Exploring Augmented Reality in Education Viewed Through the Affordance Lens

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ABSTRACT

Augment reality is slowly emerging as a new way of better engaging and supporting learners. Its adoption within education has shown to improve learning achievement, increased motivation and engagement with learning. However, despite this interest, this area its application within education is still developing with most studies confined to being small scale and exploratory. For AR to reach its true potential a number of barriers are still to be overcome and more work is needed to determine its true place in education. An important first step to support this adoption is to start identifying the how AR is different to other technologies that support learning. This paper explores four key affordances identified that make AR unique in terms of what it can offer education. These affordances include; visualisation of the 3D and the invisible; contextualised information; portability of the device to interact with the location and social and shared engagement. These four affordances are explored within the context of current research and with these, the paper starts to build a picture of how AR can be further to developed to ensure that AR continues to be a more credible learning tool in the future.

Keywords: Augmented Reality, Virtuality Continuum, Affordance, Mobile Learning

1. INTRODUCTION

Augmented, virtual and mixed reality in education is an emerging technology that bridges the gap between computer generated and real world environments (Uluyol & Sahin, 2016). With the success of games, like Pokemon Go, along with the increase of affordable wearable devices, such as Google Cardboard (that rely on the ubiquitous nature of mobile devices), the interest in how these technologies can be incorporated into education is growing. According to the latest Horizon Report (Adams Becker, Cummins, Davis, Freeman, Hall Giesinger & Ananthanarayanan, 2017), augmented reality (AR), virtual reality (VR) and mixed reality (MR) is to play a significant role in the future of education. However, despite this interest, this area of research is still emerging with many studies still either small scale in nature or conceptual in nature (Bacca, Baldiris, Fabregat, Graf & Kinshuk, 2014).

Despite the emerging nature of these technologies, research has shown that these technologies can provide great benefit to supporting and engaging learnings. In particular, research has shown that the effective adoption of these technologies can create engaging learning spaces and push the boundaries of learning (see for example see Akçayır and Akçayır, (2017), Kurilovas (2016) and Saltan and Arslan, (2017) for a systematic review of the literature within this area). In particular, studies have shown that the integration of natural user interfaces has enabled students to explore and interact with digital and real environments (supplemented with rich digital content) and enable educators to enhance learning. Specifically, the benefits of these technologies have been shown to improve learning achievement, increased motivation and engagement (Akçayır & Akçayır, 2017) and engage learners in authentic learning contexts (Cheng & Tsai, 2013). The adoption of mobile devices to support the integration of these technologies have further enabled learning to occur anywhere any place and has made these technologies even more accessible (Bacca, Baldiris, Fabregat, Graf & Kinshuk, 2014).

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To start exploiting the benefits of these technologies to bring these technologies into more mainstream adoption, a good starting point is to start with identifying the unique attributes that these technologies beneficial to learners. By examining these technologies through the lens of affordance can help to determine where these technologies can fit within education and how they can be further exploited to better support and develop learning.

This paper will provide a starting point for future exploration of AR technology by examining it in terms of its specific affordances. The aim is to through the lens of affordance to start examining the future potential of AR and to start answering the question of why AR has yet to reach its full potential. Despite the introduction of this paper covering both AR, VR and MR we will focus specifically on AR technologies, as this is seen to provide the greatest potential for education, at this current time. However, since AR, MR and VR are tightly entwined we will first introduce these three technologies and provide a justification of why we are specifically exploring AR. Then we will further explore AR technology in the context of the relative affordances which this technology brings to the area of education. With these affordances in mind, we then examine why AR is still fairly limited in its adoption with education, and particular in NZ. This then provides a focus for future research and implications for future research.

2. THE VIRTUALITY CONTINUUM

Before we start examining the unique affordances of AR, we need to provide a clear explanation of AR/VR and MR and in particular how these technologies merge and converge. The merging of these technologies is referred to as the Virtuality Continuum (Milgram & Kishino, 1994), as depicted in Figure 1. The AR and VR appear at either end of the VC spectrum whereby the AR superimposes the virtual environment into or more specifically over the real environment. The VR presents a purely virtual representation of a real environment - this in itself presents a greater demand on the enabling technologies, which will be discussed further. Retrospectively the degree of AR immersion in the real environment is at a lower level suggesting in general that a lesser demand is made on the enabling technologies.

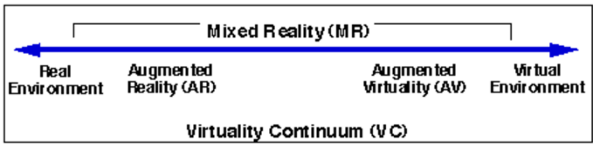

Figure 1: Simplified representation of a "virtuality continuum". ***Source: Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. IEICE Transactions on Information and Systems, 77(12), 1321-1329.***

2.1 Virtual Reality

The VR experience provides a simulacrum of the real world environment as far as we can perceive it. As a concept it can be traced back as early as the 1950's with the advent of projection (Addison, 2000) and simulation technologies (Rosen, 2008), however, it was not until the improvement of digital technology that the VR environment started to advance and the simulation to full immersion became a possibility. It can be argued, computer games are a rudimentary form of VR sans the sensory input and output that enables the degree of immersion. However, the full VR experience has still not reached the popularity and adoption status such as the likes of Facebook, Whatsapp and other technologies.

The uptake of VR outside education is growing, however, it wasn't until 2015, when a little a known Kickstarter project was launched, that VR popularity increased. This project was the first beginnings of what is now known as the Oculus Rift System and is considered the impetus of VR becoming a household technology (Dredge, 2014). The later purchase of Oculus by Facebook has only increased its massive marketing penetration capabilities, where Oculus was now able to leverage from Facebook's over 2 billion users (Constine, 2017). This VR technology promises the ability for almost total immersion within a virtual environment. Total immersion here referring to the user's ability to totally interact with the virtual environment in such manner as they would interact in the real world (van der Ham, Faber, Venselaar, van Kreveld & Löffler, 2015). This near total immersion has the ability to provide the opportunity for numerous inputs into the VR environment and limited feedback. The feedback being audio, visual and limited tactile. At the same time as this early beginnings, AR was also being incorporated within other products with the likes of HTC's Vive, Sony's Project Morpheus and many other lesser known VR kits. At this time the Oculus and the Vive were the only two consumer available kits that could provide the near total immersion. The lesser known VR kits provided at a minimum, the helmet and some sensory outputs. The limitation came in the sensory input for is the location real space. On the other hand, new projects like Samsung Gear VR helmet have started to leverage a user's mobile device, for the computing power and most of the sensory inputs and output, making these tools more accessible and cheaper. However, it is still to be seen if the integration of mobile devices to engage with VR prove to increase the popularity and ultimately provide a more viable future for VR (Emad, 2017).

Despite the increasing number of products being developed there is still a limited market and application for VR technology. One of the main concerns with the VR is the possible physiological effect of limited extended use. In particular, concern with the possibility that a user may become "detached" from the real world (LaViola, 2000, Barrett, 2004, Lawson, 2014) and eventually after a short period time, around 30-40mins of use, become physically ill much like that of motion sickness. This can be considered one of the issues when considering VR for education. In addition that this effect certainly discounts its use with children around 2-12 as they are more susceptible to motion sickness which eventually reduces by adulthood (> 21) (Reason, 1975, Kolasinski, 1995).

2.2 Augmented Reality

Experiencing AR is very different to VR in that we do not have the near or total immersion found with VR. What we do have is where the virtual environmental elements are superimposed upon the real environment. As with VR mobile technology, mobile devices are seen as an accessible way to engage with AR. Due to their size and portability means that mobile device allows for easier interaction, by allowing the student to more easily point the webcam device at a suitable target. The target in this situation translates to the "fragment" that is to be superimposed over the real world view. For example using a mobile device to translate street sign written in some foreign language on the fly where the translations are overlayed in the user's preferred language (Khan, Hora, Bendre & Tirth, 2014). The use of the mobile enables the user to engage with the environment and AR can be used in more ways.

What is immediately apparent in this scenario is the user of the technology is fully grounded, sensory wise, within the real world. The physiological issues apparent with VR are not present in AR, suggesting a more appealing type of virtual technology than when compared with VR. As with VR, AR is not a new concept and shares a similar beginning to VR (Zhou, Duh, & Billinghurst, 2008). Its appeal, however, becomes more apparent when you compare not only the affordability of the technology by also the technology required to enable AR activity (Azuma, Baillot, Behringer, Feiner, Julier & MacIntyre, 2001). Generally, it can be considered to be a far lower performance demanding technology simply because the AR does not require the simulation of the real world environment. In particular, where "fragments" of reality are virtualized over the real world, this this, therefore, does not require the same processing capabilities as for VR.

2.3 AR and VR and its Application to Education

Worldwide the adoption and use of AR and VR are still small and only seen in the limited application within specific areas of education (Akçayır & Akçayır, 2017). Largely the adoption of these technologies has been primarily focussed on consumption of learning over social constructivist and constructionist learning. In addition, learning is typically focused on a narrow set of learning objectives (Bacca, Baldiris, Fabregat, Graf & Kinshuk, 2014, Martín-Gutiérrez, Mora, Añorbe-Díaz & González-Marrero, 2017). Within VR and the more blended MR, these issues are especially true. The development of learning artefacts is typically complex and relatively difficult to do, with development largely within the domain of large corporates or one off applications. In addition, the application of these technologies to encourage social engagement is also difficult, as interaction with the technology requires the use of a headset and typically engagement is wrapped around the individual rather than a group of learners. There are some exceptions to this, for example; Google Tilt Brush allows for 3D virtual worlds to be created and shared, and Google Expeditions allows teachers to create their own tours and lead a group of students on this tour. However, these are largely the exception rather than the rule.

When considering AR separately, AR has typically become more popular than both MR and VR. AR provides many advantages over VR. Since AR does not typically require the purchase of an additional bespoke hardware to engage and that it can typically be accessed from the student's own mobile device helps to make it more appealing to education (Alvarez, Pérez-Pérez, Paule & de Freitas, 2016). In addition, there is an increasing number of tools that now enable educators and students to develop their own AR environments that require little to no programming (for example using tools such as Augment.com, Aurasma.com, Quiver.com and for more technical tools Unity.com). Exploration of these AR environments can also be shared collaboratively as users can engage with each other simultaneously without the barrier of a headset (Szalavári, 2008, Billinghurst, 2002).

Based on these advantages of AR over VR this paper will, therefore, focus solely on AR. The following starts to identify and define the key affordances that make AR appealing to education.

3. EXAMINING AR THROUGH ITS AFFORDANCES

To truly understand the potential of AR it might be best to determine how AR is unique terms of its affordance to supporting education. Addressing the unique characteristics of AR through the lens of affordance will help to clarify what features AR brings to the context of education. In addition, this approach will provide a possible focus for how AR could be further exploited in the future to better facilitate learning. From examining the literature we have identified the following affordances which AR technology provides education, these affordances are identified in table 1 and further discussed in the rest of this paper.

Table 1: Affordances of Augmented Technology

Affordance	Context of use	Examples in education
Visualisation of the 3D and the invisible	Viewing 3D digital representations of objects to enable students to visualise and explore abstract concepts or unobservable phenomena	Enhanced textbooks to demonstrate concepts Demonstrating mechanics or functions of physical interactions in a classroom Augmented a paper-based colouring book with 3D content and provided children with a pop-up book experience of visualizing the book content
Contextualised information	The overlaying of visual or digital information over the physical environment	Overlaying information textbooks Overlaying technical/concepts information to support interaction linked to real world objects
Portability of the device to interact with the location	Mobile devices enable learners to engage in real environments.	Game-based learning Exploration of an environment
	Information and digital content is accessed based on learner's current context	Immediacy of information to support engagement Authentic learning situations and Language translation
Social and shared engagement	Supporting engagement and interaction between students collocated or remotely	Collaborative manipulation of 3D objects Field trips exploring an environment Game-base
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Based on the above affordances we can start exploring how these affordances are exploited and can be further exploited in education. The following section starts to explore these four affordances in context with the literature.

3.1 Visualisation of the 3D and the Invisible

AR is able to enhance the learning experiences by making the invisible visible and supporting the exploration of objects but enabling students to manipulate 3D objects (Wu, Lee, Chang & Liang, 2012). Using AR technology students are able to engage and view 3D representations that would be otherwise not visible or difficult to show within a classroom environment. The visualisation of these 3D models has been shown to give students a better understanding of concepts since these models facilitate the ability for these models to be manipulated and examining in different ways (Yuen, Yaoyuneyong & Johnson, 2011). In addition, by superimposing animation or video within these models they can further expand learning and understanding. By enabling students to interact with 3D objects studies have shown that it supports more engaged learning and can make learning more "real" (Kaufmann & Schmalstieg, 2003). As students are able to view how parts are linked together and manipulate objects from different angles which would not be possible in a 2D interface or with video or images this enables learners to engage with the objects and provide an authentic learning experience (Kaufmann & Schmalstieg, 2003). For example, in study looking at teaching students basic chemistry concepts, students are able to select chemical elements, then using their mobile devices compose these chemical elements into 3D molecular models, and rotate these models, therefore, enabling students to develop deeper understanding of these elements in a way that was more engaging (Fjeld & Voegtli, 2002).

AR has also been adopted as a good way to supplementing traditional 2D textbook images. AR is used to activate interactive 3D models with the use of the mobile device. Publishers, such has Pearsons International, have invested significant research into how AR technology can better facilitate learning (Yuen, Yaoyuneyong & Johnson, 2011). Research has shown that the use of augmented book enhance the perceived value of the learning material, support better illustration of concepts and provide a better understanding of text material (Dias, 2009). By integrating 3D objects into augmented books has allowed students to explore objects from a variety of different perspectives which enhances understanding (Wu, Lee, Chang & Liang, 2012). AR technology with 3D modelling has been adopted in a number of studies teaching a number of different subjects. For example in Liarokapis, et al., (2004) they explore the development of 3D models for teaching engineering. In this study, they describe how 3D models could be used to better teach the inner working of a camshaft. A 3D model was used to teach students the components and workings of the camshaft. Students were able to interact with this model by rotating, showing the different components or scaling the model, therefore, giving students a better understanding of the inner workings of the camshaft. In Kaufmann and Schmalstieg, (2003) they discuss how AR technology can be used to explore geometric objects when teaching maths. In this study, they used 3D models of geometric shapes which could be manipulated and arranged together. The use of 3D modelling was shown to better improve the students' spatial abilities and modelling. In addition, it also encouraged the learners to experiment with the shapes, this ultimately helps to maximise learning especially when students were able to interact with each other and collaborate. In a different example, in Clark, Dünser, and Grasset (2011) they showed that augmented colouring book with AR enabled 3D content provided children help young children to better visualising the book contents and aided understanding.

In addition to the benefits of AR to model 3D content, thus enabling learners to explore concepts better, it also enables the depiction of what would otherwise not be visible. For example, in Blum, Kleeberger, Bichlmeier, and Navab, (2012), they use AR technology to teach anatomy. In this study, they use AR technology along with a camera to superimposing 3D models of the human anatomy over a student standing in front of a camera. The use of AR enables students to view 3D models of organs, text information and images superimposed over their body. This study showed that the use of AR in this way was able to attract and engage learners by giving learners a new way to view the interworkings of the body. The students were also able to interact with the 3D representation using gesture based slicing. By letting the students engage with this 3D model (over just viewing the representation) meant that students engaged with the tool at greater lengths of time. The tool enabled to get a greater understand of where the different organs are on the body and made learning more impactful compared to if they just view this in the 2D.

3.2 Contextualised Information

AR also allows for combining or supplementing real world fragments with virtual objects or superimposed information beyond just 3D models. This overlaying of information can be multi-sensory and therefore it can be more than just providing information with a 3D form. The overlaying of information that is contextualised is especially powerful. AR to provide contextual information has been seen by the industry as particularly powerful, systems such as the BMW maintenance support system which overlays contextual information onto a physical system (the vehicle) to enable technicians to fix and maintain the car is one such system adopting this approach (Specht, Ternier & Greller, 2011). In addition to this approach being well adopted within select industries, AR has been used to support day to do life, for example LiveGuide (http://liveguide.de) is a mobile application developed to provide residents and tourists of a German city with the opportunity to explore their surrounding by displaying points of interests viewable via their phones when walking around the city (e.g., public buildings, parks, places of events, or companies).

Augmented reality applications enable the ability to filter information and present this information as an overlay relative to the user's current context. As described in Specht, Ternier, and Greller, W. (2011), this information when displayed in context can be filtered according to location, movement path, facing direction, the object in focus, time period, or meta-information such as the learner's personal interests or profile.

Within an educational context, there are a number of examples, for example in Ibáñez, Di Serio, Villarán, & Delgado Kloos (2014) they discuss the development of an application for teaching the basic concepts of electromagnetism. This application was used by students to explore the effects of a magnetic field. Components such as cables, magnets, batteries could be could be arranged by students with information superimposed over the arrangement, accessible from their mobiles, providing information on the electromagnetic forces and the circuit behaviour.

Providing contextualized information in a just-in-time approach has been shown to be able to support scaffolding and extend students understanding and support self-directed learning. In a study by Kamarainen, et. al, (2013) they describe how AR technology helped students to learn how to use sophisticated recording devices to gather environmental information while students were on a field trip.

In addition, AR has been shown to better support learners understanding when compared to using VR technology (Liou, Yang, Chen & Tarng, 2017). In this study, the researchers compared the use of AR and VR technology to teach young children astronomy. The study found that the use of VR required significant cognitive demands compared to using AR. In the VR system students were able to explore a virtual celestial body, however, the use of the VR system meant students were often isolated in their exploration and it also required greater mental effort for students to explore the concepts underlying this system. Whereas the AR system, allowed students to easily use and explore the concepts especially as the interaction was easier to access due to the digital content and real objects were shown on the same screen. This was found to lead to decreased mental load when compared with the VR system.

3.3 Portability of the Device to Interact with the Location

When supplementing AR technology with ability contextualised information based on a location of a learner further expands the potential of AR. By using mobile devices to engage with learning environments, supported by AR technology, provides many opportunities for learning to become more authentic and situated. The mobile device provides the ability to connect to internet supplemented by location-awareness technology, can enable learning to be ubiquitous, collaborative and situated (Wu, Wen-Yu Lee, Chang & Liang, 2012). Mobile devices as especially well-suited to engaging with augmented environments due to their accessibility, portability whereby the learners are able to be immersed into their own personal learning environment but still has the ability to enable the learner to easily engage with others (Furió, González-Gancedo, Juan, Seguí, & Costa, 2013). When combining contextualised information with the real physical environment this enables learning to be more experiential and contextualised and overall more authentic. The developing of these learning activities has also become easier, with a number of applications (such as Layer and Wikitude) now enabling educators and students to create their own augmented environments using location awareness accessible via their mobile devices (Wu, Lee, Chang & Liang, 2012).

Several studies have demonstrated how supplementing location-awareness with AR educational games can help to improve learning. One such study by Alvarez, Pérez-Pérez, Paule & de Freitas, (2016) outlines the development of a web and mobile-based application, which enables learners to be immersed in a physical environment and uses AR to explore the environment. In their study, they integrate geo-located multimedia content to support 'in-situ' knowledge about the local environment (geography, geology, natural materials and vegetation) while children are on a class field trip in the woods. In a further extension of this ideas, by some of the same authors, the Conserv-AR application used GPS location awareness and game based learning to teach students about conservation (Phipps, Alvarez, de Freitas, Wong, Baker, & Pettit, 2016). In this application, the players choose an animal and topic that they wish to learn about and then are directed to a physical environment using a dynamic map and a waypoint arrow undertaking various tasks. Virtual 3D objects and short text based information are used to engage and inform the player about a specific location and teach them about the local environment.

3.4 Social and shared engagement

Underlying exploration within a collaborative and social interaction enables more powerful learning, thus drawing on social constructivist learning theories and collaborative interaction. VR technology, that requires the user to be fully immersed in a virtual environment, has the drawback of supporting collaborative work difficult. AR, on the other hand, lends itself much better to social learning. Learners can engage with each other and the digital environment as digital information can be engaged with multiple screens or even through sharing of the same screen (Morrison, et. al, 2011).

By supplementing the portability of mobile devices, to engage in real environments, with social interaction enables learners to co-create their own understanding. AR can be harnessed to create a learning experience that is student-centered and provides opportunities for peer-teaching, collaboration, and one-on-one teacher guidance (Kamarainen, et. al, 2013). Many of the studies discussed above had elements of social interaction and co-construction (For example, Phipps, Alvarez, de Freitas, Wong, Baker, & Pettit, 2016, Alvarez, Pérez-Pérez, Paule & de Freitas, (2016); Wu, Lee, Chang & Liang (2012); Furió, González-Gancedo, Juan, Seguí, & Costa; (2013); Ibáñez, Di Serio, Villarán, & Delgado Kloos (2014) and Blum, Kleeberger, Bichlmeier, and Navab, (2012)).

In addition, AR technology can also be employed to help learners build social presence and bring learners together. For example in a study by Pettit & Kukulska-Hulme, (2007), explored how supplementing campus map with AR digital overlay of friendship circles in order to arrange meet-up times and locations.

AR technology has also been shown to support the interaction in non-face to face environments. For example, AR can be used to support learning and sharing in a virtual environment. In a study by Specht, Ternier, and Greller (2011) showed how AR could be used to collaboratively annotate and tag real-world objects and share this information with others. This was further expanded by embedded shared artefacts in AR games that support the collaborative manipulation of 3D objects.

4. CONCLUSION & FUTURE RESEARCH

Despite the ubiquitous penetration of AR capable mobile devices, we have still seen a slow uptake of AR related software in education. Despite AR technology be slowly adopted within everyday lives, for example, the integration of AR tools within social tools such as Instagram and MSQRD (which allowing active caricature AR images to be generated) the application within education is largely limited and confined to exploratory and short term studies.

By drawing together the unique affordances of AR technology helps to better illustrate how AR may be harnessed in the future. However, despite these already very achievable affordances, the adoption of AR technology and its application within education is still limited (Akçayır & Akçayır, (2017); Kurilovas (2016); Saltan & Arslan, (2017). This is especially true within New Zealand context. There are still a number of important factors that are still limiting the full adoption and exploitation of AR. This largely relates to the fact that AR technology is still only focused on limited applications of use with only limited applications, cannot be easily created by educators other than small exceptions mentioned previously and there are still only small cases of educators trailing and employing this technology. Large scale and extensive studies are still needed, especially those showcasing how AR may be effectively employed with more than limited, a single application for AR to go beyond the novelty effect and become more widely adopted.

Significant further development, resources and training of teachers is needed for the discussed affordances to be truly realised. However, this paper does highlight the potential that AR technology could offer educators if we are able to move beyond these limitations.

Concluding this paper, we refer to the musing of one of the most popular authors in this area, a Bernstein analyst called Toni Sacconaghi (as quoted in Ray, 2017) prophesied that Apple smart glasses (a major contender for AR and MR technology – moving beyond mobile phones) could generate over ~USD$25B which has the potential to really kick start AR, like the iPhone did for smartphones, however as he ominously concludes, it, however "always remains the possibility that all of this hubbub over AR could lead to nothing."

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