AUGMENTED REALITY IN EDUCATION – CASES, PLACES, AND POTENTIALS

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ABSTRACT

Augmented Reality is poised to profoundly transform 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 enable learning in a range of other ways. This paper will review uses of Augmented Reality both in mainstream society and in education, and discuss the pedagogical potentials afforded by the technology. Based on the prevalence of information delivery uses of Augmented Reality in Education, we argue the merit of having students design Augmented Reality experiences in order to develop their higher order thinking capabilities. A case study of 'learning by design' using Augmented Reality in high school Visual Art is presented, with samples of student work and their feedback indicating that the approach resulted in high levels of independent thinking, creativity and critical analysis. The paper concludes by establishing a future outlook for Augmented Reality and setting a research agenda going forward.

KEYWORDS

Augmented Reality, AR, Pedagogy, Mobile, Design Based Learning, Higher Order Thinking

INTRODUCTION TO AUGMENTED REALITY

Augmented Reality technology is gaining popularity within society and becoming more ubiquitous in nature (Johnson, Smith, Levine, & Haywood, 2010). Augmented Reality Systems can be defined as those that allow real and virtual objects to co-exist in the same space and be interacted with in real-time (Azuma, 1997). The process of combining virtual data with real world data can provide users with access to rich and meaningful multimedia content that is contextually relevant and can be easily and immediately acted upon (Billinghurst, Kato, & Poupyrev, 2001). Unlike Virtual Reality, which completely immerses the user's senses in a synthetic environment, Augmented Reality permits the user to perceive the real world through a virtual overlay. Virtual objects used in Augmented Reality Systems may include text, still images, video clips, sounds, 3-dimensional models and animations. Ideally these virtual objects will be perceived as co-existing within a real world environment. Several researchers have identified Augmented reality as having immense potential to enhance learning and teaching (for instance, Billinghurst & Duenser, 2012; Dede, 2009; Dunleavy, Dede, & Mitchell, 2009; Johnson, Adams, & Cummins, 2012; Kaufmann & Schmalstieg, 2003; Shelton, 2002; Squire & Jan, 2007).

Augmented Reality can be considered to lie on a 'Reality-Virtuality Continuum' between the Real Environment and Virtual Environment (Milgram, Takemura, Utsumi, & Kishino, 1994). Augmented Reality is the type of 'mixed reality' whereby digital content is infused into the real environment, as opposed to Augmented Virtuality where real world content is transplanted into a Virtual Environment (see Figure 1). Thus Augmented Reality can be seen as a conduit for bringing together education in virtual environments and the real world.

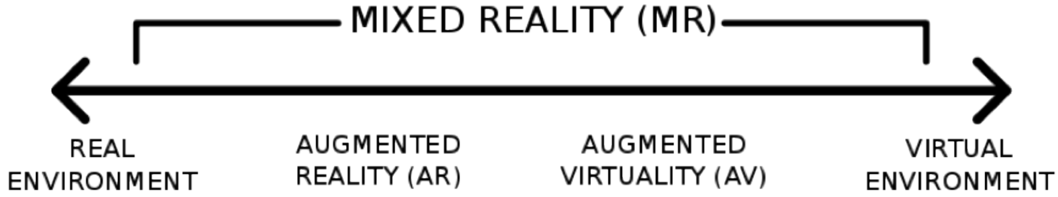

Figure 1. Milgram et al's (1994) Reality-Virtuality Continuum

The basic hardware requirements of an Augmented Reality System include (Azuma, 1997; Billinghurst, et al., 2001):

- the presence of a video camera to capture live images,
- significant storage space for virtual objects,
- a powerful processor to either composite virtual and real objects or display a 3D simulated environment in real-time, and
- an interface that allows the user to interact with both real and virtual objects.

Although these are the basic requirements to run an Augmented Reality system, other technologies may be utilised in order to enhance the overall experience for the user (Johnson, et al., 2010). For example:

- *GPS Technology* – allows the system to take into account the user's real world location, ensuring that contextually relevant virtual data is provided to the user at geographically significant locations.
- *Image Recognition Software* – enables real world images and objects to act as 'triggers' for multimedia and model overlays, and also to anchor virtual data in the environment.
- *Speakers and Sound Systems* – enables relevant sounds and audio recordings to be played.
- *Internet Access – p*rovides a means of storing, retrieving and sharing content using social media and Web 2.0 technologies.
- *Intuitive Interfaces* – advances in touch screen, gyroscope, and haptic input technologies provide more natural means to interact with and manipulate virtual objects.

The sophisticated software and numerous hardware devices used by Augmented Reality systems are also utilised by a number of other technologies, however, the distinguishing ability of Augmented Reality is the seamless compositing of virtual objects onto a real environment in a contextually relevant manner (Billinghurst, et al., 2001; Chang, Morreale, & Medicherla, 2010). As a result of this distinctive function, Augmented Reality is predicted by some academics to be the fundamental user interface of the 21st century (Kroeker, 2010).

USES OF AUGMENTED REALITY

The use of Augmented Reality systems has been investigated in a range of industries since the early 1990's, including medicine, manufacturing, aeronautics, robotics, entertainment, tourism and more recently, social networking and education (Azuma, 1997; Billinghurst, 2002; Hincapie, Caponio, Rios, & Mendivil, 2011; Shelton, 2002; Shin, et al., 2010; Shuhaiber, 2004). By overlaying media elements into the users' real world context Augmented Reality can provide cognitive support for difficult tasks. Examples from industry include driver training (Regenbrecht, Baratoff, & Wilke, 2005), practising aspects of complex surgery (Cristancho, Moussa, & Dubrowski, 2011), and learning how to change a filter on a space station (Regenbrecht, et al., 2005). Recent improvements in mobile computing power and functionality have led to larger resources being directed to the development of mobile Augmented Reality systems (Johnson, et al., 2010), and thus Augmented Reality is now widely available to regular consumers rather than solely residing in the domain of high-end laboratory research and industry.

Some more popular uses are emerging that illustrate the possibilities of Augmented Reality. For instance, there are several location based content aggregators emerging, which can siphon information about the surrounding environment. For instance Wikitude (http://wikitude.com) allows information about sights, restaurants and events to display in a text layer on top of the camera viewport. Plane Finder AR (http://my.pinkfroot.com/page/plane-finder-ar-track-live) superimposes an information layer over planes in the region, providing their flight number and distance in real-time. Worksnug (http://worksnug.com) finds free wifi in the locality, superimposing the direction and distance of the wifi service over the camera view. Other location based augmented applications enable users to exchange location-based information in the real environment. For example SekaiCamera (http://sekaicamera.com) enables users to leave 'airnotes' using text or audio in locations around the globe, and provides the functionality for others to leave replies. Alternately, StreetTag (http://www.designboom.com/technology/street-tag-iphone-app/) enables people to leave graffiti in a layer over the world, meaning that users do not need to disturb streetscape in order to leave graffiti tags.

Several vendors have released showcases of how augmented reality can use images to trigger engaging and interactive models. For example the Paper4D showcase (http://paper4D.com) has various image markers that manifest steaming hamburgers, a moving sportscar that enables users to change its colour, a box of popping popcorn with a movie embedded, and a rattle-snake that strikes at users who venture too close. String (http://poweredbystrong.com) uses markers to create effects such as dragons popping out of walls, writing with 3D ink, and a pet alien that can be walked around the room. Some applications such as those by AR Media (http://www.inglobetechnologies.com/en/products.php) and BrainGapps (http://braingapps.com) enable the user to select and manipulate multiple models via the application interface using only one marker. AdSugar Media (http://adsugarmedia.com) demonstrates how models triggered by separate markers can interact using a physics engine, cannon balls fired from one trigger image gradually knocking down a wall of boxes triggered by another image.

There is also a range of augmented reality games that demonstrate potentials of the technology. Games like Live Butterflies (http://sealiongames.com) and Alien Attack (http://www.apptoyz.com/apps/alien-attack/) superimpose beings on the screen in camera mode for users to catch or shoot. Note that these do not use any information from the real-world environment other than to consistently situate the multimedia overlays. AR Basketball (http://augmentedpixels.com) extends upon this by using a marker to enable multiplayer basket shooting. ARSoccer (http://labs.laan.com) allows the user to control a virtual soccer ball through kicking motions. There are also extended role-play games such as Ingress (http://ingress.com) and Shadow Cities (http://shadowcities.com) that use location-based augmented reality to superimpose information throughout cities and turn the world into a real-time playing field.

Educational applications of Augmented Reality are also emerging. The LearnAR resource centre provides a package of ten marker-based Augmented Reality learning experiences for biology, physics, languages, English, mathematics, and religious education (http://learnar.org). Fetch lunch rush (http://pbskids.org/mobile/fetch-lunch-rush.html) helps students develop elementary mathematics skills by asking them questions and requiring them to find an Augmented Reality marker with the correct answer. Zooburst (http://zooburst.com) supports students to develop 3D digital stories by enabling their uploaded photos, text and audio to appear in augmented reality form on top of an image marker. By superimposing language translations on top of signs and documents, Wordlens (http://questvisual.com) can be used to scaffold language learning.

Disciplines where more Augmented Reality apps have been developed enable teachers to create an integrated sequence of Augmented Reality experiences around themes. The topic of Space is one example. In search of an alternative sustainable place for humans to live, students could use the SkyView (http://www.terminaleleven.com/skyview) Augmented Reality star viewing application to plot a path to the Moon and Mars. Transparent Earth (http://www.hogere.com/transparentearth) could be used to peer through the globe and pick an appropriate launch site for the journey. Students could use ISS Live (http://spacestationlive.nasa.gov) to find the International Space Station and deduce how and where to dock. MoonGlobe and MarsGlobe (see http://www.midnightmartian.com) could enable students to explore the moon and mars for best places to inhabit. Spacecraft 3D (http://www.nasa.gov/connect/apps.html) could then be used to simulate Martian data collection.

Ventures to further planets could be facilitated through the Augmented Reality Planets3D book (https://popartoys.com). In this way combinations of augmented reality applications can provide students with a more immersive and situated experience.

Potentially even more exciting for educators is the emergence of Augmented Reality systems, which allow users to define their own triggers and overlays. Examples include Aurasma (http://aurasma.com) Layar (http://layar.com) and Junaio (http://junaio.com). BuildAR extends upon this to provide the first Augmented Reality Content Management System (http://buildar.com). This means that educators and students can start to design, build and manage their own Augmented Reality experiences.

AUGMENTED REALITY IN EDUCATION LITERATURE

Several educational uses of this Augmented Reality have already been documented in the literature. Augmented Reality has been used to develop students' understanding of science, including environmental science (Hsiao, Chen, & Huang, 2011; Squire & Klopfer, 2007), micro-biology (Chen, 2006) and biomedical science (Rasimah, Ahmad, & Zaman, 2011). The scenario-based "Alien Contact!" simulation has been used to develop mathematical thinking skills (Dunleavy, et al., 2009; Mitchell, 2011). Gamification and role-play based Augmented Reality has been applied to enhance motivation and a sense of authenticity in medical science (Rosenbaum, Klopfer, & Perry, 2007). There have been illustrations of how Augmented Reality could be used in the humanities, for instance through provision of a more engaging literary experience (Billinghurst, et al., 2001) and through the development of visual poetry (Lin, 2012). Augmented Reality has been used to enable students to study the virtual life cycle of a variety of butterflies (Tarng & Ou, 2012). There are also examples of students learning through the authorship of augmented reality systems, for instance as creators of science games (Klopfer & Sheldon, 2010), and students building Google Earth models using ARSights (Thornton, Ernst, & Clark, 2012). For a more detailed review of Augmented Reality usage in school and tertiary education see (Lee, 2012).

In an integrated sense the Augmented Reality technology allows educators to create a scenario, provide location-specific information based upon GPS position, inject scripted or Non Player Characters into the learning experience, and embed data (via image or object triggers) seamlessly within the real world context. Squire & Jan (2007) use all of these capabilities in their murder mystery game that requires students to deduce how a person died by gather evidence and interview virtual Non Player Characters. However the role of the educator as designer and facilitator appears to be a critical factor. In their use of Augmented Reality to track objects and graph vertical and horizontal velocity and displacement, Jerry & Aaron (2010) found that the teacher's use of thought provoking questions and their facilitation skills were critical in order to stimulate students' sense of challenge and enable the class to learn from the activities.

The use of Augmented Reality in the classroom has repeatedly been shown to increase student motivation (Billinghurst & Duenser, 2012; Johnson, et al., 2010; Tarng & Ou, 2012). Importantly, it has also been shown to contribute to student learning outcomes (Jerry & Aaron, 2010; Lee, 2012; Rasimah, et al., 2011; Tarng & Ou, 2012). Furthermore, the use of an Augmented Reality System had a small, yet positive effect on some students' learning attitudes and contributed to their perception of the relevance of their learning to their everyday lives (Jerry & Aaron, 2010).

LEARNING BY DESIGN

In the vast majority of instances described above Augmented Reality is being used by educators to provide students with pre-packaged learning experiences. This can lead to the situation where Augmented Reality only develops lower order thinking skills by supporting understanding and application, without encouraging higher order integrative thinking skills such as analysis, evaluation, and creation. An alternative to this is having students become designers with Augmented Reality in order to develop higher order thinking skills.

Design-based learning is founded in the Constructionist pedagogical paradigm, which espouses that students understanding of their world is best developed when they actively create real objects (Papert & Harel, 1991). Learning by design has been shown to improve student learning outcomes. For instance, science classes that used a design-based learning approach led to improved student performance and an increase in students' desire to learn Science (Doppelt, Mehalik, Schunn, Silk, & Krysinski, 2008). Using advanced video technology for design purposes has improve student understanding of topic- and domain-specific cognitive skills (Zahn, Pea, Hesse, & Rosen, 2010). As well as improved conceptual understanding, design based learning has led to improved motivation for students to pursue careers in the domain of practice (Apedoe, Reynolds, Ellefson, & Schunn, 2008).

In previous work van Haren (2010) has identified several mechanisms that underpin the positive effects of Design Based Learning approaches. Drawing on student knowledge can lead to heightened engagement. Intellectual quality can be promoted through discussing, problem solving, theorising, and drawing conclusions. The agency of students where they are enacting, developing, determining rather than passively receiving can encourage deeper understanding (van Haren, 2010).

In order to facilitate successful ‘learning by design’ Neville (2010) proposes that teachers need to have deep knowledge of the topic area and the capacity to foster a collaborative production-house learning environment. Also key is the desire and ability to select from a broad range of pedagogical approaches to enable student learning to shift from experiential to more conceptual and analytic forms (Neville, 2010). Neville suggests that the provision of dedicated time for professional learning and a willingness of teachers to engage with research breakthroughs and new knowledge are also critical elements for success.

The following section reports on how a design based learning approach using Augmented Reality was utilised to develop high school students’ Visual Arts capabilities. The project also investigated students’ insights into learning through Augmented Reality and its potential.

EXAMPLE: STUDENTS AS DESIGNERS WITH AUGMENTED REALITY

In Term 4 of 2012 sixteen High School students ranging in level from Year 8 to Year 10 were invited to participate in a Macquarie ICT Innovations Centre project aimed at exploring the potential of Augmented Reality in schools. The students, accompanied by their teachers, were invited to select a sculpture of their choice from the University Sculpture Park and then, using the Aurasma Augmented Reality platform (http://aurasma.com), design and create an augmented reality overlay that would be triggered by the sculpture. These augmented reality designs could then be used by visitors to the sculpture park so as to enhance their artistic experience.

To prepare students for their design task the Centre facilitated a one-day introductory workshop for participants. The workshop provided a background overview of Augmented Reality, a showcase of how it could be used in practice, a technical explanation of how Augmented Reality technology operates, and some hands-on tasks to help students learn how to create Augmented Reality experiences. The workshop also included a session that explored a selection of digital visual art activities and a discussion about the teachers’ and students’ experiences of learning with technology.

In the week after the one-day workshop students spent four days designing and developing their Augmented Reality experiences, guided by their teachers and Macquarie ICT Innovations Centre staff. Initially a curator from the University provided a history of the park and an overview of a selection of the sculptures, and students were given free choice over which sculpture they chose to be the focus of their work. Students were also provided with choice over whether they worked individually or in groups, with most choosing to work in small groups. Students discussed imaginative ways that they might enhance a visitor’s experience of a sculpture using Augmented Reality. The first two days were spent at Macquarie University to provide them with easy access to the sculpture park and to Centre facilities such as video cameras and a blue screen for filming. Having collected the images and film they needed, students returned to their school to complete and publish their designs.

Students were provided with accounts to Aurasma Studio where they created an Augmented Reality channel to host and organise their overlays. They created videos, animations, audio tracks, links, surveys, commentaries and interactive menus using iMovie, Photoshop, Adobe After Effects, Adobe Premier Elements, Adobe Fireworks, Keynote, Survey Monkey and GarageBand. The teachers and Macquarie ICT Innovations Centre staff provided guidance on how to use these tools where necessary, but the emphasis was upon rapid development of skills so that students could quickly become autonomous designers using the technologies. Due to difficulties with using object triggers in an outdoor environment where lighting and vegetation could change, image markers were used to launch the overlays.

Project leaders conducted and recorded a discussion with students on the last day of the project to determine students' perceptions of learning using Augmented Reality as well as their thoughts about the potential of the technology. The teachers from the schools were also asked to provide their reflections on the impact of the Augmented Reality approach. Students' planning and discussion sheets, as well as their actual Augmented Reality creations, provided further evidence as to the efficacy of the learning design. Three examples of student work are provided below, as well as a summary of key themes that emerged from the post project discussions with participants.

James and Chris's Design for 'Bridge' by John Petrie

Chris and James selected a sculpture called 'Bridge' by John Petrie. In preparation for creating their augmented reality experience they performed substantial research into how history, context and experience had informed the design of the sculpture (including information about the artist and materials used). They also studied the sculpture in detail, taking several photos from many different angles. James and Chris then created a prototype for their design, as a way of specifying the design elements and anticipating how they would function (see Figure 2).

The interface design enabled users to tap on different overlays that had been placed around the sculpture to find out more about the history, materials and design of the artwork. Students then evaluated the content that they could include for each of the elements, and subsequently created the multimedia texts that were launched when users pressed on the various button overlays. These texts included written, image and video explanations. The video was created by the students, and provided an interpretation of the sculpture that included how light and shadow had been used to project imagery on the hillside that was not apparent when inspecting the artwork out of context. The students were able to incorporate each of the elements that they had designed in their prototype, which required a significant amount of scripting and production skills in order to create, organise and automate the technological resources.

Figure 2. The student design of the 'Bridge' Augmented Reality interface

Rachel, Susie and Sammi's Design for 'Algoid' by Errol Davis

These students had a strong emotional reaction to 'Algoid', by Errol Davis, and as such decided to design a response that projected their interpretation of the sculpture. Their aim was to create an augmented reality experience that represented the mysterious, intriguing and spiritual nature of the artwork (see Figure 3). In order to create a loud and shocking atmosphere, they recorded an audio track of the metal sculpture being rattled. They superimposed a blue-screen video of a dark angel-spirit rising up from the grave to add to the ominous atmosphere that they felt the sculpture projected. They also incorporated an Augmented Reality textual explanation of their interpretation, including how their response aligned with meaning of the word 'Algoid', which is 'evil star' in Arabic.

Tom's design for 'Achievement through Unity'

Tom selected the sculpture 'Achievement through Unity' because he was struck by the feeling of unit and love projected by the two interlocking figures. He appreciated the contrast between the soft lines of their cloaks and the strong, stern lines of their faces, with their chins lifted in pride. The sculpture reminded him of Kings and Queens, of Lords and Noblemen. It prompted him to consider concepts such as honour, pride, leadership and responsibility. Thus Tom provided a personalised video interpretation of the artwork. The overlay related the sculpture to themes explored in other creative work (namely Lord of the Rings), and how unification underpinned the concepts of love, teamwork and courage. Tom also anticipated that this artwork would provoke in people a wide range of mixed feelings and ideas about its meaning, which prompted to him design a second overlay (see Figure 4).

Using Photoshop, Tom removed the sculpture from its location, leaving a silhouette of the sculpture in its place. This enabled the user of the Augmented Reality application to slide their own image into the place of the sculpture, as it stood in the courtyard. As Tom explained, the button he programmed to launch the overlay invites users to '*Change this reality. Slide a new image of unity under your camera*', as a way of emphasising how different people may choose to view the artwork in different ways.

Figure 3. Students' blue-screen video overlay providing an emotional interpretation of their sculpture

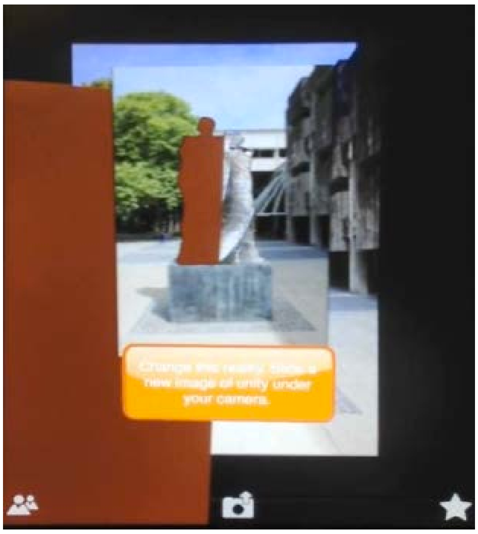

Figure 4. A student's Augmented Reality overlay that enables users to insert their own sculpture interpretation

In the above cases students were centred in the learning experience by virtue of being placed in the role of authentic designers. They demonstrated a deep level of appreciation for the artworks and created wide ranging, well considered, media rich responses. Students indicated that designing Augmented Reality experiences for the sculpture park was challenging, but because they were motivated they felt that the challenge made them "want to go in depth". They knew that their creative responses were going to be shared with the public and this was of value to them – "we are more excited about our own ideas instead of a textbook answer". Instead of merely completing pre-canned activities they were able to "think differently and have their own perspective". They also identified how the design environment stimulated them to "try new things" and "constantly be imagining new ideas". It encouraged them to search for alternatives and explore their "own choices, not pre-set choices". This led them to feel that the learning experience was both individual and personal.

Students also appreciated how Augmented Reality technology could also enable them to undertake activities that they would not otherwise be able to perform, such as creating virtual explosions or breaking apart igneous rocks. One student commented that "the AR project has helped me to think deeply about technology". Students also indicated that they enjoyed the experience immensely, and expressed a sense of pride in being able to share their creations. The teachers confirmed that the quality of students' work was beyond that which would be expected using regular approaches.

CONCLUDING COMMENTS

Augmented Reality has the potential to supplant the Internet in terms of size and application. But as often noted in the educational domain, utilisation of technology is by no means a guarantee of success. On the contrary, poor use of emerging technology can result in inferior learning outcomes. The challenge for educators is to harness the power of Augmented Reality in ways that contribute to the ultimate growth of students, and that means supporting the development of students' higher order thinking capabilities.

Of the uses of Augmented Reality described in the review section of this paper, by far the majority related to provision of information and lower order thinking capabilities. These are important functions of Augmented Reality – to offer knowledge in a way that is more closely and immediately related to the world around us. Yet, in terms of learning, solely using Augmented Reality for information provision limits the cognitive development of our students of the future. Augmented Reality is yet another example of technology making lower order thinking tasks redundant (for instance remembering capital cities and performing routine calculation processes such as long division). Technology can now perform lower order thinking processes for us, and while engaging these thinking skills can be useful mental exercise, overemphasis upon lower order thinking constrains the amount of time that can be dedicated to having students think critically and utilise knowledge in creative and meaningful ways.

It is important for educators to anticipate developments in Augmented Reality so that they can prepare for what is to come. Future developments in Augmented Reality will undoubtedly include new trigger types (sound, temperature, smell, voice recognition, etc), more intelligent input recognition (for example more accurate gesture detection as is already being evidenced by products such as Leap Motion) and increased sophistication of expression types (for instance vibration, more complex 3D interactive models, scripts to networked devices such as printers and lights as outlined by 'Internet of Things' proponents). Devices will become more transparent and integrate seamlessly into our everyday worlds – the imminent commercial release of Google glasses is a first step in this direction (see http://www.google.com/glass/start). We should expect to see augmented reality on our car windscreens, contact lenses, and household appliances in the not so distant future. Organisations will be competing for users to sign up to their AR channel/s, and we can expect that the majority of advertising will be in the augmented space. Advances in search engine technology that enable more intelligent retrieval of information (such as http://www.wired.com/business/2013/04/kurzweil-google-ai/) will contribute to heightened convergence and synthesis of information streams, so that people will have access to precisely the information they need precisely when they need it. Eventually people's needs will be even more easily satiated without need for haptic, voice or other input commands once computer-brainwave interfaces mature and our experiences are stored in cloud based neural networks (for elaboration of this concept see http://techcrunch.com/2012/11/25/5-ways-augmented-reality-is-starting-to-get-real/).

Future educational applications of Augmented Reality will most likely include overlays in the classroom with grades, special provisions, and medical and social information. As Augmented Reality becomes more intelligent it will be able to alert teachers to student learning needs, behavioural issues and recommended courses of action in real-time. Students will be able to run 3D interactive historical events on the palm of their hand, and go on virtual field trips to the zoo, or a dinosaur park, or any time and place that can be imagined. Yet at the end of the day, as is currently the case, these students will go on to be the designers of our world and learning experiences for future generations, and as such, it is critical that creative, analytic and integrative thinking features heavily in their curriculum.

Augmented Reality technology is advancing so rapidly that educational research has not been able to keep pace. Future research needs to move beyond Augmented Reality as a novel learning technology to examine learning and teaching issues of import. How can Augmented Reality be most effectively used to promote cognitive development? How can the networked nature of Augmented Reality be utilised to effectively facilitate and support collaborative learning? What Augmented Reality design and implementation strategies best support student learning? How can we best support teacher design thinking to leverage the potentials of Augmented Reality? These questions more generally are the cornerstones of educational technology research, and present the field with a significant research agenda as Augmented Reality learning design expands and evolves into the future.

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