Augmented Reality in the Future of Education

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Abstract
In recent years, augmented-reality technology (AR) has seen tremendous development, to the point where it is now available in common electronic devices such as laptop computers and smart phones. As the amount of technology applications and exposure increase, it is only a matter of time until augmented-reality educational curriculums are developed. This paper explores the potential benefits and considerations of integrating augmented-reality experiences in educational institutions. Benefits of AR-based education include the appeal to multi-modal learning, increased accessibility of educational content, increased student motivation and control, and greater opportunities for collaboration. Difficulties envisioned stem from scarcity of related research, from a lack of content-creation tools, and from increased investment and training costs for educational institutions.

Keywords
Augmented Reality, Education, Children, Interaction Design

ACM Classification Keywords
H.5.1 [Multimedia Information Systems]: Artificial, augmented and virtual realities, H.5.2. [Information Interfaces and Presentation]: User interfaces.
Introduction
Augmented-reality (AR) technology allows the mixing of virtual content into a real-world physical context. It allows students to see virtual content as appearing in the real world, and to control the virtual environment through direct, tangible interaction with objects tracked in the physical space. Augmented reality has some features which aid learning, but which are in common with virtual reality and other technologies such as games and simulations. These are features such as providing an experience that is highly visual, highly interactive, and three-dimensional. Such features have potential learning benefits whether they are in augmented reality or other mediums, but this paper will not focus on these; instead, it will focus on what we believe augmented reality can bring beyond other mediums, specifically the aspect of connecting the virtual to the real.

Augmented-Reality Impact on Education
Appealing to Multi-Modal Learning
Most current educational experiences, based in PC and virtual-reality environments, deliver content through visual and auditory modalities. In these environments there is a lack of natural motor feedback because the user is not interacting directly with objects in the physical world. Augmented reality can provide a richer multimodal learning experience by allowing users to manipulate spatial relationships of real physical objects. Manipulation of physical objects can benefit education as it provides an additional mode of learning - support for multimodal learning, especially for visual-motor learning, can be drawn from several theories: spatial cognition, animate vision, and learning theory. By analyzing the aforementioned theories, Shelton et al. has found "an inextricable link between motor movement and the visual system that implies an implicit knowledge representation" (Shelton, 2003). If schools are to leverage such experiences, then classrooms need to have space for students to make use of this technology. Classrooms would need to provide devices which students can use, and designated "play" spaces where students can interact with virtual content through specialized physical objects. Augmented-Reality experiences can be enabled in these spaces through personal handheld device (such as smart phones or PDAs), or through wall-mounted devices such as SMART boards. Integrating the physical world into educational experiences will lead to the development of educational experiences which are more physically interactive, making use of tangible objects and physical interactions.

Increasing Accessibility to Educational Content
One of the greatest benefits of augmented-reality to education is increasing the accessibility of virtual educational content. Students typically can access virtual content through computer devices such as desktops, laptops, or specialized kiosks. Highly portable devices such as mobile phones can allow students to access educational content in environments when traditional computers are not readily available, such as when walking on the street or when reading a textbook. Augmented reality allows the student to connect to the virtual educational content by simply pointing a camera at their environment. This ease of access is highly beneficial to students, since contextually-relevant information can be procured to satisfy the student’s interest. In recent years, mobile devices have become a commodity for most people - smart phones such as the iPhone, Blackberry and Android are becoming
gateways for augmented-reality technology to reach the general public. Although there are still technical limits due to lack of processing power from these small devices, it is expected that learning with portable AR applications will be harnessed in the near future.

These advances will likely lead to an increase in educational experiences outside of the classroom, as students can access content based on their immediate context. This may lead to context-aware educational innovations such as textbooks which adapt to their surroundings. Such technologies can give students greater control over their own learning, while allowing educators to electronically monitor how students explore the educational content. In the classroom, it is expected that lightweight technologies (i.e. mobile devices such as PDAs and smart phones) will be introduced in order for students to connect to virtual content, avoiding the need to move the class to a computer lab. This increased integration of virtual educational content into the classroom will potentially lead schools to a higher dependence on hardware and educational software, an issue which we will discuss in a future section.

Increasing Student Control

Typically when a student accesses educational content using a computer, he must hold knowledge regarding computer-based interactions. At the very least, he must be able to use a keyboard and mouse; additionally, he might need to be familiar with a variety of interaction techniques (such as moving windows, accessing menus, etc). Since the student must know how to apply these interactions, there is a learn cost while the student trains (mentally and physically) to use an application, and there is a cognitive load imposed while the student interacts with the application. In an augmented reality experience, the student’s body is immersed in the educational content – the student can see the educational content in the space around them. This differs from a virtual reality experience, since the student can see the educational content in relation to the world around them and to their body, bypassing the disorientation effects of VR environments (Shelton & Hedley, 2002).

Augmented-Reality technology allows students to interact with the educational content by leveraging what they know about interacting with the physical world – they can move around to change perspective, move closer/farther to change scale, they can select virtual objects by pointing to them, they can reach out to grab and move objects, etc. Because AR permits these natural interactions, there is a reduction in the knowledge and skills required of users, and the technology interface between student and educational content becomes more transparent. The user still needs to learn interactions specific to the application itself, but the operations of basic navigation and object manipulation are most probably intuitive to the user. The nature of the interaction reduces the amount of learning that must be performed by a user of the application, and it can also reduce cognitive load experienced while learning through the application. Cognitive load occurs when activities use the resources of working memory, decreasing the potential for learning (Fredrickson, 1998). The use of “natural” interfaces are believed to reduce cognitive load – studies show that cognitive load in augmented-reality environments are less than when learning in a computer-based environment (Tang et al, 2003), and,
surprisingly, less than when learning from a text resource (Chen, 2000).

Additionally, when students are interacting with educational content through augmented-reality, they have much more control over the way information is being delivered. Student preferences can be different depending on individuals in which some would prefer to learn through looking at a stable image while others would prefer to learn by moving objects around. AR allows students to have control over how they examine the content. In the Earth-Sun project by Shelton & Hedley, students exhibited different learning preferences as they interacted with the virtual 3D model. Shelton noted that "seeing what [students] wanted to see, when they wanted to see it, provided the active students with control over the instructional content" (Shelton, 2003). Some students explored the Earth-Sun relationship with careful analysis of stable models, while others learned by rotating the model in different angles to see different aspect of it.

Augmented-reality can lower the barrier to entry for students engaging virtual content, as it makes use of natural interactions which allow more (and potentially younger) students to engage with educational content. The ease of interacting within AR-based experiences can invite teachers to bring virtual educational experiences into the classroom.

**Bringing Opportunities for Collaboration**

Collaboration can be a facilitator of learning, since it enables students to interact with each other as well as the educational content at the same time. This allows for deeper learning as students consider different perspectives and direct each other to study different aspects of the educational content. As students need to communicate their thoughts, they think about their knowledge and how to match it to what others know; this has the potential to lead to meta-cognitive skills of determining one’s own learning and tackling problems which will enhance it (Bransford et al., 2000; Bruckman, 2000). Various factors come into play into an effective collaboration. Non-verbal behaviors, such as gestures, body language and eye gaze, have a purpose in communication as well as in directing attention (Billinghurst, 2001). Physical objects often play an important part in collaboration, being used for their affordances, semantic meaning, or spatial relationship to other objects.

Some of these factors are lost when students collaborate around or through computer-based environments. If students collaborate by looking at a computer screen, they switch between looking at the screen and looking at the other person (Shelton & Hedley, 2002). Using such a system is also not suitable for large groups of students, and it also makes it difficult for a student to have individual control over the virtual content. If students collaborate in a virtual world, then more people can collaborate around the same educational content; however, communication through non-verbal cues is cumbersome or nonexistent (Billinghurst, 2001).

Augmented reality can take the best of both scenarios: students can see the virtual content and each other in the same space, thus the collaboration activity can take advantage of non-verbal cues as well as physical objects. Many people can collaborate around the same virtual content, each having an individual perspective and control over the content. In (Kiyokawa, 1998), the
researchers have observed that people collaborating in a shared space using AR exhibited similar behaviors as in face-to-face collaboration, and in (Chen, 2000), the study has shown that students using an AR environment to learn chemistry have found collaboration to be beneficial. The use of augmented-reality technology inside and outside the classroom provides increased opportunities for collaboration to occur around virtual educational content.

Motivating Students to Engage
Motivation can play a crucial role in learning. The affective aspect of a learning experience can draw a student to engage with new educational content, and, once the student has accessed the experience, it can motivate the student to continue exploring the experience more deeply (Lee, 1999). Augmented reality can be a highly affective experience due to a combination of its novelty and its potential to immerse the user into a fantasy world. Children have described AR technology as being “magic” (Billinghurst, 2000). The experience is magical because the reality around the user can be believably transformed into something out of a fantasy book. In opposition to computer games and pure virtual reality, AR does not separate the user from his reality but instead uses that and realistically transform it; this effect can cause a high degree of surprise and curiosity in users. The low amount of technological overhead required to create this experience is also a motivator for engaging with AR-based content: typically what is needed are a video camera (connected to a computer or mobile device) and a printer. Other more complex AR systems such as head-mounted displays exist, but research has shown that the technology may not make much difference to student learning (Chen, 2000).

The emotional state can make the experience more memorable, and can help memory encoding and learning (Fredrickson, 1998; Lee, 1999). Currently there is wide interest from marketing departments in using this technology to create memorable experiences for users. However, once people become accustomed to the technology, research will be able to observe whether the emotional effects of the technology are sustainable in longer-term learning experiences.

Making Abstractions be Concrete
Augmented Reality has the potential of bringing abstract concepts into the physical world. Concepts in human knowledge range from highly abstract (such as: “morals”, “intuition”) to highly concrete (such as: “keyboards”, “screws”); the highly abstract are mental concepts with no physical referents, while the highly concrete evoke representations from the physical world.

Computer graphics technology can give visual representations to abstract concepts. For example, one can take the concept of a ball’s velocity, and represent it as a visual object, and properties of the concept can be linked to its representation – velocity can be represented by a physical arrow, and the magnitude of the velocity can be represented by the size of the arrow. A student can watch this object and make deductions about the velocity of the ball. Furthermore, the student may be able to interact with the object and affect the ball velocity, for example enlarging the object may cause velocity to increase. This reification is helpful in educating students who are visual or kinesthetic learners, providing an alternate representation and helping them “grasp” abstract concepts. Research has shown that being able to
interact with representations of knowledge helps students to better learn concepts (Shelton & Hedley, 2002). This reification process can be especially helpful for visual and kinesthetic learners; furthermore, some people such as those with Autism are highly visual and have difficulty understanding abstract concepts (Bauman, 1999), thus the realism provided by this technology may be an opportunity to help such individuals learn abstract ideas.

Augmented reality can make the reification of abstract concepts into a realistic experience, by making such abstractions appear as real objects in the user’s world, and permitting the user to interact naturally with them (Shelton & Hedley, 2003). This method may make it easier to teach subjects which make use of abstract concepts. The low technological cost to access AR will make it possible for students to engage with such experiences, perhaps widening the research in this area.

**Difficulties in Using AR for Education**

*Lack of Content-Creation Tools*

One of the disadvantages of implementing an educational AR tool is content creation. Creating educational content for AR requires both domain expertise and technical expertise. The difficulty in implementation arises from two factors: (1) AR experiences typically make use of computer graphics which are typically created by trained artists, and (2) the creation of such spatially-interactive experiences is difficult and there exist very few tools to aid this process (MacIntyre, 2003).

**Investment Costs**

As mentioned earlier in the discussion, the cost of bringing AR tools into schools can be expensive. Schools have to acquire technologies such as cameras, projectors and computers. In order to leverage augmented-reality for easily accessing educational content, this technology would not just be installed in computer labs, but in typical classrooms. Secondly, there is a maintenance cost required to ensure both the software and hardware will run smoothly and are kept up to date. Aside from the technology cost, there is also a cost to train teachers in using the technology and educational content. An additional difficulty faced by institutional administrators in adopting this technology, is the lack of empirical results about the use of this technology for education.

**Technology Learning Curves**

Although augmented-reality technology is intuitive to use, it cannot be claimed that it perfectly meets user expectations. The object-tracking technology is not fully precise, and there are typically errors in detecting positions of real objects; this can cause misalignment between virtual content and its physical counterpart, or unexpected movement in virtual content. Sometimes physical objects cannot be tracked at all, due to problems with lighting conditions, object recognition, or occlusion of the video camera. As augmented-reality becomes popular in the coming years, people will gain familiarity with the technology, and it is likely that there will be an alleviation of issues relating to technology use. At the same time, the “wow” factor in response to the technology will decrease, leading people to perhaps be less emotionally affected by experiencing augmented reality, and perhaps coming to expect more from AR applications.
Limited Research
Another difficulty is the lack of scientific research performed about how augmented reality impacts learning. The bulk of existing research has looked at the relationship between AR and spatial cognition (Kaufmann, 2005); AR experiences have been built for museums and potential use in classrooms (Billinghurst, 2000), but the effects on student learning have not been thoroughly investigated. Due to scarce research on this topic, a viable research approach is to integrate knowledge from other fields such as virtual reality, tangible interfaces, collaborative computing, and other educational-technology research. The funding for such endeavors is difficult to obtain largely due to the lack of research in this field, combined with lack of public knowledge about augmented-reality. However, as noted above, the near future will see an increase in public awareness of AR technology, and will likely lead to increased demand for AR-based educational interventions.

References


