categories and sub-categories defined.

3 Results and discussion

3.1 Number of papers published

Among the 55 AR studies, only 8 were published in 2011 and 2012, while 12 of them were published in 2013, and 18 were published in 2014. According to these results, AR in education is an emerging topic and the research on AR in education is in the initial phase[5] [6]. In 2013, Bujak[7] point out: "Augmented reality (AR) is just starting to scratch the surface in educational applications."

3.2 Number of Journal Publications in this review

In total 55 studies were analyzed from the 10 journals, include that Computers & Education (17), Computers in Human Behavior(11), Journal of Science Education and Technology (6), British Journal Of Educational Technology(5), Educational Technology & Society(4), Interactive Learning Environments(4), IEEE Transactions on Learning Technologies(3), International Journal of Computer-Supported Collaborative Learning(3), Journal of Computer Assisted Learning(1), and Journal of Educational Computing Research(1).

3.3 Major contributing countries in this review

The Taiwanese authors contributed the most publications (22) followed by Spanish authors (12), US authors (9), Chinese authors (2), Switzerland authors (2) and Turkey authors (2).

3.4 Sample groups in this review

Regarding the "Target group," this category refers to the level of education of participants in the experiments in which the study of AR in education was carried out. First, it is worth noticing that AR has been mostly applied in higher education settings (Bachelor, 23.64%) and compulsory education (primary, 16.36%; Junior school, 18.18%). Most of the studies reviewed in these target groups applied AR for motivating the students, explaining topics, adding information and other purposes that are discussed later. It seems possible that AR has been applied in settings with this target group in order to improve the educational experience of the students and motivate and engage them by taking advantage of the features of this technology. In the studies reviewed there were few AR applications in the field "Early childhood education" (5%).

3.5 Research field in this review

It is indicated that 40.0% of the 55 papers report on studies in field of "Science", which is the most studied domain in the use of augmented reality by each field of education. This may be because AR has demonstrated to be effective when adopted in lab experiments[8], [9], [10], mathematics and geometry[7], [11], [12], geography and ecology[13], [14], [15], [16], scientific issues[17], [18], [19]. It can concluded that AR is effective for activities where students learn things that could not be seen in the real world or without a specialized device, and learning abstract or complex concepts. In addition, 16.36% of the AR studies focus on Social Science courses. Studies in this field focused on language learning[20], [21], [6], visual art and painting appreciation[22], [23]. AR has been widely used in Social Science due to the possibility of augment information and combining it with contextual information to provide new experiences. Also, those in the education field also explored and investigated the effects of AR in "Engineering, manufacturing and construction (14.55%)", "Health (7.27%)" and "Service (7.27%)."

3.6 Research methods and design in this review

As for the research type of in the selected AR studies in education papers from 2011 to 2016, it is shown that the most employed is experimental design and quasi-experimental design. The most frequently used of research methods is mixed methods (40.0%), followed by quantitative research methods (32.73%) and qualitative research methods (7.27%). In addition, some papers just focused on review of the literature and system design, which did not involve the methods mentioned previously. For "Data Collection methods", most of the studies applied

"Test" (47.27%), especially some studies of these adopted pre-test and post-test (29.09%). " Interviews" (30.91%), "Questionnaires" (29.09%), "video observation" (18.18%) and "surveys" (16.36%) as data collection methods. "Writing Essay" (1.82%) have used very little. Since one study can apply more than one data collection method this study counts for more than one category. In the aspects of participant, most of the studies used medium research samples "between 30 and 200" and some studies considered small research samples "30 or less than 30". In our review we find a few studies that used research samples greater than 200 participants. And the research time dimension is almost cross-sectional, only a few are longitudinal Study. In these 55 studies, the image-based AR is used more than the location-based AR, and AR of educational settings usually applied in classroom. However, it can adopted in museum[23], [11], library[24], and field trip[13], [25]. The treatment of AR in education is commonly smartphone and tablet. In Giard's[26] study, Oculus Rift glasses is mentioned, and we think it may become the important research object of AR in the future.

3.7 Effectiveness of using AR in this review

The major advantages of AR in these studies reported are learning gains and motivation. In these 55 papers, most of studies reported that AR in educational settings lead to better learning performance and promoting learning motivation, which because AR supply the authenticity graphical content and interaction. Also, deeper student engagement, improved perceived enjoyment, and positive attitudes of AR are reported as the effectiveness of using AR.

4 Trends and future vision

In the future, some recent studies have reported new research directions, for example, We suggested that larger sample sizes and extensive subject matters need to be concerned[15]; We recommend lengthening the research timeframe and mixing the teacher requirements with the developed van Hiele's level of geometric reasoning test, under the assumption that it will contribute to the acquisition of more comprehensive data[12]; Additional interactive strategies (e.g., games and role-playing) can be incorporated to enhance the first-hand experiences and interactions of users[27]; To enhance reality and magical sense for EMT, smart glasses can be used when playing toys[28].

View from these papers, we conclude that more studies need to be undertaken considering the difference of cognitive process and psychological immersion between AR and reality settings; the individual interaction, sense of identity, and adaptive application in augmented reality; AR classroom design and evaluation research; the teacher's role model in AR educational setting; designing and implicating learning resources of AR in k-12.

5 Conclusions

In this paper, we reviewed the empirical AR studies in educational settings published in SSCI-indexed journals from 2011 to 2016. The researchers in this study found that the number of AR studies in education has significantly increased since 2013. Authors from the Taiwan, Spain, and USA contributed most AR studies in education that were conducted during 2011 to 2016. In addition, the authors found that more and more empirical studies were carried out on Science, as well as on social science and Engineering. Furthermore, the quantitative research method was used more often than other methods in AR research in education in the past 5 years. Finally, we expect that the findings in this study could reveal the importance of the adoption of effective AR in education, and provide potential directions for future research.

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