Seamless Learning Through Mixed Reality: A New Zealand perspective

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ABSTRACT

Mobile Mixed Reality (MMR) provides new ways to enable seamless learning. This paper explores how the affordances of MR, explored in the context of its two extremes Augmented Reality (AR) and Virtual Reality (VR), can underpin the principles of seamless learning. These affordances and principles are explored in the context of four examples of current research. These examples were selected as a way to explore these concepts but also provide an overview of some current research happening in New Zealand. The paper explores each of these cases in terms of how they highlight effective ways that MR can be drawn into the educational context to support seamless learning.

Author Keywords

Mixed Reality, New Zealand, Seamless Learning

INTRODUCTION

Seamless learning supports the integration of "learning experiences across various dimensions including formal and informal learning contexts, individual and social learning, and physical world and cyberspace" (Berge & Muilenburg, 2013 p101). Mixed reality (MR) supports the merging of real and virtual worlds to produce new environments and visualisations where physical and digital objects co-exist and interact in real time. Within the context of educational MR, a continuum exists. On one extreme, the environment that exists is almost completely virtual, whereby the learner is embedded within the virtual environment (virtual reality), while at the other extreme the digital experience overlays a very present physical world, where reality is augmented by the digital (augmented reality). MR covers all the areas within this continuum, where its application can have either a high or low mix of either the digital or physical worlds.

The blend of physical and digital worlds and the ways we move between them are fundamental to the application of MR in supporting seamless learning. Augmented experiences embed digital, location-specific and contextual information into a physical site which enables learning to be situated. Within more virtual contexts, the orientation of the digital and real can be more blurred. These digital worlds are often adopted as a way to learn within replications of (un)real-world experiences that would otherwise not be possible.

MR technologies, have provided new opportunities for creative and innovative approaches to seamless learning (Brown & Mbati, 2015). In the past, MR tools, especially those supporting student-generated learning artefacts, have been limited. These tools often had a significant learning curve before educators and students could use and develop within these environments. However, with the recent advancements of mobile technology and other associated online tools, new low-cost options have resulted which provide for student-driven and developed virtual and augmented learning artefacts without the high technical learning curve.

This paper explores the various affordances of MR and how these affordances can facilitate seamless learning. We draw on recent examples from New Zealand which explore the adoption of MR and consider how its application can support new learning experiences that move seamlessly between blended real and virtual contexts. The study concludes by bringing together how these examples highlight future directs for exploring seamless learning opportunities and the overall future work needed to make MR more mainstream.

Before we start exploring MR, and how it can be applied to support seamless learning, the next section will first provide some context around the current educational situation in New Zealand and how this frames the current adoption of digital technologies and its integration into the curriculum.

THE NEW ZEALAND CURRICULA AND DIGITAL TECHNOLOGIES

New Zealand has recently revised its technology curriculum to more effectively embed digital skills. As a result, all New Zealand schools need to strengthen the integration of digital technologies across the curriculum. In particular, two new digital technologies areas have been added to the curriculum - 1) Computational thinking for digital technologies, and 2) Designing and developing digital outcomes. These changes are based on the aim to grow 'digitally capable individuals' and learners being 'innovative creators of digital solutions', and not just 'users and consumers of digital technologies' (MoE, 2017a). This new curriculum highlights the focus on providing opportunities for learners to use digital technologies with critical and creative thinking to solve authentic real-world problems. The focus has been strongly placed on students being creators of digital experiences not just the consumers of technology.

The driving force behind the development of this new curriculum has been due to the significant shifts within the educational sector. The recent nationwide initiative to provide Ultra-Fast Broadband to all schools (MoE, 2017b) and the recent focus on developing innovative learning environments (ILE) (MoE, n.d.) has meant a stronger focus on integrating digital technology into the curriculum. This change now means that the use and development of digital technologies can no longer be a separate activity, divorced from the general curriculum, but rather integrated into all aspects of the learning experience (Parsons, Thomas, Lynch & MacCallum, 2018). This focus will mean that all teachers, not just ICT teachers, will need to be able to design new learning experiences underpinned by the application of digital tools and skills embedded within authentic and situated learning. A strong focus on cross-curricular learning is necessary to meet these goals. The integration of digital technologies into learning across different subjects is necessary to ensure that the learning outcomes, all requiring "authentic contexts and taking account of end-users", are delivered effectively (MoE, 2017a).

As a consequence, all educators (from K12 to tertiary) will need to explore and support learners to develop their own learning underpinned with effective use of digital technologies. New Zealand (NZ) is only just starting this journey to full integration but there are some emerging examples of excellent integration of digital technologies within the education NZ context.

THE VIRTUALITY CONTINUUM AND SEAMLESS LEARNING

Wong (2012) defines seamless learning as learning supported in a variety of scenarios or contexts and where a learner can switch between different contexts in an easy and quick manner depending on their needs. Within this context, seamless learning is heavily supported by the use of technology, especially their personal device. This device mediates and supports the experience.

Within the context of MR, these principles can be encapsulated in different ways. Virtual Reality (VR) and Augmented Reality (AR) bridge the gap between the real and the virtual in a seamless way as they provide different ways that learners can engage and learn (Chang, Morreale, & Medicherla, 2010). This engagement is often supported via mobile devices which enables the context, access and (in particular) the augmentation of ubiquitous to happen. Drawing from the relative affordances of MR, users are able to access information, collaborate with others, create and share these with each other that are generally (except for learning that is location specific) supported at any time or anywhere. Within this context, learning is seen to be seamless, since learning can be supported in a variety of contexts, including informal and formal learning locations. The link with mobile learning and seamless learning (and now within the context of VR and AR) is whereby learning can support the ability for learners to manage their own learning and switch between scenarios or contexts easily and quickly to enact their own learning goals.

MR holds promise in supporting more seamless learning since it encompasses the spectrum of both AR and VR, merging both real and virtual worlds. Based on the Virtuality Continuum (VC) (Milgram & Kishino, 1994), as depicted in Figure 1. AR and VR appear at either end of the VC spectrum and MR represents a blend of the two.

AR superimposes the virtual environment over the real environment, whereas VR separates itself from the physical world and users are immersed in a completely virtual world. The VC considers AR to be closely tied to VR as the concept of AR has evolved as an extension, or variation, of VR. Due to how the real and virtual environment is situated within the two approaches its application within the education context is varied. The following sections provide a brief overview of how each has been adopted within education.

Virtual Reality in Education

The adoption of VR within education is still somewhat limited. This limited uptake is primarily driven by the cost of equipment required to engage with VR environments. In addition, since VR typically means a full immersion of a user within the VR world, students are generally disconnected from others, making interaction difficult. So for long periods of use can also result in negative physiological effect (LaViola, 2000). This immersion means that users are transported to a completely new environment, however, the way they interact with this environment may still require some connection to their present location, such as through hand-held paddles or some other VR sensor.

Despite the uptake of truly immersive VR still being limited, virtual reality in education has had a rich history, especially when considering virtual worlds as a form of VR. Unlike true VR, where users engage with the virtual environment through a Head-mounted Display (HMD) and therefore are fully immersed, these virtual worlds are typically engaged through a computer monitor. Virtual worlds, though not primarily VR, but with similar concepts, have long been used in education to support learning goals. Virtual worlds such as Second Life, saw significant uptake in the late 2000s and it was considered as one of the most popular multi-user virtual world platforms being used in education at this time (Warburton, 2009). In its time Second Life was used as a space for holding virtual lectures and meetings, to share artwork and music performances, and to create educational simulations (Baker, Wentz, & Woods, 2008) and had been adopted to teach a range of subjects, but most notably in health care (Boulos, Hetherington, & Wheeler, 2007). Today, there is still some, but limited, uptake of Second Life for educational purposes (such as the recent study by Ozonur, Yanpar-Yelken, & Sancar-Tokmak, 2018). As well as recent efforts in developing these worlds to be fully immersive (Summers, 2017). In general, adoption of virtual worlds has seen a significant decline in interest in recent years, but Minecraft has shown a significant upsurge in educational use, suggesting that Virtual Worlds of this type still have the potential for learning.

With the recent innovations in mobile VR, VR has become more accessible. Mobile VR, such as Google Cardboard and Samsung Gear, use a mobile device placed into the HMD to display the VR content. There has been some uptake in developing educational content for these platforms such as Google Expeditions and Tour Creator. Google Expeditions is a VR platform designed specifically for schools and contains large numbers of virtual reality journeys. These journeys enable teachers to take their students on a guided tour of a range of locations, including outer space and the ocean (Brown & Green, 2016). Tour Creator enables students to create their own VR tours using 360-degree images created, for example using Cardboard Camera or Google Streetview. Beyond these low tech examples of VR, adoption of fully immersive VR experiences is limited. Generally, fully immersive experiences require the purchase of bespoke proprietary hardware and software and its application have been primarily in a narrow context, such as medical education (Hussein & Natterdal, 2015). However, as mobile technologies continue to develop more opportunities may present themselves for further wider application.

Augmented Reality in Education

Compared to VR, AR has been more readily adopted in education (Mac Callum, & Jamieson, 2017). Its wider adoption has generally been as a result of new technology (such as more powerful mobile devices and software making it more accessible. Also making AR more appealing to educators is that AR environments can also be shared collaboratively since users can engage with each other simultaneously without the barrier of a headset (Billinghurst, 2002). As with VR, the development of more powerful mobile technology has meant that AR experiences have become ever more accessible and new opportunities for student developed AR experiences are becoming more sophisticated and powerful (Alvarez, Pérez-Pérez, Paule & de Freitas, 2016). While student-developed AR experiences may be relatively simplistic, the ability for student-constructed artefacts enables a greater range of learning to be integrated. The use of AR goes beyond the experience itself into a wider set of learning goals.

AR works by overlaying digital content triggered by the real world. This trigger can be either through a marker, location or through recognising an object. Therefore the experience is overlapped and often engaged with the real world. This digital content generally provides context to the exploration of the real world. For example, AR has been widely adopted for field trips, where, the contextual digital content, such as 3D models, text, video or audio, is triggered to help learners engage with their location, either providing them with information about the specific location or providing tasks (such as collecting data) for students to undertake in a specific location **(**Kamarainen, et. al., 2013).

AR is also used to bring experiences to students no matter of the location. This has led to a number of AR solutions for learning support, including in storytelling or reinforcing information, such as used in textbooks where videos and animation can be engaged with to supplement the written information.

Affordances of MR

The above descriptions of how VR and AR can be used within education, highlight the relative affordances of different types of MR. Drawing on MacCallum and Jamieson's (2017), discussion of AR affordances, outlined in Table 1, the same affordances, can be clearly applied to VR. In addition, content production can be added to the original list providing the ability for users to develop their own experiences. Though full VR student-created experiences still remain difficult, experiences created through 360-degree camera or videos and those supported within the VR or VW provide limited student-created VR experiences.

MR Affordance	Encapsulated within VR environments	Encapsulated within AR environments
Visualisation of the 3D and the invisible	The production, reproduction and simulation of inaccessible content or worlds that may otherwise be hard to access or costly to reproduce in real life.	Viewing 3D digital representations of objects to enable students to visualise and explore abstract concepts or unobservable phenomena.
Contextualised information	Though learning is not situated within a location, VR can extend the experience of a location and bring the location to the student, contextualised information can then be embedded onto this virtual environment.	The overlaying of visual or digital information over the physical environment.
Portability of the device to interact with the location	Mobile VR enables learners to be anywhere, tools like Google Expeditions enable students to be transported.	Mobile devices enable learners to engage in real environments. Information and digital content is accessed based on learner's current context.
Social and shared engagement	In collaborative experiences sharing and engagement can be supported to promote a sense of belonging and purpose.	Supporting engagement and interaction between students collocated or remotely.
Content production	Within VW there is an opportunity for creation and ownership of the learning environment and objects within it that are both individual and owned. Limited VR experiences such as created (such as with tools like TourBuilder) but the creation of fully immersive VR experiences are however significantly harder.	AR is significantly easier to develop with a variety of tools available to support development of rich interaction with little to no coding.

Table 1: Exploring the relative affordances of MR within the context of AR and VR

Based on the above affordances, we now start to explore how the principles of seamless learning can be encapsulated within AR and VR learning activities. The next section provides a brief overview of these principles and then explores them in the context of a small number of examples. These examples were selected to highlight the range of research happening within the New Zealand context.

PRINCIPLE-BASED EXPLORATION OF SEAMLESS AR AND VR EXPERIENCE

Based on the overall concept of seamless learning, Wong (2012, E19) have defined ten specific principles that encapsulate the movement between contexts, they include:

- (MSL1) Encompassing formal and informal learning
- (MSL2) Encompassing personalised and social learning
- (MSL3) Learning across time
- (MSL4) Learning across locations
- (MSL5) Ubiquitous knowledge access (a combination of context-aware learning, augmented reality learning, and ubiquitous access to online learning resources)
- (MSL6) Encompassing physical and digital worlds
- (MSL7) Combined usage of multiple device types (including "stable" technologies such as desktop computers, interactive whiteboards)
- (MSL8) Seamless and rapid switching between multiple learning tasks (such as data collection + analysis + communication)
- (MSL9) Knowledge synthesis (prior and new knowledge as well as multiple levels of thinking skills, and/or multidisciplinary learning)
- (MSL10) Encompassing multiple pedagogical or learning activity models (facilitated by the teachers).

Based on these ten principles, four examples have been drawn from the New Zealand context to explore how the principles can be encapsulated within MR experiences. These four examples were selected as they generally typify good examples of how MR can be supported in education and underpin the concepts of seamless learning. The examples we also chosen as they draw on cultural elements from NZ and Maori culture (the indigenous population of NZ) to ground the learning approach. Though these examples are grounded within the NZ culture they still provide good examples that could be adopted in other countries.

Figure 1, summaries these four case studies, outlines the specific principles encapsulated within each case situated on the VC. This mapping was done through evaluating each example to determine how SL has or could be weaved within the each approach.

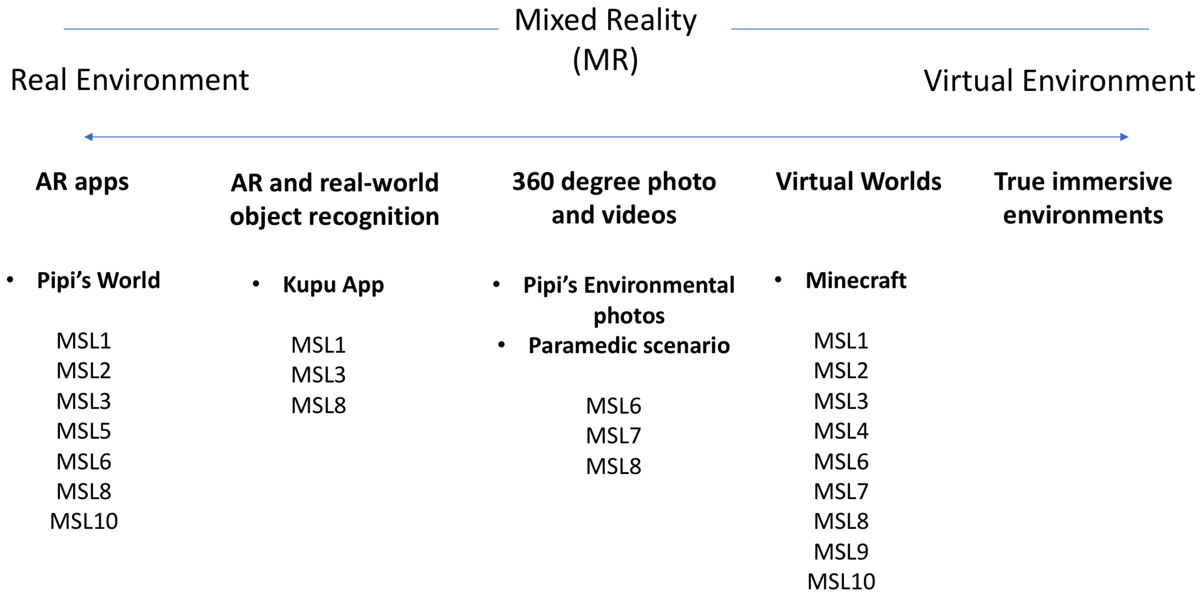

Figure 1. The four cases illustrated and where the fall within the Virtuality Continuum and the seamless learning principles encapsulated within each.

Pipi's AR and VR Adventure

The first example, drawn from the New Zealand literature, is a study undertaken by Eames, Aguayo, Hanlon and Haggitt (2018). Their research project explores how free-choice learning (where, what and when a user engages with the experience) can be used to support teaching marine ecological literacy. Pippi's World, a mobile AR and VR experience, was created to support students learning during and after a visit to Goat Island Marine Reserve and the Goat Island Marine Discovery Centre (GIMDC) in New Zealand. The focus of the study was on the importance of context, and how a field trip could be more fully engaged in when augmented with digital tools. The researchers wanted to enhance the students' experiences at the environmental centre with digital experiences underpinned with key messages such as the importance of sustainability.

Within this experience, students were given the opportunity to explore the centre with their devices and engage with an AR app to learn more about the centre and the key learning messages, told through the lens of an animated fish called Pippi. The learners would engage with the AR experience within the context of the centre and therefore draw on ubiquitous knowledge access (MSL5), as the digital experience augmented the physical environment. This AR experience was also supplemented using VR. A 360-degree, interactive VR experience was also created enabling students to explore images of the area, where the aerial, land and marine photos were made interactive (through clickable hyperlinks embedded into the photos) to show contextual information within the photos. Both of these experiences encompassed both the physical and digital worlds (MSL6).

This study highlights the key principles of encompassing formal and informal learning (MSL1), though the experience was set up within the context of the field trip to the marine reserve, students were given the opportunity to choose which experience they wanted to explore. In addition, since these experiences are set up at the reserve, this meant that any visitor could download the app or scan the QR codes to engage in the AR or VR experiences. Learners were able to rapidly shift between the real world and digital experiences; the digital experience was supported by switching between multiple tasks in the real world such as finding answers, sharing experiences and further exploring the physical space (MSL8).

In addition, the experience blended personal and social learning (MSL2). The AR experiences could be easily shared as students viewed the experiences on their devices. Social interaction was strongly encouraged and the experiences were designed to develop conversations between students, parents and the marine educators. The role of marine educators changed from just driving the learning to also facilitating the experiences of the learner, therefore multiple pedagogical or learning activity models could be incorporated within the experience (MSL10). The VR experiences though they could not be collaboratively explored, the experience could be discussed since multiple headsets were provided and only a few scenes were created.

The development of the VR and AR experiences also supported learning across time (MSL3), though the AR was primarily developed to support learning while at the centre, the study wished to also extend the experience once the students had left the centre. Therefore, the VR experience (and late a fully immersive VR experience is planned to be engaged with at home or school), supports the ongoing messages of the centre.

Kupu App for Maori Language Learning

The next example describes the an augmented reality language app developed to support NZ's learn Te Reo Māori, the local language of NZ indigenous peoples. The application was developed using Google Vision users could take pictures of physical objects with their phone and these could then be, with use of the app, identified and the English and Māori translation overlaid over the image. This application was created for the wider NZ population and supported informal learning and revitalisation of Te Reo Māori (Spark, 2018).

Though designed for informal language learning the app could easily be incorporated into formal language learning of Māori (MSL1). Due to the nature of its use, the application can be used across time (MSL3) to be more familiar with Māori for common objects and therefore try to use these words in everyday conversations. The ability to use this informally and formally will help build the users vocabulary and therefore draw together their prior and new knowledge (MSL10) and could be imbedded into other learning tasks (MSL8).

Exploring Paramedic Education using VR Scenarios

The next example, focuses on 360 mobile VR, within the study by Cochrane, Cook, Aiello, Aguayo, Danobeitia and Boncompte (2018), though this study is similar to the above scenario using 360 photos of the marine reserve, the context of use of the VR was significantly different. Its use clearly underpinned the principle of encompassing physical and digital worlds (MSL6). Within this study, the VR was used to provide students with a better understanding of the context within a simulation. Within this study a VR experience was created for students to experience a call out, the scenario covered was the ambulance travel from the hospital to the location of an incident. In the course of this, students are provided information about the incident which they were to encounter when they arrive at the incident. Once they "arrive" at the incident, the learner transitions to the real environment where they then encounter a recreation of the incident and need to diagnose and undertake a training simulation with a simulation dummy. This VR simulation was seen as a significantly more enhanced way to provide students with the context to a simulation exam, where students needed to identify environmental risk factors before treating a critical care patient. Prior to the development of this VR experience, the scenario was communicated by the instructor in the form of a written scenario. This scenario was read by the instructor before the student entered the incident room to identify and diagnose risks.

Though this example encapsulates fewer principles of seamless learning, there are opportunities to extend this application to include additional principles and extending the initial scenario to include additional experiences added to the initial VR one. This transition between the digital virtual world to real world means that students need to relate what they have learnt in one context to the physical context. Therefore, this supports to some degree the principle of seamless and rapid switching between multiple learning tasks - where data collection happened via the VR, and analysis and communication happen in the real world, but could also happen via alternative methods (MSL8). This alternative method could also be in the form of other devices (MSL7) but currently is only in the form of verbal discussion with the instructor and performing on the simulation dummy.

Minecraft Virtual World

As introduced earlier, virtual worlds area significant aspect of VR. Minecraft is one such VR, though generally played view ipads on other gaming devices, such as Xbox, more immersive experience exists, accessible through the VR edition of Minecraft developed for Samsung's Gear VR headset (Minecraft Virtual Reality, 2019).

Minecraft is an open-ended game allowing players to build their own virtual worlds. The adoption of Minecraft in education has been primarily targeted at younger children and has been used to teach a range of subjects, but especially for STEM-based subjects (Nebel, Schneider, & Rey, 2016). To support the adoption of Minecraft within schools, Microsoft (who have purchased the rights) have developed a Minecraft Educational Edition, which includes a range of teaching material and resources to support its use in teaching a range of subjects including history, chemistry, foreign languages and programming (Mojang, 2019). So what was originally developed for informal use has now been incorporated into the formal environment (MSL1).

There are a number of examples of Minecraft's adoption within education that combine a range of learning opportunities. One such example is the recreation of the 1915 Gallipoli campaign, which was the scene of one of NZ's most significant engagements in the First World War and a pivotal moment in the nation's history (Harper, 2013). A group of college students used collections of photos, maps and stories from the Auckland War Museum to build a representation of Gallipoli within Minecraft (MSL2). Their learning happened over the year and included weekend trips to the museum where they engaged with exhibits, took part in re-enactments and learned about soldiers' experiences (MSL3 & MSL4). They used these experience gained to recreate stories and explain what conditions were like for NZ soldiers fighting overseas.

The creation of the virtual Gallipoli drew on the affordance of VR to create their own learning artefacts as well as draw on multiple contexts. Since it was not just the work inside the VW that was the focus the development meant a strong connection with the real world. In development, they would have used a number of different devices to develop, conceptualise and then interact with the world (MSL7). The learning also blended between the real and virtual worlds, as the learning that they in the real world would then be conceptualised within the virtual (MSL6). They would have needed to switch between the multiple learning tasks (MSL8) and synthesise the experience to recreate the vision in Minecraft (MSL9).

The development of this VW highlights the advantages of how the creation of artefacts can extend the learning to make the total experience more seamless.

CONCLUSION AND FUTURE WORK

MR highlights a number of specific affordances that make seamless learning possible. Overall it is not just the actual AR or VR experience that makes this seamless, rather it is the overall activity designing around the experience. Therefore when examining the four examples provided we can see that MR when carefully constructed provides a more holistic integrated experience. Mobile devices like phones and tablets have enabled more readily accessible examples of MR, so too has mobile technology-enabled seamless learning to happen. Therefore the blending of the two highlights particular affordances of both.

Within the New Zealand (NZ) context the research into seamless, AR, VR and MR is still emerging. Thought there was a significant push to introduce ICT more into the schools and providing infrastructure to support digital learning, there are still barriers to the full adoption. The higher integration of technology within education will provide increased means to support learning that happens in a more seamless manner. NZ is only just starting this journey into full integration of ICT into the curriculum. Unlike other countries, which have already developed and integrated a strong digital focus within their curriculum, NZ is still finding its way within this more digital landscape. As NZ's adoption and roll out of the new curriculum occurs consideration will be needed to ensure that adoption and access is equal and fair. Within NZ there is still a significant digital divide and unequal access to suitable infrastructure is still an issue in some areas. However, as the technology matures and more examples of effective practice emerge so too with NZ mature and develop their adoption and support of these tools and integrate the necessary infrastructure to support. Though the examples provided in this article are generally more one-off trials and explorations, they do provide principles that can be further developed to encourage wider adoption.

Overall. the adoption of MR to support seamless learning shows significant promise, however, further work is needed to make these one-off examples more established practice. In addition, future work is needed exploring and integrating these and other MR approaches into teaching and learning, and from this draw out the perceptions and learning from both students and teachers. The analysis highlights that the MSL dimensions are also covered move at the edges of the continuum, rather than in the center, this finding may be more related to the specific examples selected, there the assessment of wider range of application is needed. In addition the analysis lacks any examples relating to true immersive VR. Due to the technology and costs required for developing and experiencing true VR, this has limited the adoption therefore, more focus is needed in how VR could be adopted with an educational context and further more how this could support the principles of seamless learning.

REFERENCES

Alvarez V, Perez-Perez JR, Paule-Ruiz P, de Freitas S (2016, October) *Ariane: a web-based and mobile tool to guide the design of augmented reality learning activities*. In Proceedings of the 15th World Conference on Mobile and Contextual Learning (mLearn 2016), Sydney, 24-26

Berge, Z. L., & Muilenburg, L. (2013). Seamless learning: An international perspective on next-generation technology-enhanced learning. In *Handbook of Mobile Learning* (pp. 133-146). Routledge.

Baker, S. C., Wentz, R. K., & Woods, M. M. (2009). Technology and teaching: Using virtual worlds in education: Second Life as an educational tool. *Teaching of Psychology*, 36(1), 59-64.

Billinghurst, M. (2002). Augmented reality in education. *New Horizons for Learning*, 12(5), 1-5.

Boulos, M. N. K., Hetherington, L., & Wheeler, S. (2007). Second Life: an overview of the potential of 3-D virtual worlds in medical and health education. *Health Information & Libraries Journal,* 24(4), 233–245. https://doi.org/10.1111/j.1471-1842.2007.00733.x

Brown, A., & Green, T. (2016). Virtual reality: Low-cost tools and resources for the classroom. *TechTrends*, 60(5), 517-519. doi:http://dx.doi.org/10.1007/s11528-016-0102-z

Brown, T. H., & Mbati, L. S. (2015). Mobile learning: Moving past the myths and embracing the opportunities. *The International Review of Research in Open and Distributed Learning*, 16(2).

Cochrane, T., Cook, S., Aiello, S., Aguayo, C., Danobeitia, C., & Boncompte, G. (2018, December). *Designing Immersive Mobile Mixed Reality for Paramedic Education*. In 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE) (pp. 645-650). IEEE.

Chang, G., Morreale, P., & Medicherla, P. (2010, March). *Applications of augmented reality systems in education*. In Society for Information Technology & Teacher Education International Conference (pp. 1380-1385). Association for the Advancement of Computing in Education (AACE).

Eames, C., Aguayo, C,. Hanlon, J., & Haggitt. T., (2018, April). *Researching mobile learning in education outside the classroom to enhance marine ecological literacy*. New Zealand Association for Environmental Education 9th Biennial Conference, Wellington, NZAEE, DOI:10.13140/RG.2.2.17309.61928

Harper, G. (2013). *Letters from Gallipoli: New Zealand soldiers write home*. Auckland University Press.

Hussein, M., & Natterdal, C. (2015). *The benefits of virtual reality in education: A comparison study*. (Bachelor thesis). Chlamers University of Technology, University of Gothenburg, Göteborg, Sweden. Retrieved from http://hdl.handle.net/2077/39977

Kamarainen, A. M., Metcalf, S., Grotzer, T., Browne, A., Mazzuca, D., Tutwiler, M. S., & Dede, C. (2013). EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips. *Computers & Education*, 68, 545-556.

LaViola Jr, J. J. (2000). A discussion of cybersickness in virtual environments. *ACM SIGCHI Bulletin*, 32(1), 47-56.

Milgram, P., & Kishino, F. (1994). *A taxonomy of mixed reality visual displays. IEICE Transactions on Information and Systems*, 77(12), 1321-1329 retrieved from http://etclab.mie.utoronto.ca/people/paul_dir/IEICE94/ieice.html

Mac Callum, K., & Jamieson, J. (2017, October). *Exploring Augmented Reality in Education Viewed Through the Affordance Lens*. In E. Erturk, K. MacCallum & D. Skelton (Eds.), Proceedings of the 8th Annual Conference of Computing and Information Technology Education and Research in New Zealand, Napier, New Zealand, 2nd-4th October 2017 (pp. 114-120). Retrieved from http://www.citrenz.ac.nz/conferences/2017/pdf/2017-CITRENZ-PACIT.pdf

Mojang. (2019).*Why Minecraft | Minecraft: Education Edition*. Retrieved from https://education.minecraft.net/how-it-works/why-minecraft/

Minecraft Virtual Reality. (2019). *Minecraft.net*. Retrieved from https://www.minecraft.net/en-us/vr/

MoE. (2017a). *Digital Technologies | Hangarau Matihiko*. Retrieved from https://education.govt.nz/assets/Documents/Ministry/consultations/DT-consultation/DTCP1701-Digital-Technologies-Hangarau-Matihiko-ENG.pdf

MoE. (2017b). *Getting ready for broadband*. Retrieved from https://education.govt.nz/school/running-a-school/technology-in-schools/getting-ready-for-broadband/

MoE. (n.d.). *Innovative Learning Environments*. Retrieved from http://ile.education.govt.nz/

Nebel, S., Schneider, S., & Rey, G. D. (2016). Mining Learning and Crafting Scientific Experiments: A Literature Review on the Use of Minecraft in Education and Research. *Educational Technology & Society*, 19 (2), 355–366.

Ozonur, M., Yanpar-Yelken, T., & Sancar-Tokmak, H. (2018). Social presence and motivation in online environments: Second Life versus the Enocta Learning ManagementSystem/Adobe Connect. *Australasian Journal of Educational Technology*, 34(3), 1-14. https://doi.org/10.14742/ajet.3128

Parsons, D., Thomas, H., Lynch, J. & MacCallum, K. (2018, April). *Digital Fluency and the Entitlement Curriculum: Who are the computational thinkers?* In Proceedings FLANZ 2018 Conference, Palmerston North, New Zealand.

Spark (2018). *Spark launches Kupu: a picture to Te Reo Maori translation app.* Retrieved from https://www.sparknz.co.nz/news/Spark_launches_Kupu/

Summers, N. (2017) *The VR successor to "Second Life" is now in public beta*. (n.d.). Retrieved June 5, 2019, from https://www.engadget.com/2017/07/31/sansar-vr-creator-beta-second-life/

Wong, L. H. (2012). A learner-centric view of mobile seamless learning. *British Journal of Educational Technology*, 43(1), E19-E23.

Warburton, S. (2009). Second Life in higher education: Assessing the potential for and the barriers to deploying virtual worlds in learning and teaching: Second Life in higher education. *British Journal of Educational Technology*, 40(3), 414–426. https://doi.org/10.1111/j.1467-8535.2009.00952.x