Augmented Reality in Education and Training

Kangdon Lee
University of Northern Colorado & KOSHA
Republic of Korea
lee4650@bears.unco.edu

Abstract: There are many different ways for people to be educated and trained in regards to specific information and skills they need. These methods include classroom lectures with textbooks, computers, handheld devices, and other electronic appliances. The choice of learning innovation is dependent on individual's access to various technologies and the infrastructure environment of the surrounding community available. In a rapidly changing society where there is a great deal of available information and knowledge, adopting and applying information at the right time and right place is needed to main efficiency in both school and business settings. Augmented Reality (AR) is one technology that dramatically shifts the location and timing of learning and training. This literature review research describes Augmented Reality (AR), how it applies to learning and training, and the potential impact on the future of education.

The general meaning of AR

Augmented Reality (AR) is a technology that allows computer-generated virtual imagery information to be overlaid onto a live direct or indirect real-world environment in real time (Azuma, 1997; Zhou, Duh, & Billinghurst, 2008). AR is different from Virtual Reality (VR) in that in VR people are expected to experience a computer-generated virtual environment. In AR, the environment is real, but extended with information and imagery from the system. In other words, AR bridges the gap between the real and the virtual in a seamless way (Chang, Morreale, & Medicherla, 2010).

The origin of AR in learning and training.

According to Johnson, Levine, Smith, & Stone (2010), the history of AR goes back to the 1960s and the first system was used for both Augmented Reality and Virtual Reality as well. It used an optical see-through head-mounted display that was tracked by one of two different methods: a mechanical tracker and an ultrasonic tracker. Due to the limited processing power of computers at that time, only very simple wireframe drawings could be displayed in real time (Sutherland, 1968). Since then, Augmented Reality has been put to use by a number of major companies for visualization, training, and other purposes. The term 'Augmented Reality' is attributed to former Boeing researcher Tom Caudell, who is believed to have coined the term in 1990.

Marker- and Markerless-based AR.

According to Johnson, et al. (2010), augmented reality systems can either be marker-based or markerless-based. Marker-based applications are comprised of three basic components which include a booklet for offering marker information, a gripper for getting information from the booklet and converting it to another type of data, and a cube for augmenting information into 3D-rendered information on a screen. On the other hand, markerless-based applications need a tracking system that involves GPS (Global Positioning System), a compass, and an image recognition device instead of the three elements of maker-based systems. Markerless applications have wider applicability because they function anywhere without the need for special labeling or supplemental reference points.

Adopting AR in learning and training.

According to Chang, Morreale, and Medicherla (2010), several researchers have suggested that students and trainees can strengthen their motivation for learning and enhance their educational realism-based practices with virtual and augmented reality. In spite of a great amount of research during the last two decades, adopting AR in learning and training is still quite challenging because of issues with its integration with traditional learning methods, costs for the development and maintenance of the AR system, and general resistance to new technologies. Now that AR, however, has the promise to attract and inspire learners with exploring and controlling materials from a diversity of different perspectives that have not been taken into consideration in real life, AR in education and training is believed to have a more streamlined approach that has wider user adoption than ever before due to the improvement in computer and information technology. Kerawalla, et al. (2006) stated that even though many AR applications have been developed for educational and training purposes since the advent of AR in the late 1960s, its potential and pragmatic employment has just begun to be explored and utilized in real life. He emphasized that AR has the potential to have learners more engaged and motivated in discovering resources and applying them to the real world from a variety of diverse perspectives that have never been implemented in the real world.

How it applies to learning and training

Johnson, et. al. (2010) stated, "AR has strong potential to provide both powerful contextual, on-site learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world." (p. 21). AR has been experimentally applied to both school and business environments, although not as much as classic methods of learning and training during the last two decades. In addition to that, now that the technologies that make augmented reality possible are much more powerful than ever before and compact enough to deliver AR experiences to not only corporate settings but also academic venues through personal computers and mobile devices, several educational approaches with AR technology are more feasible. Also, wireless mobile devices, such as smart phones, tablet PCs, and other electronic innovations, are increasingly ushering this technology, AR, into the mobile space where the AR applications offer a great deal of promise, especially in learning and training.

AR in school

Professionals and researchers have striven to apply AR to classroom-based learning within subjects like chemistry, mathematics, biology, physics, astronomy, and other K-12 education or higher, and to adopt it into augmented books and student guides. However, Shelton (2002) estimated that AR has not been much adopted into academic settings due to little financial support from the government and lack of the awareness of needs for AR in academic settings.

AR in business

In corporate venues, AR is a collaborative, skill-learning, explainable, and guidable tool for workers, managers, and customers. Also businesses have a better environment than those of educational settings regarding the ability to maintain the costs and support of AR applications. Many corporations are interested in employing AR for the design and the recognition of their products' physical parts. According to the evaluation of Shelton (2002), for example, enterprises not only may imagine designing a car in three dimensions in which they can make immediate changes when needed but also can create virtual comments that explain to the technicians what needs to be fixed.

The current position of AR in learning and training

During the last few decades, many professionals and researchers have been developing pragmatic theories and applications for the adoption of AR into both academic and corporate settings. By virtue of those studies, some innovations of AR have been developed and are being used to enhance the learning and training efficiency of students and employees. In addition to that, there are a great number of studies going on to improve the compatibility and applicability of AR into its real life. However, according to Shelton & Hedley (2004), many questions still linger about its use in education and training including issues of cost effectiveness, of efficiency between AR instructional systems and conventional methods, and the like.

Augmented astronomy

In an astronomy class, students learn about the relationship between the earth and the sun. For the sake of students understanding, educators may employ AR technology with 3D rendered earth and sun shapes.
Shelton’s (2004) study described the following:

The virtual sun and earth are manipulated on a small hand-held platform that changes its orientation in coordination with the viewing perspective of the student. The student controls the angle of viewing in order to understand how unseen elements work in conjunction with those that were previously seen. (p. 324)

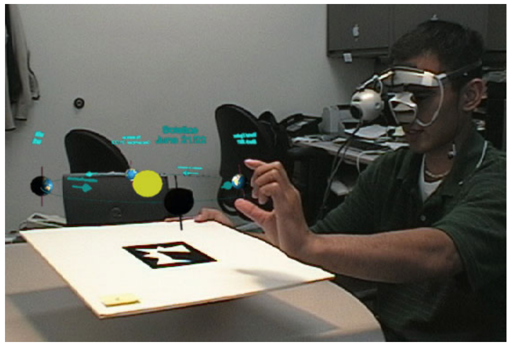


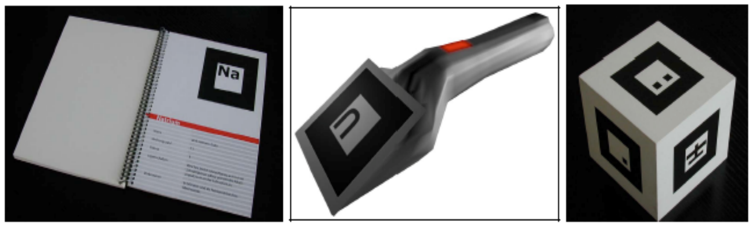
Figure 1. A view of a student interacting with real objects (foam core card, table, wall) and artificial objects (Sun, Earth, annotations) through the augmented reality interface. This view is as would be seen if wearing an HMD (Shelton, 2004).

As another example for the employment of AR in astronomy, Johnson, et. al. (2010) described Google’s SkyMap as an application using AR technology. SkyMap overlays information about the stars and the constellations as users browse the sky with the see-through view from the camera on their smart phones. (p. 23)

Figure 2. Google SkyMap (Retrieved from http://www.youtube.com/watch?v=p6znyx0gjb4).

Augmented chemistry

Augmented chemistry is an interactive educational workbench that can show students how and what an atom or a molecule consists of via AR. Three elements, a booklet, a gripper, and a cube, are required to implement this task with both hands. Fjeld & Voegtli (2002) said that the booklet displays components by a printed picture and a name. One hand browses the booklet with a gripper which has a button used to connect an atom to the molecular model. According to Fjeld & Voegtli (2002), firstly, users bring the gripper around the element in the booklet and get information about the element by clicking the button of the gripper. Second, users move the gripper next to a cube, called a platform, which holds a molecule. Subsequently, by rotating a cube operated by the other hand, users can determine where and how the element connects to the molecule.



a b c

Figure 3. a) Booklet offering one element per page – here Na – sodium. Each element is represented by a pattern. b) Gripper with a button (red) and a pattern. c) Cube with one distinct pattern for each surface (Fjeld & Voegtle, 2002).

Figure 4. System set-up with a typical situation of use: charging the Gripper with an element from the booklet (left). The platform (right) holds an unsaturated atom, with which a binding with the charged atom may be triggered (Fjeld & Voegtle, 2002).

Augmented biology

AR can be used to study the anatomy and structure of the body in biology. The Specialist Schools and Academies Trust (SSAT) demonstrated that teachers could use AR technology to show what organs of human beings consist of and how they look by watching 3D computer-generated models in the real classrooms. Moreover, students may be able to study humans' organs independently with their camera-embedded laptops and AR markers that connect PCs with AR information about biological structures of the human body. (Retrieved from https://www.ssatrust.org.uk/achievement/future/Pages/AugmentedReality.aspx)

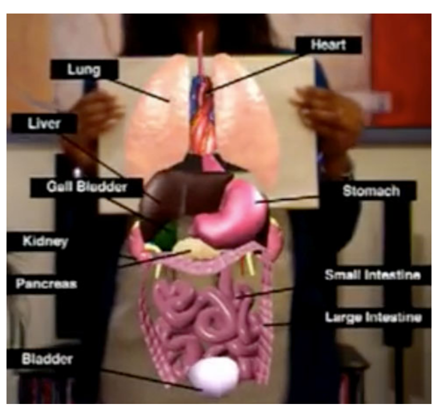


Figure 5. A model of human beings' internal organs with AR technology that can be used in Biology class (Retrieved from http://www.learnar.org).

Mathematics and geometry education

With AR technology, teachers and students can collaborate by interacting with each other for some issues on shapes or arrangements. According to Chang, Morreale, & Medicherla (2010), an AR application, called Construct3D, specifically was designed for mathematics and geometry education with three-dimensional geometric construction models (as cited in Kaufmann, 2006; Kaufmann & Schmalstieg, 2002; Kaufmann, Schmalstieg, & Wagner, 2000). This application allows multiple users, such as teachers and students, to share a virtual space collaboratively to construct geometric shapes by wearing head mounted displays that enable users to overlay computer-generated images onto the real world.

Figure 6. Students working with construct3D inscribe a sphere in a cone (Kaufmann & Schmalstieg, 2002).

Furthermore, Kaufmann (2009) determined that AR can be used in dynamic differential geometry education in a wide range of ways. For instance, using the AR application, teachers and students can intuitively explore properties of interesting curves, surfaces, and other geometric shapes.

AR in K-12 education

Freitas & Campos (2008) developed SMART (System of augmented reality for teaching) that is an educational system using AR technology. This system uses AR for teaching 2nd grade-level concepts, such as the means of transportation and types of animals. This system superimposes three dimensional models and prototypes, such as a car, truck, and airplane, on the real time video feed shown to the whole class. Because most children spend a great deal of time playing digital games, game-based learning is one way to engage children in learning. Several experiments by Freitas & Campos (2008) were performed with 54 students in three different schools in Portugal. The results of a number of studies by Freitas & Campos (2008) indicated that SMART helps increase motivation among students, and it has a positive impact on the learning experiences of these students, especially among the less academically successful students.

How AR is applied to the business training

Cultural heritage

From cultural and traditional perspectives, AR can be used as an influentially interactive tool in cultural heritage sites by showing visitors the original images of the sites and informing travelers of historical episodes of the places with 3D effects. Vlahakis, et al, (2002) demonstrated on their research of ARCHEOGUIDE (Augmented Reality-based Cultural Heritage On-site GUIDE) that the AR tour assistant system provides on-site help and Augmented Reality reconstructions of ancient ruins, based on users' position and orientation in the cultural site, and real time image rendering. ARCHEOGUIDE is based on computer and mobile technologies including AR, 3D-visualization, mobile computing, and multi-modal interaction techniques. The equipment consists of a Head-Mounted Display (HMD), an earphone and a mobile computing unit. But other versions include a PDA or a lightweight portable computer with a simple input device. With these AR devices, individuals can visit historic sites and tour around, both comparing an original image to an augmented modeling and viewing three-dimensional models of what the construction was, how it looked, and who the person was, even though it does not exist any more or just remains some ruins.

a b

Figure 7. a) The original image of a heritage site. b) An image of AR modeling. Examples of ARCHEOGUIDE's original image and AR modeling (Vlahakis, 2002).

Industrial maintenance

In the field of industrial maintenance, AR is a very practical assistance for staff in their highly demanding technical work. Henderson & Feiner (2009) observed that corporate sectors such as military, manufacturing, and other industries are the applied fields where AR competitively thrives and expands the scope of the technology itself. Particularly, according to their studies (Henderson & Feiner, 2009), which concentrate on the military sector, with the assistance of AR technology, military mechanical staff can conduct their routine maintenance tasks in a bulletproof vehicle more safely and conveniently. To do this, there are several required devices and apparatuses such as a tracked head-worn display to augment a mechanic's natural view with text, labels, arrows, and animated sequences designed to facilitate task comprehension, location, and execution.

a b

Figure 8. a) A mechanic wearing a tracked head-worn display performs a maintenance task inside an LAV-25A1 armored personnel carrier. b) The AR condition in the study: A view through the head-worn display captured in a similar domain depicts information provided using augmented reality to assist the mechanic (Henderson & Feiner, 2009).

Conclusion

The future of Augmented Reality as a visualization technology looks bright, as shown by the interest generated in business and industrial circles as well as discussed in popular periodicals and research papers in the learning and training fields. Many questions still linger in terms of efficiency and when compared to traditional methods, particularly given the investments needed in research and design. However, there is much optimism of AR in learning and training for the future. New technologies and information communications are not only powerful and compact enough to deliver AR experiences via personal computers and mobile devices but also well developed and sophisticated to combine real world with augmented information in interactively seamless ways.

The future of learning and training with AR

Several cutting-edge AR applications to date have been mostly developed for location-based information, social network services, and entertainment. New AR tools for other purposes such as learning and training, however, will continue to be developed as the technology becomes more highly evolved and advanced than ever before. A considerable number of professionals and researchers from the field of learning and training science predict that simple AR applications in education will be realized within a few years.

Interactive education

It is highly likely that AR can make educational environments more productive, pleasurable, and interactive than ever before. AR not only has the power to engage a learner in a variety of interactive ways that have never been possible before but also can provide each individual with one's unique discovery path with rich content from computer-generated three dimensional environments and models.

Simplicity

As shown in a great deal of previous research and professionals' opinions, AR could probably be focused on simplicity and ease of providing learning and training experiences, so that students and trainees can accept knowledge and skills with 3D simulations generated by computers and other electronic devices. In addition to that, related industries and technologies, such as computer and mobile industries, information and communication technologies, and Internet network infrastructures, including both wired and wireless services, possibly enable AR in learning and training to be much more straightforward and succinct to approach and utilize than ever before.

Contextual information

In the view of many professionals and experts in the field of educational AR, it is possible that learning and training-oriented AR can improve the extent and quality of information in both school and business settings by making learning and training environments more educational, productive, and contextual. In this perspective, there seem to be many contextual elements possibly embedded in educational AR applications in order to enhance the quality of learning and training by producing and delivering rich, constructive, and gainful content. For instance, Geo tag information for historical and cultural heritages could be connected as well as annotation regarding complex physical objects and artifacts could readily be added to AR tools in both business and school venues.

Efficiency and effectiveness

There is the potential that AR can promote the efficiency of learning and training in academic and corporate surroundings by providing information at the right time and right place and offering rich content with computer-generated 3D imagery. AR may appeal to constructivist notions of education where students take control of their own learning and could provide opportunities for more authentic learning and training styles. Besides, there are no real consequences if mistakes are made during skills training in terms of dangerous and hazardous work environments. As the results of several studies have shown, AR systems can provide motivating, entertaining, and engaging environments conducive for learning. In addition, AR applications in educational settings are attractive, stimulating and exciting for students and provide cost-effective support for the users.

References

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments 6,* 4 (August 1997), 355-385. Cambridge, MA: The MIT Press.

Augmented reality. (n. d.). Retrieved from https://www.ssatrust.org.uk/achievement/future/pages/AugmentedReality.aspx

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). The Magic Book — Moving seamlessly between reality and virtuality. *IEEE Computers, Graphics and Applications, 21*(3), 2-4.

Billinghurst, M. (2002). Augmented reality in education. *New Horizons for Learning.* Retrieved from http://www.newhorizons.org/strategies/technology/billinghurst.htm

Chae, C., & Ko, K. (2008). Introduction of physics simulation in augmented reality. *ISUVR 2008 International Symposium on Ubiquitous Virtual Reality*, 37-40.

Chang, G., Morreale, P., & Medicherla, P. (2010). Applications of augmented reality systems in education. In D. Gibson & B. Dodge (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2010,* 1380-1385. Chesapeake, VA: AACE.

Duarte, M., Cardoso, A., & Lamounier Jr., E. (2005). Using augmented reality for teaching physics. *WRA'2005 – II Workshop on Augmented Reality*, 1-4.

Dünser, A., Steinbügl, K., Kaufmann, H., & Glück, J. (2006). Virtual and augmented reality as spatial ability training tools. *Proceedings of the 7th ACM SIGCHI New Zealand chapter's international conference on Computer-human interaction: design centered HCI*, 125-132. Christchurch, New Zealand.

Fjeld, M., & Voegtli, B. M. (2002). Augmented chemistry: an interactive educational workbench. *Proceedings of the international symposium on mixed and augmented reality (ISMAR '02)*. Damstadt, Germany.

Freitas, R., & Campos, P. (2008). SMART: a System of augmented reality for teaching 2nd grade students. *Proceedings of the 22nd British Computer Society Conference on Human-Computer Interaction (HCI 2008)*, 27-30. Liverpool John Moores University, UK.

Henderson, J., & Feiner, S. (2009). Evaluating the benefits of augmented reality for task localization in maintenance of an armored personnel carrier turret. *Proc. Int. Symp. on Mixed and Augmented Reality (ISMAR '09)*, 2009, 135-144.

Johnson, L., Levine, A., Smith, R., & Stone, S. (2010). Simple augmented reality. *The 2010 Horizon Report,* 21-24. Austin, TX: The New Media Consortium.

Kaufmann, H. (2009). Dynamic differential geometry in education. *Journal for Geometry and Graphics, 13*(2), 131-144.

Kaufmann, H., & Dünser, A. (2007). Summary of usability evaluations of an educational augmented reality application. *Second International Conference, ICVR 2007.* Beijing, China.

Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). Making it real: Exploring the potential of augmented reality for teaching primary school science. *Virtual Reality , 10*(3-4), 163-174. London, United Kingdom: Springer-Verlag London Ltd.

Kondo, T. (2006), Augmented learning environment using mixed reality technology, Proc. E-Learn, 83-88.

Liarokapis, F., Mourkoussis, N., White, M., Darcy, J., Sifniotis, M., Petridis, P., . . . Lister, P. (2004). Web3D and augmented reality to support engineering education. *World Transactions on Engineering and Technology Education, 2004 UICEE Vol. 3. No. 1.* Melbourne, Australia.

Schrier, K. L. (2005). Revolutionizing history education: using augmented reality games to teach histories. Master Thesis, Massachusetts Institute of Technology, Cambridge, MA.

Shelton, B. E. (2002). Augmented reality and education: Current projects and the potential for classroom learning. *New Horizons for Learning.* Retrieved from http://www.newhorizons.org/strategies/technology/shelton.htm

Shelton, B. E., & Hedley, N. R. (2002). Using augmented reality for teaching Earth-Sun relationships to undergraduate geography students. *The First IEEE International Augmented Reality Toolkit Workshop.* Damstadt, Germany.

Shelton, B. E., & Hedley, N. R. (2004). Exploring a cognitive basis for learning spatial relationships with augmented reality. Technology, Instruction, Cognition and Learning, 1(4), 323-357. Philadelphia, PA: Old City Publishing, Inc.

Sutherland, I. (1968). A head-mounted three-dimensional display. *Proceedings of Fall Joint Computer Conference, 1968*, 757-764.

Vlahakis, V., Ioannidis, N., Karigiannis, J., Tsotros, M., Gounaris, M., Almeida, L., . . . Christou, I. (2002). ARCHEOGUIDE: First results of an augmented reality, mobile computing system in cultural heritage sites. *Computer Graphics and Applications, IEEE,* 52-60.

Wichert, R. (2002). A mobile augmented reality environment for collaborative learning and training. In M. Driscoll & T. Reeves (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2002,* 2386-2389. Chesapeake, VA: AACE.

Zhou, F., Duh, H. B. L., & Billinghurst, M. (2008). Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR. *IEEE International Symposium on Mixed and Augmented Reality*, 15-18. Cambridge, UK.