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Teaching and Learning Context in the Augmented Reality Environment[1]

Introduction

What is Augmented reality (AR)?

Augmented reality is a technology that lays computer-generated virtual imagery on top of a live direct or indirect real-world environment in real time. This disruptive technology is growing at a significant pace due to its new and innovative nature (Dingli, Seychell 2015). Currently, AR is mostly being used for advertising and commercial purposes, and in the entertainment, medical and educational fields (Wu *et al.* 2013). AR's usefulness in educational contexts has driven the focus of the creation by Jun Lee and Marylee Ang-Sadecki's Google Site, Augmented Reality 101 (AR 101), as educators are recognizing its numerous benefits to teaching and learning (Lee *et al.* 2012). AR enhances reality, presenting content in 3D perspectives. It promotes collaboration and strengthens the sense of presence, immediacy, and immersion in learning. Bridging formal and informal learning, AR also enables students to visualize the invisible. This increases motivation and student engagement as it offers opportunities for just-in-time learning and makes connections to real-world applications. It also enables learners to better understand complex concepts. As a result, this technology holds the possibility for a wider adoption by educators (Blagg 2009).

What is the significance of AR to teaching and learning?

AR has begun to show promise in helping students learn more effectively (Billinghurst, Duenser 2012). Through the creation of authentic learning environments, AR helps increase knowledge retention and memorization (Martin *et al.* 2011). In addition, AR supports the understanding of complex tasks by combining real and virtual information. AR allows learners to interact with digital content by allowing participants to manipulate images (Billinghurst, Duenser 2012). This facilitates skill acquisition more effectively, and leads to an increase in the student excitement with technology (Billinghurst, Duenser 2012).

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AR enhances student motivation, involvement and engagement. This results in increased student understanding of spatial and temporal concepts (Billinghurst, Duenser 2012; Martin *et al.* 2011), as AR enables learners to delve more deeply into topics. A visual map of the benefits of AR was created, and the idea of AR in teaching and learning was highlighted in the New Media Consortium's Horizon Report for K-12 in 2012.

There are two forms of AR currently available to educators: 1. location-aware and 2. vision-based. Location-aware AR presents digital media to learners as they move through a physical area with a GPS-enabled smartphone or similar mobile device. The media (i.e., text, graphics, audio, video, 3D models) augment the physical environment with narrative, navigation, and/or academic information relevant to the location. In contrast, vision-based AR presents digital media to learners after they point the camera in their mobile device at an object (e.g., QR code, 2D target). The following scenario provides a contextualized example of both forms of AR: as the 7th grade life science student passes by an oak tree in her school playground, software-leveraging GPS plays a video on his/her smartphone describing the various habitats and animals that are found near the tree (location-aware). At the end of the video, the student is prompted to point his/her phone's video camera at a placard at the base of the tree, which triggers a three-dimensional model illustrating the anatomical structure of the oak (vision based).

The potential power of AR as a learning tool is its ability "to enable students to see the world around them in new ways and engage with realistic issues in a context with which the students are already connected" (Klopfer, Sheldon 2010). These two forms of AR (i.e., location-aware and vision-based) leverage several smartphone capabilities (i.e., GPS, camera, object recognition and tracking) to create "immersive" learning experiences within the physical environment, providing educators with a novel and potentially transformative tool for teaching and learning (Azuma 1997; Klopfer *et al.* 2009). Immersion is the subjective impression that one is participating in a comprehensive, realistic experience. Interactive media now enable various degrees of digital immersion. The more a virtual immersive experience is based on design strategies that combine actionable, symbolic, and sensory factors, the greater the participant's suspension of disbelief that she or he is "inside" a digitally enhanced setting. Studies have shown that immersion in a digital environment can enhance education in at least three ways: by allowing multiple perspectives, situated learning, and transfer.

Furthermore, these two forms of AR both leverage the affordance of context sensitivity, which enables the mobile device to "know" where it is in the physical world and to present digital content to the user that is relevant to that location (Klopfer, Squire 2003). This review will primarily focus on location-aware AR played outdoors in the physical environment; while vision-based AR holds enormous potential for educators, there are few current studies on this version of AR. Research on related immersive media suggests ways in which vision-based AR could be powerful. For example, using the medium of sensorial immersive virtual reality, Project Science Space contrasted egocentric rather than exocentric frames of reference. The "exocentric" frame of reference provides a view of an object, space, or phenomenon from the outside, while the "egocentric" frame of reference provides a view from within the object, space, or phenomenon. The exocentric and the egocentric perspectives were found to have different strengths for learning, and the "bicentric" perspective alternating between the egocentric and exocentric views was shown to be particularly powerful (Dunleavy, Dede, Mitchell 2009).

Theoretical foundation for AR

The assertion that AR could provide enhanced learning experiences is grounded in two interdependent theoretical frameworks: 1. the situated learning theory and 2. the constructivist learning theory.

The situated learning theory posits that all learning takes place within a specific context and the quality of the learning is a result of interactions among the people, places, objects, processes, and culture within and relative to that given context (Brown, Collins, Duguid 1989). Within these contexts, learning is a co-constructed, participatory process in which all learners are "transformed through their actions and relations in the world" (Brown, Collins, Duguid 1989: 37). Situated learning builds upon and extends other learning theories such as social learning theory and social development theory, which posit that the level of learning is dependent upon the quality of the social interaction within the learning context (Bandura 1977; Vygotsky 1978).

Situated learning through immersive interfaces is important in part because of the crucial issue of transfer (Dede 2009). Transfer is defined as the application of knowledge learned in one situation to another situation and is demonstrated if instruction on a learning task leads to improved performance on a transfer task, ideally a skilled performance in a real-world setting (Mestre 2002). Researchers differentiate between two ways of measuring transfer: sequestered problem-solving and preparations for future learning (Schwartz, Sears, Bransford 2005). Sequestered problem-solving tends to focus on direct applications that do not provide an opportunity for students to utilize resources in their environment (as they would in the real world); standardized tests are an example of this. Giving students presentational instruction that demonstrates solving standard problems, then testing their ability to solve similar problems, involves near-transfer: applying the knowledge learned in a situation to a similar context with somewhat different surface features.

When evaluation is based on the success of learning as a preparation for future learning, researchers measure transfer by focusing on extended performances where students "learn how to learn" in a rich environment and then solve related problems in real-world contexts. With conventional instruction and problem solving, attaining preparation for future learning requires far-transfer: applying the knowledge learned in a situation to a quite different context whose underlying semantics are associated, but distinct (Perkins, Salomon 1992). One of the major criticisms of instruction today is the low rate of far transfer generated by presentational instruction.

Even students who excel in educational settings often are unable to apply what they have learned to similar real-world contexts.

The potential advantage of immersive interfaces for situated learning is that their simulation of real-world problems and contexts means that students must attain only near-transfer to achieve preparation for future learning. Flight and surgical simulators demonstrate the near-transfer of psychomotor skills from digital simulations to real-world settings; research on the extent to which AR can foster transfer is an important frontier for the field (Gallagher, O'Sullivan 2012; Hays *et al.* 1992).

Constructivist/interpretivist theories of learning assume that meaning is imposed by the individual rather than existing in the world independently (Dede 2009). People construct new knowledge and understandings based on what they already know and believe, which is shaped by their developmental level, their prior experiences, and their socio-cultural background and context (Bruner 1966; Vygotsky 1978). Knowledge is embedded in the setting in which it is used: learning involves mastering authentic tasks in meaningful, realistic situations (Lave, Wenger 1991). Learners build their personal interpretations of reality based on experiences and interactions with others, creating novel and situation specific understandings. Instructional design approaches based on constructivist theories include anchored instruction, case-based learning (Kolodner 2001), cognitive flexibility theory (Spiro *et al.* 1991), collaborative learning (Barron 2000), micro worlds and simulations (White 1993), mind tools (Jonassen 2005), and situated learning in communities of practice (Lave, Wenger 1991).

Instruction can foster learning by providing rich, loosely structured experiences and guidance (such as apprenticeships, coaching, and mentoring) that encourage meaning making without imposing a fixed set of knowledge and skills (Lave, Wenger 1991).

Constructivist learning theory outlines five conditions most likely to enhance learning:

1. embed learning within relevant environments;
2. make social negotiation integral to the learning experience;
3. provide multiple perspectives and multiple modes of representation;
4. provide self-directed and active learning opportunities;
5. support and facilitate meta-cognitive strategies within the experience (Cunningham 1992; Driscoll 2000; Piaget 1969; Vygotsky 1978).

As a cognitive tool or pedagogical approach, AR aligns well with situated and constructivist learning theory as it positions the learner within a real-world physical and social context, while guiding, scaffolding and facilitating participatory and meta-cognitive learning processes such as authentic inquiry, active observation, peer coaching, reciprocal teaching and legitimate peripheral participation with multiple modes of representation (Dunleavy, Dede, Mitchell 2009).

Augmented reality is poised to transform profoundly education as we know it. The capacity to overlay rich media onto the real world for viewing through web-enabled devices such as phones and tablet devices means that information can be made available to students at the exact time and place of need. This has the potential to reduce cognitive overload by providing students with "perfectly situated scaffolding", as well as enabling learning in a range of other ways. This article reviews uses of AR both in mainstream society and in education, and discusses the pedagogical potentials afforded by the technology. Based on the prevalence of information delivery uses of AR in education, I argue the merit of having students design AR experiences in order to develop their higher order thinking capabilities. A case study of "learning by design" using AR in high school visual art is presented, where samples of student work and their feedback is indicating that the approach results in high levels of independent thinking, creativity and critical analysis. The article concludes by establishing an outlook for AR and setting a research agenda going forward.

AR is likely to be a new form of demonstration where there is no need to have any physical model presented, hence it should be available for students at home (only a printed AR marker, a webcam and a computer with internet connection are required), and AR books, AR development and logical games are just about to appear in education. The usage of AR technology could be inserted in many subjects i.e., maths, on the lessons about geometry, or with 3D representations of cells in biology, in chemistry displaying molecular structure, or in PE where a team sport simulation can be established. Additionally, any subject can be more colourful, more interesting and interactive. Furthermore, education may profit from AR development or logical games. In computer science lessons, students can familiarize themselves with the background of AR and they can create their own AR projects. For instance, beginners can create their own 3D pop-up books at ZooBurst. After having registered, storytellers can create their own world in which their stories can come to life. An AR marker can be assigned to the virtual book that helps the physical book come "alive". On the next level of the use of AR, students may construct a 3D model with 3D editing tools and an AR marker accompanied by their own AR source codes.

In the article I introduced the relevance of AR and presented how the technology works, showing some examples of popular products and the direction where it is heading. I described this area, explaining the different modules of the AR portal and their use. I Demonstrated some of the applications, which were elaborated on in an experiment, in university education. My present findings so far have convinced me that AR technology could be a very good practical extension to textbooks and exercise; they give virtual hands on experiences to understand better the models within a learning context.

While AR succeeds as a motivational hook, gains in learning are demonstrated consistently less. Successful use of new technologies depends on matching technologies with the learning outcomes it best supports. Because of the visual-spatial nature of 3D AR, motor skill learning in particular can be enhanced, through the direct manipulation of objects that mimic real conditions. For intellectual skills, learning gains are attributable to quality engagement, rather than the AR itself. Additionally, a clear articulation of institutional support for digital learning increases the likelihood of successful implementation.

The convergence of so many technologies is creating new ways of interacting and engaging with the world, leading to new ways of thinking. It could be we have not yet discovered the best application of these new tools for enhancing learning. Perhaps there are as-yet unmeasured indicators that would support their continued use and investment in education.

We are in the era where connecting the senses of the audio, visual and touch zones in our brains is necessary to enhance the way our cognitive development is constructed as well as our education system to get the correct cognitive outcome. The time is exactly right to start looking into our education system the same way we do with our brains – involving and connecting the sense of specific teaching with modern learning, together with the sense of cognitive gaming, to augment the education to build a new module of information, and to cope with the huge and extremely fast update of information in this age of technology.

Conclusions and future directions

The article describes augmented reality applications in the field of education as a teaching and learning enhancement. AR is an applied technology of many cross-cutting areas. Meanwhile, it can be certainly used in many fields. Here, I have focused mainly on education because the needs of AR applications and education are partly similar, but for exhibition, we could discuss augmented reality applications in museums, cultural heritage relics and commercial showcases. These could provide extra and extensive information through a friendly and intuitive way. Some typical instances could be introduced in the details. Nevertheless for education, I would firstly classify this area into the two fields of personal devices and multiuser installations. Then, AR applications in video game players, handheld game consoles, and mobile phone are carefully discussed. Lastly, multiuser theme park attractions with augmented reality are introduced, like creative interactive 3D live.

From the discussions above, we can easily find that AR is suitable for education, entertainment and exhibition. It gives a better immersion feel and appealing form by combining the real and virtual worlds together. These are meeting the needs of those fields. AR in new product releases and live learning provides an interesting and unforgettable amount of information or experience of teaching and learning. Nevertheless, AR in these fields has different requirements. AR in education should be more playable, while in an exhibition it should focus on its functions and convenient use for users.

Therefore, when we develop an AR education system, we should pay more attention to its design and plan first on its playability, then the vivid mixed reality view rendering. On the other side, actual and useful function should be considered firstly for its applications in education. Lastly, user survey is needed for its massive use for the students and educators. Nowadays, many applications are emerging on the online stores, with mobile technology as a personal device, its computing ability and display indeed inspire lots of imagination, and bring a bright future of augmented reality applications in education, entertainment and exhibition for students, educators and the public.

Vision

Envisioning the future, we could see education delivery happening in non-traditional spaces outside the regular school day as the learners' devices engage the learners in problem solving activities customized to their demonstrated levels of proficiency. The activities will be tied to their current activity in their current location. Teachers will not deliver lessons, but will coordinate learning. Skill development will focus less on specific content, and more on process and problem solving. In a time when everything you might ever want to know is instantly accessible, there is a need to rethink the focus of education (Warchoł 2015).

Imagine a twelve year old girl in the back seat on a family trip looking out the Google glass window. Content delivery systems identify a gap in her content learning from a geography activity and as the family travels it begins to label landforms. She accesses an AR model of the terrain outside and using her book as a target image, she views the surrounding terrain from all sides in three dimensions. She completes the quiz on her learning group's learning management system and receives a badge of achievement on her digital backpack.

Her younger brother is struggling with perspective in art so his window creates a vanishing point grid aligned with the scene outside. Coming to an understanding, he uses his mobile device to sketch out a picture using perspective and sends it to his learning cohort. Within a few minutes, he receives some responses congratulating him on his progress along with some pictures his peers drew.

The convergence of so many technologies into a unified system of information sharing enables a greater, deeper understanding of our world. The fact that these are systems integrated increasingly into our sensory experiences brings us closer to Ray Kurzweil's *Singularity*, the complete integration of the human organism with digital communication: one of the things our grandchildren will find quaintest about us is that we distinguish the digital from the real (Kurzweil 2005).

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Summary

The article presents Augmented Reality (AR) as a step between reality and virtual reality for the benefit of education. After some introductory examples of where AR is heading, the technology itself will be explained. Then, I describe the modules of the AR that are developed and how it can be used in university courses and activities.

AR is the mid-point on a continuum between the real physical world around us and the virtual digital world online superimposing information on our sensory experiences as we move through time and space. Viewing physical objects through a mobile's camera, AR uses image recognition, geo-location, the device's accelerometer, and online databases to provide information relevant in time and space to the user. Research continues into different interaction methods and display possibilities making engagement with online data more natural and intuitive. The article explores current research in AR and associated technologies in order to understand possibilities for learners today and in the future.

This literature review focuses on AR for learning that utilizes mobile, context-aware technologies (e.g., smartphones, tablets), which enable participants to interact with digital information embedded within the physical environment. Summarizing research findings about AR in formal and informal learning environments (i.e., schools, universities, museums, parks, zoos, etc.), emphasis is placed on the affordances and limitations associated with AR as it relates to teaching, learning, and instructional design. As a cognitive tool and pedagogical approach, AR is primarily aligned with situated and constructivist learning theory, as it positions the learner within a real-world physical and social context while guiding, scaffolding and facilitating participatory and meta-cognitive learning processes such as authentic inquiry, active observation, peer coaching, reciprocal teaching and legitimate peripheral participation with multiple modes of representation.

Keywords

teaching, learning, augmented reality, technology

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