Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 103 (2013) 657 – 664

Procedia
Social and Behavioral Sciences

13th International Educational Technology Conference

Mobile Augmented Reality: the potential for education

Danakorn Nincarean[a], Mohamad Bilal Ali[a]*, Noor Dayana Abdul Halim[a], Mohd Hishamuddin Abdul Rahman[a]

[a]*Department of Educational Sciences, Mathematics and Multimedia Creative, Faculty of Education, Universiti Teknologi Malaysia, UTM, Johor Bahru, 81310, Johor, Malaysia*

Abstract

The rapid evolution of technology has changed the face of education, especially when technology was combined with adequate pedagogical foundations. This combination has created new opportunities for improving the quality of teaching and learning experiences. Until recently, Augmented Reality (AR) is one of the latest technologies that offer a new way to educate. Due to the rising popularity of mobile devices globally, the widespread use of AR on mobile devices such as smartphones and tablets has become a growing phenomenon. Therefore, this paper reviews several literatures concerning the information about mobile augmented reality and exemplify the potentials for education.

Selection and peer-review under responsibility of The Association of Science, Education and Technology-TASET, Sakarya Universitesi, Turkey.

Keywords: Augmented reality; mobile augmented reality; education

1. Introduction

Basically, a traditional method of education was carried out through face-to-face instructions where the knowledge and learning activities were all arranged and conveyed by the teacher (de Freitas, Rebolledo, Liarokapis, Magoulas & Poulovassilis, 2010; Liu, 2010). In addition, the learning material were also based on static material such as papers (Chao & Chen, 2009; Huang, Wu & Chen, 2012; Taketa, Hayashi, Kato & Noshida, 2007) in which static materials do not show any information in a dynamic way such as motion or continuous movement (Craig & Grath, 2007; Kühl, Scheiter, Gerjets & Gemballa, 2011). Although sometimes these existing methods work effectively, however there is an increasing interest of educators and researchers in

* Corresponding author. Tel.: +067-5534440
E-mail address: mba@utm.my

Selection and peer-review under responsibility of The Association of Science, Education and Technology-TASET, Sakarya Universitesi, Turkey.
doi:10.1016/j.sbspro.2013.10.385

introducing more useful methods to improve the teaching and learning experiences. As technology becomes increasingly widespread in the past few years, the integration of technology has influenced and revolutionized the way we teach and learn.

The transformation of teaching and learning caused by technology has certainly provides an exciting opportunities to design learning environment that are realistic, authentic, engaging and extremely fun (Kirkley & Kirkley, 2004). Besides, researchers also found that technology have always held a great promise for increasing student engagement and level in understanding the learning content (Di Serio, Ibáñez, & Kloos, 2012; Kreijns, Acker, Vermeulen, & Buuren, 2013; Roca & Gagné, 2008) among the key elements that leads to better academic results. Therefore, there has been a considerable concern over the use of emergent technology to support learning process. Indeed, there are many different technologies that have been integrated in the educational arena, among others such as the use of computer, multimedia, internet, e-learning, social web, simulations and more recently mobile devices and immersive environments such as games, virtual worlds and augmented reality (Dror, 2008; Martin, Diaz, Sancristobal, Gil, Castro & Peire, 2011).

As mentioned by the Emerging Technology Initiatives of New Media Consortium (NMC) in the most recent Horizon Reports (NMC 2010, 2011 and 2012), Augmented Reality (AR) is one of the emerging technologies that might have potential and impact on learning and education. Besides that, the emergence and widespread ownership of mobile devices has lead to an increased interest to integrate the benefits of mobile learning and AR applications. The advancements of AR is now a growing rapidly on mobile device, reflected by the increase in handheld computing usage in recent years across the world and resulted in creating a subset of AR: mobile AR. Due to the fact that educational research concerning mobile AR learning system is in its infancy and in an embryonic stage (Martin et al., 2011), this article is intended to provide an overview on information about Mobile Augmented Reality (MAR) and its potential used in education.

2. Understanding Augmented Reality

2.1 Definition and Taxonomy

Educators are always looking for a new way to teach students and Johnson, Smith, Willis, Levine and Haywood (2011) argue that AR is one of the new technologies which considered as having potential for pedagogical applications. Although in recent years AR is becoming increasingly widespread and has garnered much attention, the term AR has been defined in different meanings by researchers. Early on, as mentioned by Milgram, Takemura, Utsumi and Kishino (1994), they defined "augmented reality" into two approaches: broad and restricted approach. In term of broad sense, AR was defines as "augmenting natural feedback to the operator with simulated cues" while restricted approach highlight and defined AR as "a form of virtual reality where the participant's head-mounted display is transparent, allowing a clear view of the real world". Researcher such as Azuma (1997) tended to present a definition of AR based on a system that fulfills three basic criteria: (1) combination of real and virtual, (2) interactive in real time, and (3) 3D registration of virtual and real objects. A similar definition is proposed by other researchers (Höllerer & Feiner, 2004; Kaufmann, 2003; Zhou, Duh & Billinghurst, 2008), who define AR based on its features which the real and computer-generated information are combined in a physical world, interactively in real time, and display virtual object intrinsically align to real world orientation.

Besides that, Klopfer and Squire (2008) give an even broader perspective on AR, stating it as a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information. A less inclusive definition is provided by Martin et al., (2011) who indicated that the term AR is a system that is basically merging information such as images with video streamed from a webcam while as El Sayed, Zayed, and Sharawy (2011) states in their recent article, they describe AR as technology of adding virtual objects to real scenes through enabling the addition of missing information in real life. Even though a number of

available AR experiences and applications have been increasingly receiving attention and continues to grow at an accelerating rate however, a consistent definition of AR does not exist (Mehler Bicher, Reiß & Steiger, 2011). Therefore in order to define AR, the commonly accepted definition by relevant studies always refers to a helpful visualization called "Milgram Reality-Virtuality Continuum" (see Fig 1.) by Milgram et al. (1994).

Milgram Reality-Virtuality Continuum is a scale ranging from a completely real environment (reality) which we can observed when viewing a real world to a completely virtual environment (virtuality). Within this continuum the space between real environment and virtual environment is called mixed reality (MR). It is straightforward to define MR as an environment where the real world and virtual world are blending together. As we can see from Fig. 1, MR consists of two main elements: one side is augmented reality and the other side is augmented virtuality (AV). AR is a combination of real and virtual object and contains a small amount of virtual data while AV is a concept where elements of reality being added to a virtual environment and contains more digital data.

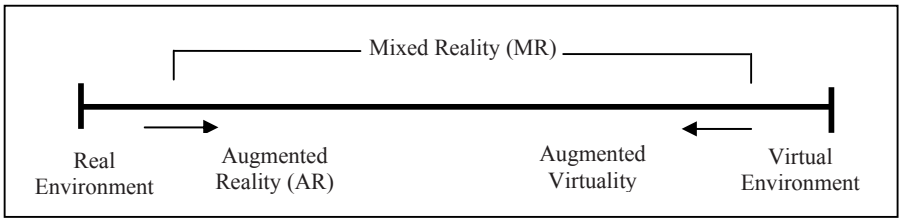

Fig. 1. Milgram Reality-Virtuality Continuum

2.2 Affordances of AR

Although AR is a new technology but the affordances and benefits to support learning were worth to mentioned and discussed. According Chien, Chen and Jeng (2010), AR has an ability to encourage kinaesthetic learning. Furthermore, since AR use 3D registration of virtual and real objects, it could allow user to view the learning content in 3D perspectives. This affordance can help students who usually encounter difficulties to visualize the phenomena that are not possible to view in real world or complex concept. AR can support students by inspecting the 3D object or class materials from a variety of different perspectives or angles to enhance their understanding (Chen, Chi, Hung, & Kang, 2011). Squire and Klopfer (2007) also suggested that AR in a form of games can stimulate student' prior knowledge and increase the student level of engagement in academic activities. Moreover, AR also can enhance collaboration between students-students and also student-instructors (Billinghurst, 2002) as a result the transfer of learning can be maximized (Kaufmann & Schmalstieg, 2003). Additionally, in Di Serio et al., (2012) study, AR technology also has showed a positive impact on the motivation of middle-school students. It's proved that AR environments could boost students' motivation and interest, which in turn could help them to develop a better understanding in learning contents.

3. Mobile Augmented Reality

3.1 Introduction

In the present day, in conjunction with widespread use and emergence of mobile devices such as smartphones and tablets from a decade earlier provides individual people with communication, work, entertainment, internet access and even learning and instruction. A number of studies have found that mobile devices play a major role in education nowadays and sees the impact and advantages of these device in regards to the potential for pedagogical perspectives (Chen, Kao, & Sheu, 2003; Denk, Weber, & Belfin, 2007; FitzGerald, Adams,

Ferguson, Gaved, Mor & Thomas, 2012; Hwang, Yang, Tsai, & Yang, 2009; Uzunboylu, Cavus, & Ercag, 2009; Zurita & Nussbaum, 2004). Interestingly, because of the development and rapid increase in mobile phone usage have made mobile augmented reality (MAR) possible (Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre, 2001; Papagiannakis, Singh & Thalmann, 2008) and beginning to expand rapidly. Therefore, in the next section, we want to introduce and discuss about some of the exemplary uses of MAR in education.

3.2 Mobile Augmented Reality application in Education

In 2006, Wagner, Schmalstieg, and Billinghurst developed an educational game based collaborative handheld called Virtuoso. Besides the AR version, the game was also implemented in Macromedia Flash on a desktop PC and as a paper game without any technology. The aim of this game is to sort a collection of artworks according to their date of creation along a timeline with 3 different conditions: a paper, a PC and a PDA. The results showed that although the players were tested with 3 different game conditions, there was no significant differences in educational outcomes were found. Interestingly, the players have paid more attention toward the conditions is in how space was used which players preferred paper and PDA version because of it allow them to collaborate more effectively over than PC version. Besides that, they also chose the PDA interface as the most enjoyable among the three conditions (Wagner et al., 2006)

The CONNECT is a project that use MAR technology based system developed to support students learning science both in the formal and informal learning environment. The CONNECT concept required student to wear a head mounted display (HMD) and related computer-mediated learning platform in order to visualize and interact physically and intellectually with learning environment that deal with instructional materials, through "hands on" experimentation and "minds on" reflection. In addition, student can also perform experiments that are not possible in school. To evaluate the usability and effectiveness of the CONNECT project, a study have been conducted with learners with physical disabilities (Arvanitis, Petrou, Knight, Savas, Sotiriou, Gargalakos, et al., 2007). The interesting finding from the study was that comparing the tests of the disable students with able-bodied students showed that they had almost the same results and this finding provides some support for the conceptual premise that the CONNECT project have the potential to improve the landscape of education especially for disabilities students

Schmalstieg and Wagner (2007) introduced Studierstube as a framework for the development of handheld Augmented Reality. Two mobile AR games were developed: "medien.welten" and "Expedition Schatzsuche". In medien.welten case study was designed for a target group of high school students aged 12-15. For this game, a group of players (two or three students) receiving one handheld that show a map of the exhibition and specify the current position of the players and lists of solved and remaining tasks. In Expedition Schatzsuche game, each of the subjects had been given their own handheld to play the game. The game concept was to answer the quest composed of puzzles and other tasks related to the exhibits. The evaluation was conducted through interview, observation, and logging data in a case study with 12 students, all at age 12 years old who used handheld devices to discover historical artifacts. The results indicate that the students were very motivated and highly satisfactory (Schmalstieg & Wagner, 2007)

Squire and Klopfer (2007) collaborate with environmental science faculty at Massachusetts Institute of Technology by developing an augmented reality simulations called Environmental Detectives. This game required student to play the role as an environmental engineers and to give students experiences in conducting the environmental investigation in real world. Each pair of students can see their location on a map since there were given a mobile device equipped with GPS. After they used the application, its showed that Environmental Detectives can assists students to understand the socially situated nature of scientific practice.

In 2009, Dunleavy, Dede and Mitchell designed Alien Contact!, a MAR game that focus to teach math, language arts, and scientific literacy skills to middle and high school students. Alien Contact! was designed based on Massachusetts state standards and nurtures multiple higher-order thinking skills. In Alien Contact! as the

students move around to their spot fields for example, a map on their handheld will displays virtual objects and people that exist in AR world superimposed on real space. The concept of the game is based on the scenario that aliens have landed on earth and working in a teams (four students per team) which consist of four roles: Chemist, Cryptologist, Computer Hacker, and FBI Agent. The students can interview virtual characters, collect digital items and solve science, math and language problems to answer the question and determine why the aliens have landed on earth. The objectives of this research are to determine how teachers and students feel toward teaching and learning within AR simulation environment and how they used the application. The results obtained from the study documented high student engagement across the three case study sites (Dunleavy et al., 2009)

In 2009, Ardito, Buono, Costabile, Lanzilotti and Piccinno presented a MAR game called Explore! with the aim to support during a visit and explorations of middle school students to archaeological sites in Italy. This game was played by groups of 3-5 middle school students in which each group was given 2 cell phones and the site's map on a paper. The concept of the game required students to explore important places in the sites supporting by some hints given on the cell phone by the game application. They can also discover the 3D reconstruction of how the places may have looked by using cell phone. The evaluation of field study using Explore! involved for a total of 42 students where19 students played the paper-based version of the game and another 23 students, played the mobile version. From the result of the study, its show those students enjoyed playing the game with Explore! but in term of learning, there are no significant differences were found between the two versions.

In 2009, Huizenga, Admiraal, Akkerman, and Dam have conducted a research by integrating the MAR games called Frequency 1550. This hybrid reality game was developed by The Waag Society to facilitate children to gain historical knowledge about Medieval Amsterdam. The research seeks to address student engagement in the game, historical knowledge, and motivation for History in general and the topic of the Middle Ages in particular. In order to answer their research questions, the children in 10 of the classes played the mobile history game whereas the children in the other 10 classes received a regular, project-based lesson series. For children who played the mobile history game, the game procedure start by forming a group of four or five children and divided into 2 teams: a city team (CT) consisting of two or three pupils who walk through the city and a headquarter team (HQT) consisting of the other two or three pupils who operate from behind the computer in the main building. They switch places after lunch so that each child has participated in both the CT and HQT at the end of the day. From the results of the study, they found that children who played the game to be engaged and to gain significantly more knowledge than those who received regular project-based instruction. For motivation aspect, no significant differences were found between the two groups.

Juan, Alem and Cano (2011) presented mobile AR game, ARGreenet that aim to increase people awareness of how important of recycling is and how to do it. In their study, they compared the ARGreenet with the basic mobile phone game for recycling topic. The participants involved in this study involved a total of 38 children where all of them experienced both games but in a different order. The evaluation aspects consist of the knowledge of recycling that the children perceived, the level of engagement, fun and easy to use, perceived willingness to change behaviour and comparison toward AR and non AR games. Based on the results of the study, there is no significant difference between the two games; however 69.4% of the children preferred the ARGreenet game, which they perceived it as easy to use and more engaging and fun than basic mobile phone game. In addition, the findings also show that the games had a positive influence on their intentions to change behaviours (Juan et al., 2011)

In a recent article, Tang and Ou (2012) carried out an experiment using AR and mobile technologies as an assistant tool for learning butterfly ecology. By integrating AR in this project, students can breed their own virtual caterpillars on host plants using the programs on their smart phones, and become familiar with butterfly's life cycle by observing their growth. The campus AR butterfly ecological learning system was designed based on the learning unit of "Butterfly's Life Cycle" in nature science for the fourth-grade students in elementary schools. After using the AR system, the participants were randomly selected and assigned to experimental group and the

control group. The statistical tests indicate that the learning effectiveness of experimental group was better than the control group. Therefore, it was shown that by using the AR butterfly ecological learning system can effectively help students enhance their learning.

Santoso, Yan and Gook (2012) from Institute of Ambient Intelligence (IAI) work together with Sungsan Elementary School (SES) by developing a Digital Edutainment Content based on Tangram toy as an existed edutainment media. The tangram toy edutainment content was used because of its value that can enhance student spatial cognitive ability. The application was developed using ipad version where the built-in camera will be activated automatically once the user chooses an AR session. After that, user needs to point the camera to the colourful marker on the book then the software will start looking and track the marker and displays the 3D virtual object of each marker.

Since history maybe considered as one of the hardest subjects for students, Martín, Díaz, Cáceres, Gago and Gibert (2012) presented an educational application called EnredaMadrid to cope with this complexity. The objective of EnredaMadrid is to teach the history of the city in the 17th century to students in the activity through previous online training and a later physical technological gymkhana. This application was built using mobile device based on geolocalisation and AR technology. The evaluation session toward the technology used in EnredaMadrid was carried out through questionnaire and the results indicate that AR is the most positive element in EnredaMadrid. Moreover, students stated that AR definitely contributes to make learning more fun and motivating and they believe that AR is the most appropriate tool to learn the history of the city (Martín et al, 2012).

Table 1. A summary of selected studies on MAR

Researcher	Application	Participant	Topic
Wagner et al. (2006)	Virtuoso	48 participants (aged 20- 43)	Art
Arvanitis et al (2007)	CONNECT	5 disabilities students (aged 15-18)	Science
Schmalstieg and Wagner (2007)	medien.welten	19 students (aged 12-15)	Historical
	Expedition Schatzsuche	12 students (all at age 12)	Historical
Squire and Klopfer (2007)	Environmental Detectives	two phases : university student (58 students) high school (18 students)	Environmental
Dunleavy et al. (2009)	Alien Contact!	80 middle and high school students	Math, language arts, and literacy skills
Ardito et al. (2009)	Explore!	42 students (aged11- 13)	Historical
Huizenga et al. (2009)	Frequency 1550	458 children (aged12-16)	Historical
Juan et al. (2011)	ARGreenet	38 students (aged 8-13)	Recycling
Tang and Ou (2012	Butterfly Ecological Learning System	60 students (elementary school)	Science
Martín et al. (2012)	EnredaMadrid	65 people (aged over 36)	Historical

4.0 Conclusion

As information technologies transform, educators have always looked to adopt new technologies into their classroom to enhance student learning experience. AR is one the growing technologies that have a great

pedagogical potential and have been increasing recognized by educational researchers. With capabilities of merging virtual and real worlds together have give birth to new possibilities in improving the quality of teaching and learning activity. The effectiveness of AR can be further extended when it combine with other type of technologies such as mobile device. When AR is connecting to innovative technology such as mobile device, the term Mobile Augmented Reality (MAR) arises.

As has been presented earlier, MAR learning based systems are more focus mostly on games or simulation and with the ability of mobile devices which has the features and properties such as portability, social interactivity, connectivity, context sensitivity and individuality (Huizenga et al., 2009) have make a learning experience more meaningful. Based on the previous studies that has been discussed previously, most of the participants had never experienced an AR and MAR, however overall participants felt motivated, enjoyed and the research show a positive educational effects on participants that leads to students to achieve higher levels of engagement in learning performance.

In conclusion, although most of previous studies showed a positive impact and encouraging results, it is advisable to focus also on pedagogical and learning theory when implementing and developing the AR application since the educational value of AR are not solely based on its features. Expect that there will be many more research on AR and MAR in the future because this technology has a vast potential implications and benefits especially in learning environment.

References

Ardito, C., Buono, P., Costabile, M. F., Lanzilotti, R., & Piccinno, A. (2009.). Enabling interactive exploration of cultural heritage : an experience of designing systems for mobile devices, *Knowledge Technology And Policy. 22*, 79-86.

Arvanitis, T. N., Petrou, A., Knight, J. F., Savas, S., Sotiriou, S., Gargalakos, M., & Gialouri, E. (2007). Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities. *Personal and Ubiquitous Computing, 13*(3), 243-250.

Azuma, R. T. (1997). A survey of augmented reality. Presence-Teleoperators and Virtual Environments, 6 (4), 355 – 385.

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S. and MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications 21*(6): 34-47

Billinghurst, M. (2002). Augmented Reality in Education. New Horizons for Learning, December 2002. Retrieved Feb 12, 2013 from http://www.newhorizons.org/ strate -gies/technology/billinghurst.htm

Chao, P. Y., & Chen, G. D. (2009). Augmenting paper-based learning with mobile phones. *Interacting with Computers, 21*,173–185

Chen, Y.-C., Chi, H.-L., Hung, W.-H., & Kang, S.-C. (2011). Use of tangible and augmented reality models in engineering graphics courses. *Journal of Professional Issues in Engineering Education and Practice, 137* (4), 267 – 276

Chen, Y. S., Kao, T. C., & Sheu, J. P. (2003). A mobile learning system for scaffolding bird watching learning. *Journal of Computer Assisted Learning, 19* (3), 347 – 359.

Chien, C. -Huan, Chen, C.- Hsu, & Jeng, T.- Sheng. (2010). An interactive augmented reality system for learning anatomy structure. *Computer, I. IAENG*

Craig, A., & Mc Grath R (2007). Augmenting Science Texts with Inexpensive Interactive 3D Illustrations.

Denk , M., Weber, M., & Belfin, R. (2007). Mobile learning-challenges and potentials. *International Journal of Mobile Learning and Organisation, 1* (2), 122 – 139.

Di Serio, Á., Ibáñez, M. B., & Kloos, C. D. (2012). Impact of an augmented reality system on students' motivation for a visual art course. *Computers & Education*, 1-11. Elsevier Ltd.

Dror, I. (2008). Technology enhanced learning: the good, the bad, and the ugly. *Pragmatics Cognition, 2*(2), 215 – 223, John Benjamins Publishing Company

de Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., & Poulovassilis, A. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology*, *41(1)*, 69–85.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology, 18*. 7-22.

El Sayed, N. A . M., Zayed, H. H., & Sharawy, M . I. (2011). ARSC: augmented reality student card- an augmented reality solution for the education field. *Computers & Education, 56*(4), 1045– 1061

FitzGerald, Elizabeth; Adams, Anne; Ferguson, Rebecca; Gaved, Mark; Mor, Yishay and Thomas, Rhodri (2012). Augmented reality and mobile learning: the state of the art. In: *11th World Conference on Mobile and Contextual Learning* (mLearn 2012), Helsinki, Finland.

Höllerer TH, Feiner SK (2004) Mobile augmented reality. In: Karimi HA, Hammad A (eds) *Telegeoinformatics: location-based computing and services*. CRC Press, (pp. 392–421)

Huang, H.-W., Wu, C.-W., & Chen, N.-S. (2012). The effectiveness of using procedural scaffoldings in a paper-plus-smartphone collaborative learning context. *Computers & Education*, *59*(2), 250-259. Elsevier Ltd.

Huizenga, J., Admiraal, W., Akkerman, S., & Dam, G. T. (2009). Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game. *Journal of Computer Assisted Learning, 25*(4), 332-344

Hwang, G.-J., Yang, T.-C., Tsai, C.-C., & Yang, S. J. H. (2009). A context-aware ubiquitous learning environment for conducting complex science experiments. *Computers & Education, 53*(2), 402 – 413

Johnson, L., Adams, S., and Cummins, M. (2012). NMC Horizon Report: 2012 K-12 Edition. Austin, Texas: The New Media Consortium

Johnson L, Smith R, Willis H, Levine A, Haywood K (2011) The 2011 horizon report. The New Media Consortium, Austin

Juan, M. C., Furió, D., Alem, L., Ashworth, P., and Cano, J. (2011). ARGreenet and Basic-Greenet: Two mobile games for learning how to recycle. *In Proceedings of the 19th International Conference on Computer Graphics, Visualization and Computer Vision'2011*, 25–32.

Kaufmann H (2003) Collaborative augmented reality in education. In *Proceedings from Imagina* 2003, pp 1–4

Kaufmann, H., & Schmalstieg, D. (20 03). Mathematics and geometry education with collaborative augmented reality. *Computers & Graphics, 27*(3)

Kirkley, B. S. E., & Kirkley, J. R. (2004). Creating Next Generation Blended Learning Environments Using Mixed Reality , Video Games and Simulations, *TechTrends 49*(3). 42-53

Klopfer, E., & Squire, K. (2008). Environmental Detectives—the development of an augmented reality platform for environmental simulations. *Educational Technology Rese arch and Development, 56* (2), 203-228

Kreijns, K., Van Acker, F., Vermeulen, M., & van Buuren, H. (2013). What stimulates teachers to integrate ICT in their pedagogical practices? The use of digital learning materials in education. *Computers In Human Behavior, 29*(1), 217-225

Kühl, T., Scheiter, K., Gerjets, P., & Gemballa, S. (2011). Can differences in learning strategies explain the benefits of learning from static and dynamic visualizations? *Computers & Education*, *56*(1), 176-187. Elsevier Ltd.

Liu, C.-hong (2010). The comparison of learning effectiveness between traditional face-to-face learning and e-learning among goal-oriented users. *6th International Conference on Digital Content, Multimedia Technology and its Applications (IDC),* 255,260

Martín, S., Díaz, G., Cáceres, M., Gago, D. & Gibert, M. (2012). A Mobile Augmented Reality Gymkhana For Improving Technological Skills And History Learning: Outcomes And Some Determining Factors. In T. Bastiaens & G. Marks (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2012*. 260-265

Martin, S., Diaz, G., Sancristobal, E., Gil, R., Castro, M., & Peire, J. (2011). New technology trends in education: Seven years of forecasts and convergence. *Computers & Education*, *57*(3), 1893-1906. Elsevier Ltd.

Mehler-Bicher A, Reiß M, Steiger L (2011) Augmented reality: Theorie und Praxis. Oldenbourg, München

Milgram P, Takemura H, Utsumi A, Kishino F (1994) Augmented reality: a class of displays on the reality-virtuality continuum. *SPIE proceedings: telemanipulator and telepresence technologies*, Boston, MA

New Media Consortium (NMC) (2010) The 2010 horizontal report. http://wp.nmc.org/horizon2010/

New Media Consortium (NMC) (2011) The 2011 horizontal report. http://wp.nmc.org/horizon2011/

New Media Consortium (NMC) (2011) The 2012 horizontal report. http://www.nmc.org/publications/horizon-report-2012-higher-ed-edition

Papagiannakis, G., Singh, G. and Magnenat-Thalmann, N. (2008), A survey of mobile and wireless technologies for augmented reality systems. *Comp. Anim. Virtual Worlds, 19*: 3–22.

Roca, J. C., & Gagné, M. (2008). Understanding e-learning continuance intention in the workplace: A self-determination theory perspective. *Computers in Human Behavior, 24*, 1585–1604.

Santoso, M., Yan, W. F., & Gook, L. B. (2012). Development of Edutainment Content for Elementary School Using Mobile Augmented Reality, *4th International Conference on Computer Research and Development IPCSIT, 39*

Schmalstieg, D., & Wagner, D. (2007). Experiences with Handheld Augmented Reality. *6th IEEE and ACM International Symposium on Mixed and Augmented Reality*, Japan 1-13.

Squire K, Klopfer E (2007) Augmented reality simulations on handheld computers. *J Learn Sci 16*(3):371–413

Taketa, N., Hayashi, K., Kato, H., & Noshida, S. (2007). Virtual Pop-Up Book Based on Augmented Reality, 475-484.

Tarng, W., & Ou, K.-L. (2012). A Study of Campus Butterfly Ecology Learning System Based on Augmented Reality and Mobile Learning. 2012 IEEE Seventh International Conference on Wireless, *Mobile and Ubiquitous Technology in Education*, 62-66.

Uzunboylu, H., Cavus, N., & Ercag, E. (2009). Using mobile learning to increase environmental awareness. *Computers & Education, 52*(2), 381 – 389.

Wagner, D., Schmalstieg, D., and Billinghurst, M. (2006). Handheld AR for Collaborative Edutainment. *Advances in Artificial Reality and TeleExistence,* 85–96

Zhou F, Duh H-L, Billinghurst M (2008) Trends in augmented reality traching, interaction and display: A review of ten years in ISMAR. In: *Proceedings from ISMAR 7th IEE/ACM international symposium*: Mixed and Augmented Reality. Cambridge: IEEE, 193–202

Zurita, G., & Nussbaum, M. (2004). A constructivist mobile learning environment supported by a wireless handheld network. *Journal of Computer Assisted Learning, 20* (4),235 – 243