Augmented Reality & Virtual Reality: Connecting Emerging Technologies to the UDL Framework

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Abstract
This paper examines how the emerging technologies of Augmented Reality (AR) and Virtual Reality (VR) are potential UDL resources supporting the Summit Goal of "Identification and dissemination of effective implementation tools." In less than ten years mobile devices (smartphones & tablets) became common educational tools providing multiple means of representation, action and expression, and engagement. AR and VR are potential new platforms for UDL implementation that need to be incorporated into the existing research- based framework. New AR and VR platforms provide educators unprecedented new resources to support all learners by connecting these tools to the UDL framework.

Keywords
Augmented Reality, Virtual reality, universal design for learning.

INTRODUCTION
In the summer of 2016 an augmented reality application called Pokémon Go became a worldwide phenomenon with over 500 million downloads and over 500 million dollars in revenue (TechCrunch, 2016, Sept 9). Also, in 2016 virtual reality became more mainstream with dedicated headsets from Oculus Rift and HTC's VIVE. As these two emerging technologies become more common, they will be applied to many different fields from gaming, business, medicine, and of course in education. But before schools introduce a new generation of educational technology simply because it is available, educators should understand the capabilities and limitations of these immersive learning applications. The success of these new AR and VR educational applications may depend on the instructional design choices made by educators.

Understanding the nature of these two immersive technologies is fundamental to determining how we can use them to support educational experiences for all learners. Figure 1 below shows the mixed reality continuum which is one of the frequently used means of describing the capabilities of immersive technologies.

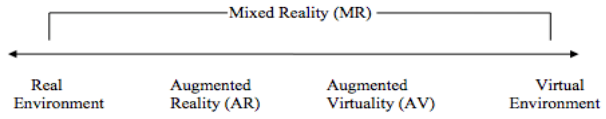

Figure 1. Milgram and Kishino's Mixed Reality Continuum.

Augmented Reality
Milgram and Kishino (1994) described AR as any instance where the "display of an otherwise real environment is augmented by means of virtual (computer graphic) objects" (p. 2). The term "augmented reality" was introduced in 1992 to describe a manufacturing advancement by Boeing engineers which allowed workers to see digital prompts over real-time imagery to assist in the completion of assembly tasks (Caudell & Mizell, 1994). Some examples in popular culture include Iron Man's heads-up displays and the display technology in Minority Report. Two real life examples of AR include the Yelp app's Monocle feature showing you nearby restaurants and their ratings and the Ikea App's AR feature that allows you place furniture in your room and use your mobile device to view it so you can determine if you like it before you buy it. Both of these examples use handheld mobile devices (smartphones and tablets) to display the AR content. In addition to these commercial applications there are a collection of AR apps that are practical education tools that are ready to use in the classroom (Walker, McMahon, & Rosenblatt, 2017). Handheld mobile devices offer a low-cost platform for AR but there are several high-end wearable Smartglasses that are also available such as the Microsoft Hololens. As the technology continues to advance and the cost of AR Smartglasses decreases, we are likely to see more opportunities to use AR tools to support learning.

Virtual Reality
Virtual Reality generally refers to a fully artificial digital environment in which a user navigates as an avatar in order to complete tasks or have experiences. Milgram and Kishino specify that a "Virtual Reality (VR) environment is one in which the participant-observer is totally immersed in, and able to interact with, a completely synthetic world" (1994. p. 2). VR on mobile devices has become practical for classroom applications with the low cost and easy to use platform Google Cardboard (Brown & Green, 2016). This system uses a mobile phone screen and a Google cardboard headset to deliver a VR content using the mobile devices collection of sensors (accelerometers, etc.) and doubles the image to create one view of the scene for each eye. Using mobile devices to deliver VR has the advantage of being an easy entry point since most people have a mobile phone and the headsets like google cardboard are low cost ($4 to $20). These phone-based VR systems are limited by the capabilities of the phone and generally offer less resolution, limited ability

to use additional controllers, and VR experiences that do not require high graphics produced by a video card. These limitations do not apply to VR experiences on dedicated headsets such as the Oculus Rift or HTC VIVE.

AR and VR as Classroom Platforms

Technology trends usually grow along predictable lines of public interest and development. Gartner (2013) described this process as the Hype Cycle shown in Figure 2. In brief, this cycle begins with the introduction of a new technology, an explosion of the technology in popularity and interest, a gradual then sharp drop in interest because lack of practical applications, followed by a steady increase in use as the technology is systematically perfected. Eventually, based on effective use and research, the technology plateaus at a consistent level of productivity and usage.

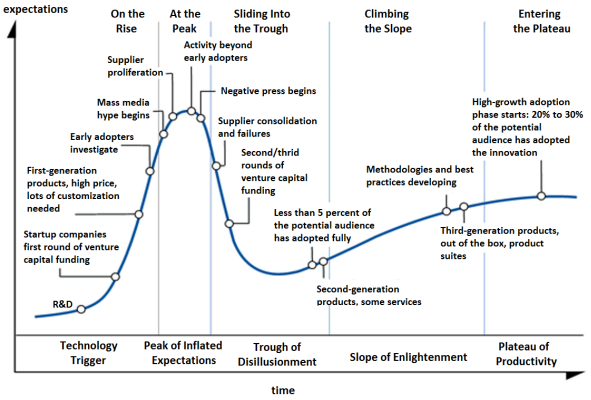

Figure 2. The Gartner Hype Cycle of New Technology. Image credit (Tarkovskiy, 2013)

In order to advance immersive learning tools of AR and VR beyond the initial stages of the Hype Cycle and eventually establish them as strategies for diverse groups of learners, it is necessary to make clear and strong connections to established supporting research. Unfortunately, there is a limited amount of research on AR and VR as instructional tools to support learning. AR and VR are immersive technologies that are just beginning to be implemented in educational settings. One practical means of addressing the lack of research evidence of these emerging technologies is to use a framework to implement them in classrooms based on their potential to support the UDL guidelines. In the interest exploring immersive technology in education and the UDL Framework this paper will match tools to each guideline. For each guideline one AR option and one VR option will be provided. A mix of mobile device resources (smartphones and tablets) and high-end resources (VR – HTC VIVE & Oculus Rift, AR – Microsoft Hololens) will be presented to demonstrate the range of technologies currently available.

MULTIPLE MEANS OF ENGAGEMENT

Immersive learning with AR and VR provides many opportunities to address the UDL principle of Multiple Means of Engagement. The goal of this principle is to develop students into expert learners that are purposeful and motivated.

Provide Options for Recruiting Interest

Immersive learning with AR or VR can increase engagement by addressing the UDL checkpoints of this guideline. *Earth AR* by Magic Software is an app available on mobile devices which uses the iPad's camera to recognize a trigger image and display a 3D model of the Globe that the user can control. Since they are controlling their individual devices to explore and learn, this can help optimize choice and autonomy. *Google Earth VR*, available on the HTV VIVE and Oculus Rift headsets can provide educators with opportunities to optimize relevance, value, and authenticity for their learners. For example, students learning about ancient culture such as the Incas in Peru could explore the incredible feats of engineering at Machu Picchu in VR and even experience sunrise at that location. This immersive experience may make this more relevant by creating a simulated experience of Machu Picchu.

Provide Options for Sustaining Effort and Persistence

Immersive learning provides many opportunities to heighten the salience of goals and objectives to help learners understand the value of their efforts. *AR Basketball* is a simple basketball game where users "shoot" a basketball into a goal displayed in AR. But when used by an educator in the design of a lesson on MEAN, MEDIAN, and MODE, this simple game can be the gateway to helping learners understand why learning these math terms matter by connecting them to the familiar idea of sports stats. Basketball scores of users can become the dataset used in class. VR can also provide options for sustaining effort by providing alternative tools and scaffolds to learn content such as using VR lessons on the mobile app *Nearpod* (Free/subscription). Using the *Nearpod* app and a Google Cardboard headset, students can see lessons in a wide range of subjects and grade levels delivered in VR. These lessons can be teacher led where the entire class gets the content at the same time or student paced.

Provide Options for Self-Regulation

Both AR and VR can be used to support personal coping strategies. In this example, consider how both of these technologies can facilitate personal coping skills. A high-end AR example could be using Smartglasses to create a personal "sensory room" while still in the regular classroom. Using the Microsoft Hololens and the app *HoloQuarium* (Free) users can place aquarium fish and plants around themselves. For learners who need immersive sensory experiences they can see and hear the calming experience of the fish, water sounds, and bubbles while still remaining in the instructional setting. VR can also provide rich sensory experiences to support personal coping strategies. For students who benefit from brief mindfulness breaks, the VR application *Nature Treks VR* on the HTC Vive allows users to peacefully explore a relaxing selection of interactive natural environments for a few minutes. In addition to being a

viable coping strategy to get a break from a situation, this option does not necessarily require an additional staff person to help take the student on a walk or out of the classroom.

MULTIPLE MEANS OF REPRESENTATION

As student's progress toward the goal of being expert learners that are resourceful and knowledgeable, they can use these new platforms to explore the content.

Provide Options for Perception

AR and VR are heavily visual mediums so they are limited in their ability to provide alternative to visual information but they can address other checkpoints such providing alternatives for auditory information or customizing the display of information. In a science lesson on the solar system this could be achieved by the mobile app *solAR – Discover our solar system* (Free). Using this tool, learners can use their mobile devices to walk up to explore the planets by bringing the planets into your classroom. Keeping with the solar system theme VR can take your students into the solar system. *Space Tours VR* ($1.99 HTC Vive/Oculus Rift) takes your student into space with detailed scientific data on each planet of our solar system. For example, orbiting above Jupiter your students can see information on its size, moons, rotation, and orbit. Both of these technologies can help your learners experience options for perception such as these spatial models to support their learning.

Provide Options for Language and Symbols

There are many means AR/VR can provide options to illustrate through multiple media. *HP Reveal* (formerly called Aurasma) is an AR app on mobile devices that displays either pictures or videos above a trigger image. One way teachers could use this to illustrate through multiple media is by having students create their own interactive AR vocabulary cards (McMahon, Cihak, Wright, & Bell, 2016). Each student could create their own video that explains the vocabulary being made and then all students can share and see these AR vocabulary lessons as an interactive word wall. VR tools such as the Google Expeditions app (Free) using Google Cardboard can also provide educators with tools to make explicit links between the content in texts and the immersive learning. In Google Expeditions learners can experience VR lessons such as 360-degree pictures of a location while the teacher annotates and explains what they are seeing. For example, a class learning about aqueducts could be taken on Google Expedition to look at Roman aqueducts and the teacher could annotate what they are seeing to help them understand the key concepts using variety of media.

Provide Options for Comprehension

Immersive learning tools using AR and VR have incredible promise to support the UDL check points related to this guideline. *AR Atlas Anatomy* ($1.99) is a gross anatomy lab with AR features available on mobile devices like smartphones and tablets. You can place a very detailed human body on a table and select, dissect, and learn about thousands of different parts of the body from bones, organs, or entire body systems. Since it is an AR experience, two or more students can look at the screen at the same time to work on exploring the interactive model as they highlight patterns and critical features of the body systems. In VR, learners can also use immersive visualizations to understand complex topics such as human anatomy. On the HTC Vive the application *3d Organon VR Anatomy* ($29.99) provides an interactive human anatomy model with over 4000 detailed features. In addition to stationary models, it includes human motion visualizations which can help learners understand how complex processes such as joints and muscles work together. While these two technology examples are in science education, the mediums of AR and VR can be used to provide options for comprehension learners across any subject area.

MULTIPLE MEANS OF ACTION & EXPRESSION

The immersive learning tools available on AR and VR platforms provide many resources that could help students grow to be expert learners that are strategic and goal directed.

Provide Options for Physical Action

AR and VR are emerging educational mediums that are still working toward wide spread adoption and use. Their overall accessibility and use by people who need assistive technologies will vary greatly based on the platform and tools being used. AR and VR are primarily visual mediums and at this time do not have many accessibility tools for people with vision impairments. But they do present educators with other potentially important assistive technologies. The Microsoft Hololens smartglasses are basically a wearable computer. For individuals with a physical impairment that affects the ability to use a mouse, the Hololens may provide new means to have alternative inputs. The user sees a small dot in the center of their field of view which is the mouse. The user can put the mouse over an object and select what they want to see. For example, a user laying on their back could be positioned below a screen of an internet browser so they can see the screen in a comfortable way. They could either type the address of a website with the mouse and clicker (a small handheld switch) or say "Hey Cortana" and use a voice input to dictate the website they would like to visit. VR may provide the ultimate means of addressing the need to provide options for physically interacting with the physical world by providing an option to opt out of the physical space. Social VR applications such as *rumii* (9.99 per month) or VR Chat (Free) can provide learners with a virtual environment to discuss, create, and learn with peers that does not require them to physically be in the same location but still allows them to experience, collaborate and learn with peers. Learners put on a VR headset and then use a virtual avatar to interact, create, draw, ask questions, and experience content.

Provide Options for Expression & Communication

It could be easy to focus on all the ways AR and VR can provide rich content to our learners. But it is important to remember that these are also new mediums for our learners to express and communicate their ideas. World Brush is an

AR mobile app that allows users to create drawings and place objects around themselves. World Brush could be used to have students label objects in space such as "living/non-living" or to draw/show the steps of completing an assembly task. Similarly in VR there are many options for expression and communication with the major difference that they occur in a completely virtual environment. A good example of this in VR is Google Tilt Brush. Google Tilt Brush on the HTC VIVE provides learners with the capability of creating their own 3D sculptures and entire VR environments. An exciting classroom example of this UDL Guideline could be to ask students learning about the water cycle to use Google Tilt Brush to create their own VR version. Creating a VR world explaining the water cycle would definitely count as using "multiple means for communication."

Provide Options for Executive Functions

AR and VR can support executive functioning by providing new tools to support planning and strategy development. AR's ability to provide digital prompts over the physical world around us is a powerful tool for managing information and resources. One means of guiding this is providing organizational tools and supports. AR Smartglasses such as the Hololens can be used to place prompts and scaffolds in the physical space around the individual to help them set and complete goals. For example, maybe there is a learner who regularly is missing the final step in a multistep task such as how to assemble an electrical circuit. They could place a lightning bolt above the part of the electrical circuit model they keep missing. Another example could be a student with more severe cognitive impairments working on a learning multistep functional skill such completing all the steps of doing laundry. The student could use the Hololens to place a Youtube video above the washing machine showing task analysis demonstrations as a scaffold so they could complete all steps of the activity.

VR can provide rich tools for executive function by supporting planning and strategy development. A simple means for embedding coaches or mentors who can model how to solve a complex process is to use a 360 Video camera ($199 to $500) dollars to record pov of view videos. Then the learner can watch the VR 360 video of the mentor explaining a "how to" on any topic. Youtube now supports 360 VR video so all students need to do is use the Youtube app on their mobile device with a set of Google Cardboard and watch the coach/mentor explain their process and strategy for reaching the goal. Using immersive VR videos with embedded prompts and scaffolds is a great way to vary the instructional tools for educators who what to flip their classrooms. This can be applied to the complex AP Chemistry lab or an elementary classroom working on long division.

CONCLUSION

Augmented reality (AR) and virtual reality (VR) are two related technology platforms that are likely to be increasingly used in our daily lives as the cost of these tools decrease and their capabilities increase. The UDL Framework is one potential way educators can implement emerging technologies as curriculum resources in a coherent way. The examples given here are in no way exhaustive of what is available or what is possible. The future use of these two mediums in education is only limited by the creativity of educators designing instructional experiences. The UDL framework provides educators with a research-based method for applying these and other new technologies by matching their capabilities with the UDL guidelines and checkpoints.

As future research explores the potential of AR and VR in education, researchers can use the UDL framework in the research design process to examine how these immersive technologies can function as supports for the learning networks described by Rose and Meyer (2002).

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