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Table of Contents

Roundtable and Practitioner sessions

Demos

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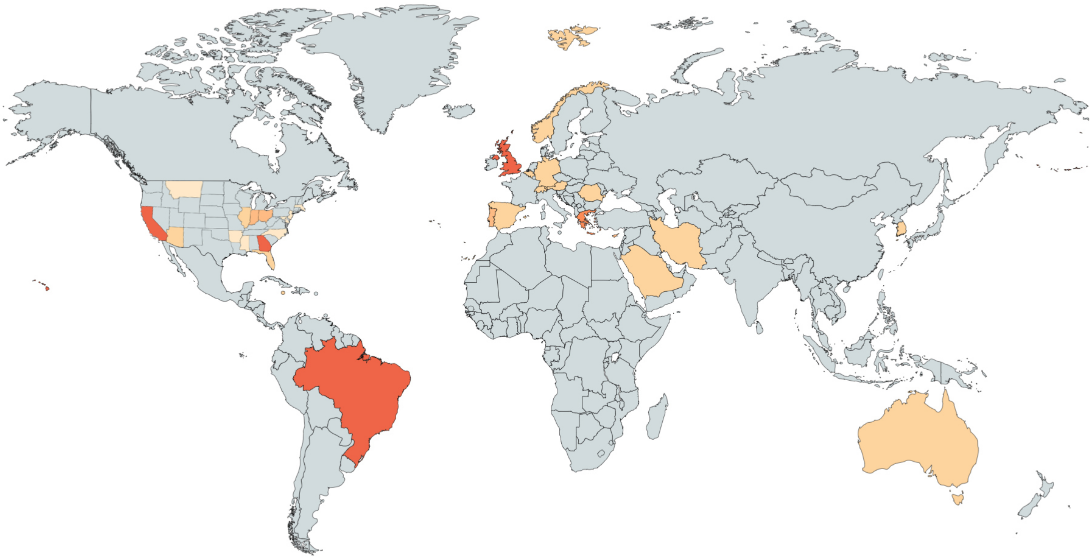
iLRN 2019 Main Conference Preface

ILRN 2019 is the fifth annual international conference of the Immersive Learning Research Network held in Westminster, London, UK, following the 2018 edition in Missoula, Montana (USA), and returning for the third time to Europe, after the Coimbra (Portugal) edition in 2017.

The topic is becoming increasingly relevant as the power and affordability of suitable computers, mobile devices, network connectivity and interface technologies has made virtual and augmented reality environments more accessible than ever before. The vision of the iLRN is to develop a comprehensive research and outreach agenda that encompasses the breadth and scope of learning potentialities, affordances and challenges of immersive learning environments. To achieve this, the iLRN mission is to invite and organize scientists, practitioners, organizations, and innovators across the disciplines to explore, describe, and apply the optimal use of immersive worlds and environments for educational purposes. Further the conference, meetings, and virtual symposia aim to build capacity to explain and demonstrate how these immersive learning environments best work using a variety of rigorous, systematic, and meaningful research methods and outreach strategies. To achieve this, the ILRN has invited scientists, practitioners, organizations, and innovators across all disciplines to report on their research in the ILRN 2019 international conference. Sixty-three papers were received the conference in 2019, encompassing long and short papers, posters, demo proposals, special tracks and workshops. All papers and posters were being independently reviewed: full/long papers by 2 – 4 reviewers, short papers by 2 – 3 reviewers and posters by 2 reviewers. All authors were given a substantial mix of feedback on how to improve their submissions for publication and presentation at the conference. In cases where the reviewers agreed that much more work was needed for a given format, full/long papers were invited to be resubmitted as short papers and short papers as posters. After a rigorous reviewing process eighteen were selected as full papers to be published in an edition of Springer's series Communications in Computer and Information Sciences (27.4% acceptance rate), the remaining revised papers and poster abstracts being included in this volume.



180 authors submitted publications successfully and hail from Austria, Australia, Belgium, Brazil, Cyprus, England, Germany, Greece, Iran, Jamaica, Korea, Norway, Portugal, Romania, Saudi Arabia, Scotland, Spain, Swiss and in the United States, Arkansas, Arizona, California, Florida, Georgia, Illinois, Indiana, Massachusetts, Michigan, Mississippi, Montana, New Jersey, New York, North Carolina, Ohio, Pennsylvania and Washington D.C.; 53% being from Europe and 47% from the rest of the world, with North America accounting for 23%, South America 20%, Asia 3% and Australia 1%.

If you are not already involved in thinking about or researching immersive learning, check out these proceedings, and get excited about joining the iLRN community.

Leonel Morgado and Christian Eckhardt,
ILRN 2019 Main Conference Programme Co-Chairs

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Using Virtual Reality for Implicit Learning

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Abstract. Virtual Reality uniquely offers three illusions simultaneously: the illusion of being in the rendered place, the illusion that what is perceived to be happening there is really happing, and the illusion that the life-sized virtual body that apparently substitutes the body of the participant is their body. Needless to say, for any participant in a Virtual Reality experience these are not beliefs, but illusions, known to be false yet nevertheless profoundly influencing their physiology, attitudes, behaviour and even cognition both during the Virtual Reality exposure and also afterwards. We argue how these illusions are useful for implicit learning and unlearning, and give a number of examples.

Keywords: Implicit learning, unlearning, virtual reality, body ownership, presence, place illusion, plausibility, clinical psychology

1 Introduction

Virtual Reality can be used to give people the illusion of being in computer generated world, where the events that are occurring there are actually happening. This comprises two aspects – Place Illusion, the strong illusion of being in the virtual place, and the Plausibility Illusion , that the events that are happening there are really happening, both with the proviso that the participant knows for sure that this is not the case [1]. These two together are often called ‘presence’. This can be utilized in many possible applications. For example, with students learning geography, virtual field trips are potential sources of learning, and sometimes may be logistically more feasible than actual field trips [2], though see also caveats discussed in [3]. For the learning of history, aspects of the ancient world have been constructed [4], and the World War 2 D-Day Normandy landings represented in a video game [5], and Allison [6] reviews such applications in the context of history education. A recent example reprising an event from the 1917 October Russian Revolution is described in [7]. Virtual reality in education goes back a very long way [8, 9]. For recent reviews see [10-14].

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As summarised in [15] there are several reasons why Virtual Reality (VR) is an excellent tool for education: (1) it can change the abstract into the tangible – e.g., mathematics can be represented in tangible form – e.g. [16]; (2) VR supports 'doing' rather than just observing (e.g., learning surgery doctors can safely manipulate objects rather than only watch others do it; (3) VR can utilise methods that are desirable but practically infeasible though possible in reality – for example, a field trip to Stonehenge one week and Niagara Falls the next (practically infeasible in reality but possible in VR). (4) VR can go beyond reality and yet may lead to better understanding of reality – e.g., for learning about aspects of physical people could experience how would it be to juggle in gravity different to how it is on Earth [9].

Here we concentrate on implicit [17] rather than explicit learning, and are more concerned with unlearning rather than learning. Implicit learning is acquiring knowledge and skills without conscious effort, and without explicitly having to learn specific information [18]. Unlearning is the process of unlearning a habitual way of thinking or accomplishing something, in order to be able to release new and perhaps better ways - for example, in engineering [19]. I discuss how some of our studies combine both implicit learning and unlearning, although they were not designed for this purpose. I first consider a fundamental example of unlearning – psychological therapy, which has mainly relied on the presence (Place Illusion and Plausibility) aspects of VR. I then consider implicit learning examples, through a transformation of body ownership. The implicit learning examples also involve unlearning.

2 Unlearning – VR in Psychological Therapy

Perhaps the most profound and well-researched example of virtual reality in unlearning is its application in clinical psychology. For recent reviews see [20, 21]. Typically cognitive behavioural therapy (CBT) is used. This requires that patients be exposed to situations where they feel anxiety in the case of anxiety disorders, or other types of negative feeling such as when people with paranoia encounter other people. CBT breaks down beliefs and attempts to diffuse and reframe negative thoughts, so that patients can at the very least learn to cope with their feelings and operate normally in the world (e.g. in the case of paranoia) or learn to completely dissipate their feelings of anxiety in situations that previously provoked this [22, 23]. This is genuine Unlearning, since such patients have somehow earlier learned to feel extreme discomfort in certain situations (e.g., public speaking or a facing precipice) and the CBT process shows them how to 'unlearn' these feelings while nevertheless in the provoking situation. In a recent randomised control trial a complex virtual environment was utilised for the problem of acrophobia (fear of heights). The CBT was delivered by a virtual therapist. The experimental group (n = 51) produced large clinical benefits compared to a control group (n = 49) [24].

Applications in clinical psychology go back to the early days of VR – for example

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[25, 26] and there has been massive research in this area: fear of heights, various types of social phobia, agoraphobia, spider phobia and conditions such as post-traumatic stress disorder [27], paranoia and schizophrenia. Although there are very few RCT formal clinical studies, the overwhelming conclusion is that VR 'works', that the outcomes are at least as good as using traditional methods such as exposure through 'real' experiences (e.g., visits to high buildings, talks in front of real audiences), imaginal techniques, movies and photographs. It needs to be pointed out here that the success of these methods is not due to the VR in itself – VR is an adjunct, a tool employed in the context of CBT. The success is down to the methods of CBT, not specifically to the use of VR, which offers mainly economic and logistic advantages. However, the VR 'works' precisely because the clients have the strong illusion of being in the place (e.g., in front of an audience) and that the events that are happening are real. Even though the patients know for sure that nothing 'real' is happening, some aspect of brain processing does not distinguish between reality and virtual reality, so that people automatically respond realistically to virtual stimuli.

3 Body ownership and implicit learning

The third illusion, virtual body ownership, has been used as a method for bringing about implicit change. When a person is in a VR they will see a life-sized virtual body visually substituting their own from their first-person perspective (1PP), if this has been programmed. This 1PP view of their virtual body is typically supplemented with additional multisensory information that provides evidence that the body is their own. For example, when an object strikes the virtual body the participant should feel something synchronously in time and location on their own body (visuotactile integration) [28], or when they move their real body the virtual body should move congruently and synchronously (visuomotor integration) [29, 30] or both [31]. Under these conditions participants typically have the perceptual illusion that the virtual body is their body (even though of course they know that it is not). These ideas go back to the rubber hand illusion [32], which has also been replicated in VR [33].

Yee, Bailenson [34] observed that the form of the virtual body can have implications for the attitudes and later behaviours of participants. For example, at least four replications of studies where White people where embodied in a Black virtual body have shown that their implicit racial bias against Black people diminishes [35-38] (provided that the social context depicted is appropriate [39]). This is another type of 'unlearning' where associations between race and positive or negative attributes can (on the average) change simply as a result of an exposure to a virtual body of specific type, with some evidence that the effect endures. This has also been shown to map to behaviour, where White people will mimic the postures and gestures of a

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Black virtual character more when they are embodied as Black compared to White [38]. This is important since the Chameleon effect from social psychology suggests that such unconscious mimicry is a sign of greater social harmony.

In another example of how the virtual body can influence behaviour, participants, in a between-groups experiment, were embodied either in a dark-skinned casually dressed (Jimi Hendrix reminiscent body) or a light-skinned formally dressed body and were asked to play a hand drum. Tracking data clearly showed that those in the more casual looking body played the drums with far more body movement than those in the formally dressed looking body [40].

Changes due to embodiment in particular types of virtual body may also influence cognition. One set of studies has suggested that people embodied as Sigmund Freud, and with a strong illusion of body ownership in that body, give better counselling (to themselves) than when they do not experience body ownership, or when their counsellor is another copy of themselves [41]. Even more remarkably it seems that people with low self-esteem perform better on cognitive tasks when embodied as Albert Einstein than when embodied in a neutral virtual character [42].

There are also implications for motor learning. Embodiment in a virtual body that speaks in a higher pitched voice than the participant's own voice leads to participants not only having illusory agency over the speaking (even though they themselves did not speak) but later themselves actually speaking in a higher pitched voice [43]. However, for this to work it seems that the body ownership has to be the result of 1PP plus visuomotor rather than visuotactile stimulation [44]. We are currently exploring this finding in the context of motor learning.

4 Conclusions

Both the CBT type of approach that is explicitly aimed at transformation and the implicit methods based on body ownership have something in common: they are both ways of transforming attitudes about the self. The CBT method tackles this head-on in a deliberate way, and the clients know that this is the intention, whereas as the 'body ownership' method does not involve saying anything at all about what is expected from the client. In the body ownership – implicit learning – approach, change 'just happens'. A person can 'unlearn' how to have implicit racial bias (i.e., unlearn apparently deep-seated sets of associations), or 'unlearn' the effects of their low self-esteem without knowing that they are supposed to be unlearning these. This is a very interesting route for learning, and we are currently exploring this in a number of applications.

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Immersive Memory – Neuroscience, 3D Worlds and the Ancient Art of the Memory Palace.

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1 The Memory Palace

The Memory Palace, or 'Method of Loci' was a mnemonic system developed in ancient Greece and Rome, and later perfected throughout the medieval and early Renaissance period until the invention of print mean that people no longer had to commit large amounts of information to memory. At its simplest the method involves using real or imaginary architecture into which the user places exaggerated images to represent objects or concepts they want to remember. Following the arrival of the printing press the Memory Palace became absorbed into the quasi-mystical underground world of the Hermeticists and linked with cabbalistic wisdom pursued by alchemists, astrologers and philosophers such as Ramon Lull and Giordano Bruno.[1]

In addition to this 'Method of Loci', other similar associative mnemonic systems have been developed throughout the Enlightenment to the present day, such as the Major System in which words and sentences are built from numbers, and the Dominic System, which uses people and actions to create images for the digits 0 to 9999. By combining these systems stage magicians perform astounding feats of memorization, professional card players work the blackjack tables at casinos and memory experts compete in the World Memory Championships.

Despite the triumphalist claims of some of its proponents, and a smattering of self-help books that offer up these memorization techniques as ways to boost brain power and unlock latent genius, the Memory Palace has failed to gain traction in mainstream culture. There are a number of possible reasons for this.

To begin with it is assumed to be a method designed to memorize large numbers of facts, an activity now associated with a very narrow, traditional approach to education focussed on regurgitating knowledge in summative exams. This criticism isn't helped by the tendency of memory champions to display their prowess by such pointless feats as recalling randomly shuffled packs of cards, the contents of telephone directories and Pi to hundreds of digits.

Secondly the claim that the Memory Palace allows the user to swiftly and effortlessly store and recall knowledge is not strictly true. Building, populating and maintaining such mental architecture can demand as much effort and practice as simple rote memorisation, leading to the inevitable conclusion that you might as well expend the energy on the latter than waste time on the former.

Finally, other than recalling phone numbers, shopping lists and historical dates, there has been little progress in exploring the potential of the Memory Palace

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[1] Yates, Francis, The Art of Memory, (Chicago: The University of Chicago Press, 1966), p 229.

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as a cognitive device, to determine whether it can be used for more complex mental tasks such as analysis, abstraction and theorisation. Yet it's clear that early practitioners, such as St Augustine and the Jesuit adventurer Matteo Ricci, saw it as the vehicle for complex reasoning, and not just as a data store.

Neuroscience and the Nature of Memory

Recent research in Neuroscience, especially with the growth of fMRI imaging, has provided an interesting counterpoint to the principles of the Memory Palace. While some of the mechanisms of memory identified in studies of the brain support the methodology, others point to innate barriers or natural cognitive processes that counter-act or impede it.

At a biological level long-term memory is created when regularly used synaptic gaps fuse to create permanent links between brain cells. Furthermore, memories are coded as complex patterns, known as engrams, which over time are linked together, merged and simplified.[2] Essentially the mind associates any new experience, concept or piece of information with what is already in its memory.

This echoes the process of creating an image of the thing to be remembered and placing it within the permanent imaginary architecture of the palace. The mnemonic technique differs from automatic memory by creating association through a process of metacognition, rather than letting the connections be created by chance. In addition, as the simple act of thinking about something strengthens the connections between cells, so the process of practice and recall, whereby the user 'walks' through their palace and examines each mnemonic object in turn, consolidates knowledge.

However, a recently discovered feature of memory causes issues with the specific nature of palace imagery. Over time, as memory and experience accrues, the brain will merge engrams, so that similar patterns combine into a single uber-memory. This is the result of the mind's drive for efficiency and minimum energy usage. The process of consciously thinking about memories appears to accelerate this process, so that every time we remember something, we change it and, in doing so, subsume it into a large web of associative concepts. In addition, memory is only granular down to a certain level, which is why it is often difficult to recall objects and people in photographic detail. The fact that our memories are slightly out of focus, and become absorbed into combined recollections, means that the Memory Palace is in danger of falling victim to a form of mental entropy. This is why it needs regular review and significant mental effort to maintain.

Virtual Reality, Immersion and 3D Worlds

The increasing sophistication of VR, and 3D worlds suggest new possibilities for the development of the Memory Palace. The most immediate and obvious being the ability to create virtual architecture through the use of programmes like Minecraft and SketchUp. As long as there's functionality within the software for walkthroughs then it's possible to recreate mnemonic locations, and to even go as far as building the images used to prompt memory.

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[2] "Portrait of a Memory", Shen, Helen, Scientific American Mind, May 2018.

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By incorporating VR, we can go one step further and actually journey through a Memory Palace in full 3D. However, the amount of work involved in creating such an environment would be significant and once again begs the question as to whether the time would be better spent memorising the content directly. On the other hand, a simple program like Minecraft allows the user to quickly create a simplified and abstracted version of the Memory Palace, roughing out the architecture and letting the imagination fill in the detail. This can then act as a powerful prompt and provide a more stable spatial reference than the mind, which often seeks to compress and simplify space to reduce effort and conserve energy (i.e. it's much easier to 'jump' from one imaginary location to the other than imagine the process of walking in real time). Another alternative is to use pre-built worlds from games, especially walking games like Myst and, more recently, Dear Esther.

While computer generated Memory Palaces can be used to enhance practice, they also place yet another symbolic layer on top of the process of recall and understanding. In the traditional methodology the builder transforms a concept into a symbol and places it within imaginary architecture. Recalling the content means unscrambling the rebus to get at the original. By adding a virtual world as a 3D map of the mental landscape, a further step is added to the decoding process so that the memoriser has to read the VR space to recreate the architecture in the mind before tackling the symbolic images.

Memory Palaces are deeply personal. Indeed, they work best when the architecture and content is linked to the unique experiences, knowledge and memories of the individual. Symbols built from ideas that are significant to the creator are far more powerful than pre-made mnemonics. For this reason, Memory Palaces do not travel, meaning that multi-user versions, or 3D worlds fashioned as aids to other people are of little added value.

Ultimately it would appear that the Memory Palace does enhance cognition through the mind's ability to create immersive imaginary environments in which concepts and information can be consciously inserted into the webs of association in our brains. Journeying through such architecture, revisiting ideas as far as the natural limitations of memory allow, supports the reinforcement of connections between neurons. 3D worlds created in sandbox programmes, or appropriated from walking games, can make the recall process easier, in the same way a finger running along a sentence aids reading, but they add an additional symbolic layer to the process. Further research and experimentation is needed to understand the extent to which immersive computer-generated experiences can support or hinder practitioners of the System of Loci, and to understand the whether it can be used to facilitate abstract reasoning as well as the memorisation of information.

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Learning in Virtual Reality: Opportunities and challenges for using virtual reality in schools for young autistic people

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Abstract. In this paper I outline the argument for using virtual reality head-mounted displays with autistic groups; especially in schools. While the potential for using VR HMDs with autistic groups is not new (there have been studies addressing this since 1996), the evidence-based remains somewhat limited. There have been few studies that systematically examine the full potential of VR for autistic groups and even fewer that place autistic groups (and their stakeholders) at the centre of research using VR. Therefore this talk (and short paper) will present, examine and discuss some data that we have gathered in schools with autistic groups (and their teachers) to better understand whether VR is a comfortable, wearable technology, for people with sensory concerns, whether VR material is reported as being comfortable and/or useful, and finally if and how VR might be used by autistic groups. Implications for practice will also be presented.

Keywords: Virtual Reality (VR), Head-Mounted Display (HMD), Autism, Classroom

1.1 Introduction

The introduction of virtual reality (VR) technology in schools and higher education began in the early 1990’s with projects such as Science Space, Safety World, Global Change, Virtual Gorilla Exhibit, Atom World and Cell Biology [1, 2]. In addition, the potential of VR and head-mounted displays (HMDs) in education has been trialled on the premise that it can “expose learners to challenging or educational situations and allow them to repeatedly practice new skills in an environment that enables correction and non-dangerous failure” [3: p.13]. Within this context, and as Jensen and Konradsen [3] go one to conclude, the educational benefits of VR are mainly connected with: (1) cognitive skills (remembering and understanding spatial and visual information); (2) psychomotor stills (head-movement); and (3) affective skills (emotional responses to difficult/stressful situations). Outside of these areas the authors found limited evidence to support the view that VR HMDs had any advantage over other immersive technologies. This is despite it being noted that VR more broadly has been highlighted as “an effective means of enhance learning outcomes” in schools [2: p.37]. Similarly, other

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studies [4] suggest that: “VR and AR [augmented reality] offer the possibility to move safely around dangerous places, learning to cope with our emotions while experimenting the best solutions while far away from the real dangers” [p.1]. Further compounding the debate, Fitzgerald and colleagues [5] undertook a study that compared the effectiveness of video modelling (VM) and virtual reality (VR) for teaching autistic adults where they found the VR method was no more effective that VM in facilitating learning.

These studies [1, 2, 3, 4] provide a confused picture, but also highlight the potential of VR HMDs for learning. They also suggest there is limited and fragmented evidence to suggest how to best use VR in the context of education. This talk will explore the role, potential and user views of VR in autistic classrooms.

1.2 Autism

Autism is a lifelong developmental condition that affects how people perceive, communicate and interact with the world. All autistic people share common areas of difference but as a spectrum condition being autistic will affect individuals in different ways. Some autistic people also have learning disabilities or co-occurring conditions (i.e. ADHD, down syndrome and epilepsy). Around 1 in 59 children have been identified as being on the autism spectrum according to current estimates from CDC’s Autism and Developmental Disabilities Monitoring (ADDM) Network [6]. Within the UK, figures from the Department of Education show the number of children and young people who have autism as their primary SEN need has increased year on year from 66,195 in 2011/12 to 100,010 in 2015/16. This means that children and young people on the autism spectrum accounted for 1.17% of the total school population in England.

1.3 Virtual Reality and Autism

The field of virtual reality and head-mounted displays has been discussed in the context of autism since the 1990’s [7]. Despite some initial positive outcomes, the use of VR HMDs with autistic groups remained under-researched for many years [8]. This, in part, was mainly due to the size, cost, applicability and real-world potential of HMDs during the 1990s and to 2015. More recently (from 2015 – date), there has been renewed interest in the possibilities of VR HMD technology to support the education of people on the autism spectrum. Parsons and Cobb [9], for example, suggest that VR can “offer particular benefits for children on the autism spectrum, chiefly because it can offer simulations of authentic real-world situations in a carefully controlled and safe environment” [p. 355].

However, and despite the possible potential of VR HMDs for autistic populations, very little work exists with younger autistic populations; especially within educational contexts (i.e. schools). Moreover, limited data relate to the types of VR HMDs that are most suitable/preferred by autistic groups, or younger people in schools more broadly. This is especially important for autistic groups as they can have sensory concerns. Therefore, and to elaborate on this, the focus of this presentation is to provide some

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insights to the way we have approached working with HMDs and autistic groups, in addition to revealing some findings related to the following:

1. What type of VR HMD device (and experiences therein) are preferred by children on the autism spectrum?
2. How do children on the autism spectrum report the physical experience, enjoyment, and potential of VR HMDs in their classrooms?
3. What would children on the autism spectrum like to use VR in schools for?

2. Results, Thoughts and Discussion

This presentation offers several important and novel insights to the experience of autistic children in both mainstream and SEN settings using VR and HMDs. The need for this work is underlined by a lack of studies and data pertaining to experience of autistic groups using VR HMDs in classrooms.

This view is supported by a review of literature from 1996-2017 undertaken by Fernández-Herrero et al. [10] who suggest that on the one hand, we have seen "an increasing interest in the topic of virtual reality as an educational tool for High Functioning ASD children since 2010" [p.75], while on the other hand: "the scientific production in this field is rather small considering its relatively wide trajectory, mostly concentrated between 2010 and 2017" [p.75]. The work covered by Fernández-Herrero and colleagues covered the role of VR as an "educational tool", they don't identify previous work that has sought views, input and co-design of technology for autistic groups. Through their search, limited work, if any, highlights the preferences and choices of autistic groups. This is not a limitation of Fernández-Herrero and colleagues' work per se, but a wider-spread limitation of work conducted in the field to date; specifically focused on VR HMDs.

Other work [11] found some positive signs, reported by autistic adults, using VR HMDs, and confirmed that negative effects (that is cyber-sickness, feeling dizzy, eye strain) were very limited in the autistic population they worked with. In addition, this study found that wearing the HMD presented very few issues for autistic adults (with associated comorbidities) – there were no sensory concerns reported or observed using an HMD with VR over a short period of time. This coupled with the finding in the current study (that will be presented during this talk) that all children were happy to wear and use a VR experience using a HMD starts to suggest that issues related to negative effects and feeling unduly impacted by HMDs is worthy of further investigation to better tease out whether there is any need to be concerned about this aspect of HMD use.

In addition, further investigation would provide important data as to whom and in what circumstances HMDs are most suited for. This would be important as we strive towards safe and healthy use of HMDs in the future. Notwithstanding, the data presented in this talk (and study) highlights positive responses towards HMD use with 6-16-year olds in the U.K. A level of confidence, willingness and enjoyment using HMDs was reported across the autistic groups. However, we also suggest that as the field grows and develops, providing information and guidance related to health and safety issues (including negative effects) needs to remain central to all research; because in

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doing so there will be greater uptake and interest. This is especially important if VR HMDs can in fact provide a safe, ecologically valid, and supportive environment for autistic users to engage with a range of experiences.

We suggest these are important findings, as research examining negative effects (in particular motion sickness) have reported less favourable results. For example, one study [12: p.894] found that "after playing the game for a maximum of 15 min, motion sickness was reported by 22% of participants". Twenty-two percent in this context refers to n=8 (out of n=36 men and women). This is a finding supported by several other studies [13, 14] and an area that Jensen and Konradsen [3] refer to as: "barriers to the use" in educational contexts. And as some authors suggest [15]: "there are still many unanswered questions about immersive VR's influence on children's development" [p.113], pointing towards the need for more considered studies assessing the potential (for positive and /or negative connotations) of VR HMDs used by all children, including those on the autistic children.

This study, and the data presented, should shed some light of the perspectives and views of autistic children (and their teachers). In this context, we have better located the types of HMDs technologies that might be most successful in schools for autistic children. We suggest that based on the feedback (from pupils and teachers) that low-tech options such as cardboard HMDs coupled with a smartphone could be an appropriate first-step into using VR to transport pupils to various environments to augment their learning. In addition, the finding that VR HMDs might be most usefully received as a form of meditation, we also suggest careful thought about using VR in schools for this might provide access to a quick and easy methods to help reduce stress and increase calming feelings for autistic children. This of course needs validating, but the feedback we received in our project seems to suggest that VR could work well in this domain.

2.1 Implications for practice

This talk will conclude with several messages for practice and people wishing to use VR in schools with autistic groups. In terms of research, some messages and areas for further lines of enquiry include:

- The continued need to **collaborate**; sounds obvious, but is something this area can't grow, scale and have impact without.
- **More evidence**; evaluation of the work ahead is vital.
- The need for **content**; hardware is freely available and can be used in classrooms/centres/the home, but content is lacking.
- **Alignment** to **evidence**; we need to ensure that content is aligned well to evidence. If VR can be beneficial; how, where, when, what, etc..
- **Autistic** communities and groups (and their caregivers); why would we not?
- **Access**; placing tech in the hands of the users… (funding and scaling).

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The Augmented Employee: Immersive Technologies in Field Service Operations

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Abstract. Immersive technologies have the potential to enhance service operations, improving customer service and increasing overall efficiency. By combining them with computational intelligence (CI) mechanisms to produce adaptive context-aware environments for advanced decision-support, these solutions can lead to a much faster knowledge transfer and a deeper understanding of different processes, enhancing experiential learning. This presentation will explore uses of immersive technologies for field service operations in the telecommunications domain.

Keywords: Virtual reality, augmented reality, mixed reality, training, knowledge transfer, experiential learning.

1 Introduction

The increasing complexity in field service operations (FSO) has brought the need for upskilling employee's working efficiency, which represents a big challenge for companies and employees themselves. If we sum up, employees' mobility to this scenario, we face a number of challenges, for example, how to quickly on boarding human resources? Or how to effectively transfer and maintain knowledge within the organisation? To solve this, we need to continuously work in enhancing talent development.

Training specialized workers represents a considerable overhead in any business. In addition, the increasing complexity and number of variants in underlying technologies is complicating the process of ensuring that the workforce is permanently up-to-date and knowledgeable on every technology and product involved in the services companies provide. Furthermore, the risk of losing crucial knowledge that cannot easily be replaced when expert employees leave an organisation (e.g. retirement of aging workforce) is another factor that needs to be considered. Knowledge needs to be distributed over all the actors of the workforce community as well as documentation supports.

The confluence of Immersive Technologies (Mixed Reality (MR), Augmented Reality (AR) and Virtual Reality (VR)) aim to augment human capabilities, providing enhanced memory, improved communication, and sharpened senses for multidimensional thinking and problem solving [1] towards the vision of what has been termed the *augmented*

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employee (Fig. 1). Their use can potentially enhance working environments by removing restrictions of time and location, leading to a much faster knowledge transfer and a better understanding of different processes. Furthermore, industry can benefit from the use of immersive technologies to lower operational costs and thus sustain their growth and innovation.

These ideas align with the concept of Service 4.0, which is "a collective term for disruptive technologies—e.g., big data, wearables, and AR—that support and promote innovation for service organizations" [2]. In this regard, immersive technologies have the potential to enhance service operations, with the goal of improving customer service and increasing overall efficiency. By combining them with computational intelligence (CI) mechanisms to produce adaptive context-aware environments for advanced decision-support, these solutions can lead to a much faster knowledge transfer and a deeper understanding of different processes, enhancing experiential learning.

Potential use cases for the industrial workplace can be broadly divided into On-the-Job Support, Training, Knowledge and Skill Transfer [3]. This presentation will describe these scenarios for field service operations in the telecommunications domain using immersive technologies and will reflect on some of the lessons learned.

Fig. 1. The Augmented Employee.

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Geo Immersive Reality (GIR)

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Abstract. Maps are a reference to real-world objects. They help us navigate and make sense of the world by providing a list and locations of places and objects and a drawing to understand the attributes of objects invisible to our eyes. The height and contours of a mountain, the dimensions of a property, all relevant to help understand the environment. However, if this geospatial information is to help the user with situational awareness and operational intelligence in their current location, real benefits will be gained to deliver this data as a digital overlay on a smartphone or ultimately smart glasses for a heads up access. Apart from accessibility improvements, Immersive environments have also been proved to increase information retention after six months by 20%.

Keywords. GIS, geospatial, maps, education

1 GIS data

A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations.

2 Augmented Reality and GIS usecases

Augmented reality (AR) and virtual reality (VR) have for years been main players on the gaming world stage. But there are exciting possibilities in the health and emergency response sectors too.

VR offers a 3D artificial environment ideal for gaming which immerses the player by simulating as many senses as possible, including vision, hearing, touch, even smell. And now its cousin, AR, has come along, which overlays computer-generated graphics or animation on top of real-world environments. Think of games such as Pokemon Go, where AR brings together physical locations and virtual worlds. Now players can interact with virtual targets.

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At Ordnance Survey, our adoption of the concept of Augmented Reality predates the new wave of the technology as Andrew Radburn, a long standing senior Research Scientist at OS published an early work in year 2006 on the concept of hand-held AR overlaying master map data onto the real world using very early hardware such as Toshiba tough books and external camera and GPS antennas and accelerometer. This however was very revolutionary at its time as smart phones were still in their infancy.

2.1 Location-based Augmented Reality

This is where the location of the object in real world becomes the key to unlock the digital data attributed to it. This data and attribution in this case is usually not visible to the naked eye but is then reavealed by augmented reality technology in a smart phone/tablet or headwear such as Hololens or Magic Leap.

This type of AR has many use cases and applicatiosn with geospatial data. One of the historical parallels to this is where stars were used for navigation. This is also a very good example of a rising computer science paradigm called Spatial Computing where information and data exists in all three dimensions rather than just on the monitor. It has been proved that this method icreases data consumption by 30% as it engages humans‘ peripheral vision which is highly sensitive as it is to be alerted where a dangerous even is approaching and is still not in our full view.

Indoor navigation.

During 2017, We carried out a case study for navigation in Southampton General Hospital which revealed that 57% of visitors find it ‘difficult’ and 21% ‘extremely difficult’ to find their way around hospitals. This is contributing to many missed appointments not just in this south coast hospital but right across the country. According to an NHS report, around 6.9 million outpatient hospital appointments are missed each year in the UK, costing an average of £108 per appointment.

An augmented reality arrow overlaid on a live camera view on a phone – together with a thumbnail of where you are in a building – could not just help the millions of hospital visitors each year but staff in emergency situations too. Even 60% of hospital staff find navigation ‘difficult’ which could add delay to a life or death situation.

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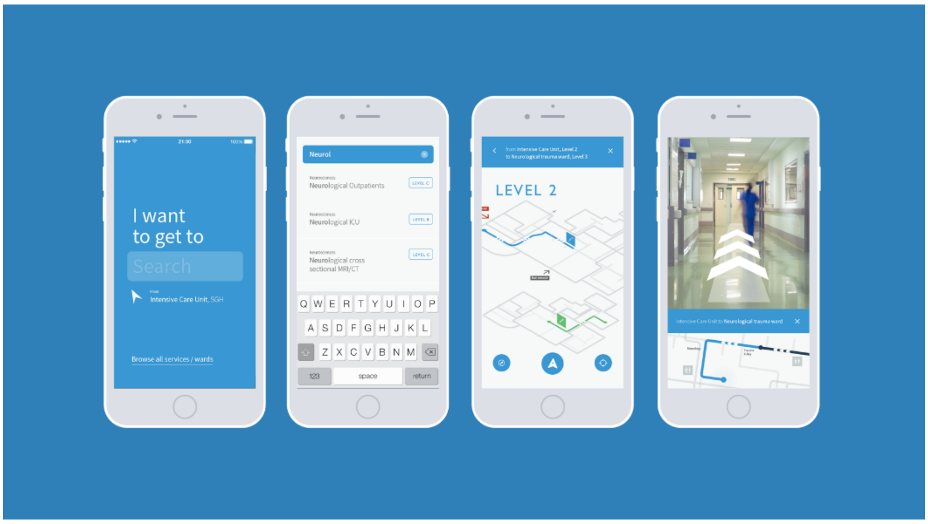

Fig. 1. UI prototype of an indoor navigation app powered by iBeacons for patients, visitors and staff

It doesn’t help that complex buildings such as these are harder to navigate under stressful conditions. Stress and its associated hormones are known to influence the function of the hippocampus, a brain structure critical for cognitive-map-based, allocentric spatial navigation, backed up by a 2015 study at the Department of Psychology in Canada’s University of Victoria.

Therefore, what we propose is a turn-by-turn navigation for patients and staff to improve the wayfinding.

This technology along with iBeacon based indoor positioning was used in producing an app for an event Ordnance Survey sponsored in 2017 called Digital Shoreditch. Event visitors used the app for navigating in the venue and also networking and getting live alerts from the talks delivered to the app.

Another example of a complex building with stressed users is an Airport. Despite the open plan of the building and therefore less complexity we are still facing the reduction of navigation skills discussed above. Ordnance Survey has produced proof of concept apps using iBeacons and AR as demos to showcase the benefits of this type of application in three different areas:

Airport utility/asset managers staff.

Here the fixed and moveable assets can be located and visualized by airport utility staff. In case of items such as defibrillators where due to price of the unit can be shared by nearby buildings or even misplaced, it is very important to be able to locate them as quickly as possible to respond to a medical emergency.

Again, fire hydrant cabinet as displayed below can be highlighted for rapid access.

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Fig. 2. Concept design for a prototype location-based AR asset management app in an airport for utility managers

- Passengers
  Here as seen below, the app of the airport or airline will help the passengers navigate to the gate via shops or via the quickest route. The app will also show alerts from the flight information system to help inform the passenger as they make their way to the departures lounge.
  The arrow is again used for reasons of user experience simplicity and an easy to follow methodology. This technique has long been in practice with many years ago where hospital corridors were painted with various colors to follow to get to a certain destination. In this case the painting is done digitally to deliver a custom route for the individual using the app considering their destination and even accessibility limitations such as need the avoid the steps, etc.

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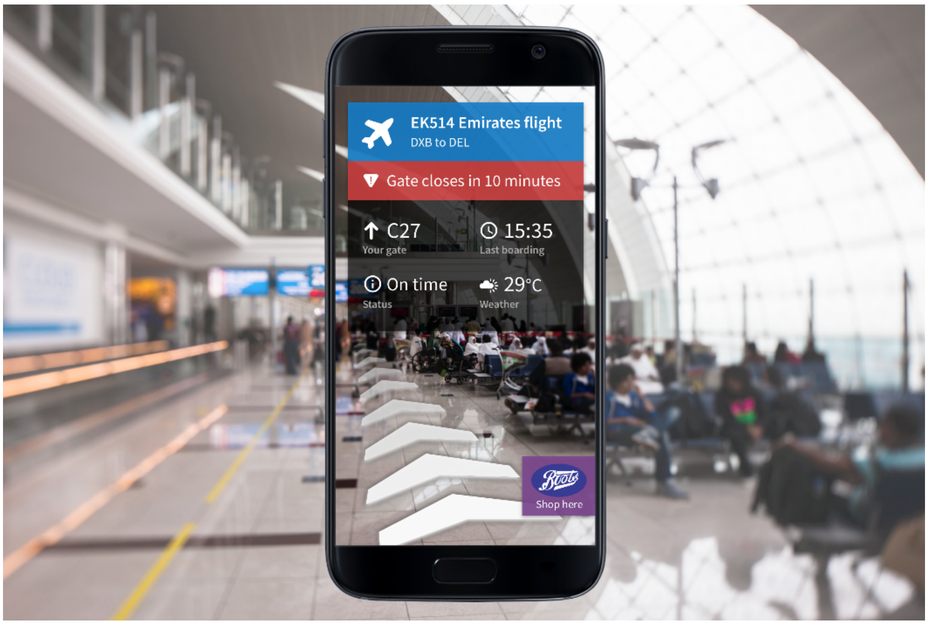

Fig. 3. Concept design of a prototype augmented reality app for navigation in a smart airport

- Autonomous baggage handling systems

Another use case for this type of AR in the airport is for baggage handling staff in a smart city airport which has autonomous pods for loading and offloading of the passengers' baggage into and from aircrafts. Like any other IOT system, there will be a cloud service to feed data to an augmented reality platform to be visualized in an app. To detect which baggage QR codes can be placed on the platform to identify the load. Below pictures shows a dashboard in AR view to help the staff with offloading of the baggage from the conveyor belt.
[1]

[1] All images are sole property of Ordnance Survey and produced by internal staff apart from where indicated

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Fig. 4. AR dashboard for the baggage handler staff connected to an autonomous baggage handling system

Points of interest discovery.

When planning to explore a place you have never been to, we always look at a map. This shows us the places and information we need to plan our trip. But once we are there, although we will carry on using the map to see the big picture of where everything is, the other way we can engage with those 'interest' points is to be alerted about them and being able to click and see more information about them as we walk around and one is in our 'view point'.

An example of this is an already released AR feature within the OS Maps `app` which is used by walkers in their discover of nature trails. The `algorithm` was developed in house by me in OS Labs and therefore there is no reliance on external SDK's for the augmented reality technology.

This feature won the Yahoo Sports Technology award of year 2018 for best use of AR technology and it continues to benefit walkers with their discoveries of points of interests in outdoor trails.

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Fig. 5. Snapshot of Ordnance Survey Leisure OS Maps app AR view

There is also the scenario of city navigation and health routes. This scenario has the potential to benefit from IOT sensors and connected information with the use of Artificial Intelligence for data discovery and delivery. Imagine a scenario where a person with a health condition such as asthma is taking a walk through a large polluted city center. The sensors within the city are constantly monitoring the pollution levels in the busy parts of the center. Since this is an IOT scenario, there will be APIs and cloud services available for accessing the live readings from the sensors and perhaps predicted values too.

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Fig. 6. Concept prototype of a urban ride sharing and health optimized routing app for smart cities citizens

The smart navigation app will combine the user's health conditions with the real time values to deliver a visualization of location-based points of interest to help with finding the least polluted route for the user to take.

This will all be powered by AI and IOT in a smart city.

Connected vehicles can also play a part in this scenario, where lift available in real time from a friend or a ride sharing service such as Uber or Lift.

Most large cities are currently suffering from increased pollution due to large number of single passenger commutes. The simplest remedy for this would be to use ride sharing apps to reduce the number of cars for work journeys as one geographical destination is shared by many users. However, one of the barriers for their lack of widespread use lies in the population's perception of lack of flexibility in these services. Many people work patterns includes shifts and irregularities hence the reluctance to make fixed arrangements for ride sharing with work colleagues. Other factors that are in play include the lack of reliability by families in case of emergencies with illnesses of young kids.

Augmented reality and real time ride sharing can remedy this by enabling an on-demand service where people can just 'e-hail' a ride on the spot.

Emergency services incidence management.

This is another group of users who are again under stress, the navigation can also be hampered by poor vision due to smoke, helmets or low lighting. AR has the capability

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to make buildings smarter by highlighting fire safety routes, electricity junctions, wiring, exits, and even who's attending which function in what room. This helps with collaboration between different fire crews by showing them where everyone else is in real time.

In future where heads up displays can be mounted on the safety helmets the information above will be added to the HUD to for example show where a vulnerable person is in a particular floor of a high rise as the crew approach whilst still outdoors without the need to take out a map which speeds up the rescue response time.

Fig. 7. Concept design of a location-based AR app used indoors to reveal the 'beyond the wall' features of the building that the human eye can not normally see. The positional accuracy of 2-3 meters is achieved by using over 30 iBeacons installed in the underground of Shoreditch Townhall basement

It can also be used for alerting the emergency services about any hazards such as chemical spillages and help visualize this data in relation to real world buildings and roads.

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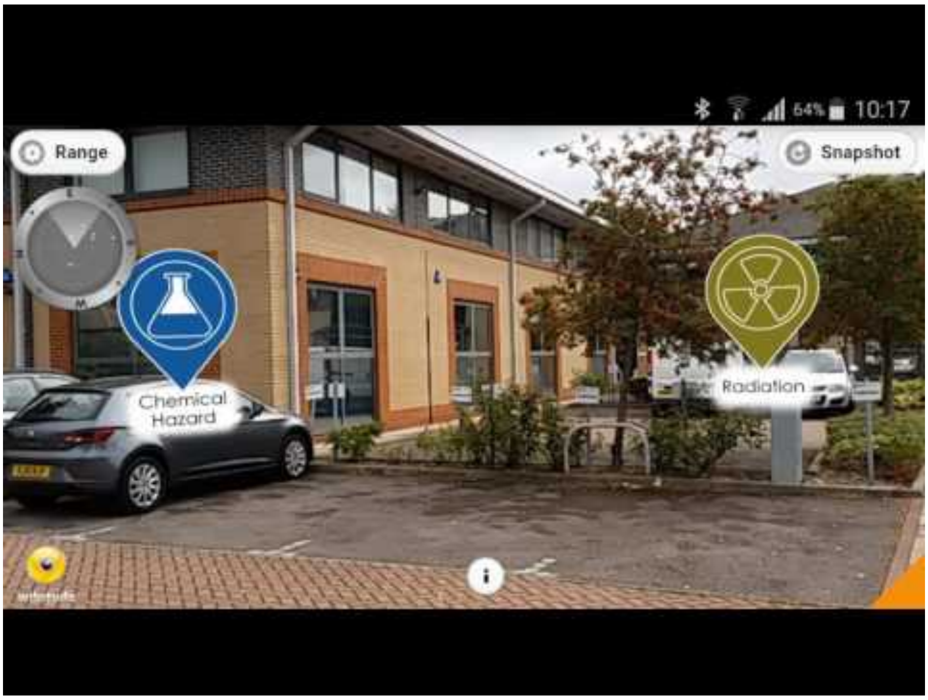

Fig. 8. Snapshot of Ordnance Survey partner Aligned Assets Symphony AR app for local authorities[2]

Underground utility asset management.

This is where the augmented technology can be the holy grail of field workers and utility inspectors. It is a scenario where AR is giving 'X-ray' vision to the utility staff for visualizing buried assets and a dashboard of readings from wireless IOT sensors that are inside the pipes and junctions.

In this scenario AR is increasing operational intelligence and also safety and therefore adding value and saving money and lives.

Hazards can be detected quickly and accurately by this 'X-ray' vision capabilities and it also remedies the difficult task of correlating the information displayed usually on a map of the assets which are normally not even in the same scale as real world to real world scales.

There are already off the shelf apps such as Augview that deliver this type of AR technology specifically for utility services, but this of course relies on accurate geospatial data being available from the assets and the device needs to be capable of centimeter accuracy positioning. Capturing the buried assets data can be achieved by using ground penetrating radar. Satellite positioning systems and the use of surveying grade antennas and differential GPS can also provide centimeter accurate position of the user in x, y and z.

[2] Sourced from the website of Aligned Assets

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Fig. 9. Concept design of a prototype app for AR visualization of buried assets and the attribution of each individual physical item

2.2 Marker based Augmented Reality

In this type of augmented reality, a symbol, a pattern, a barcode such as QR code or even a three dimensional shape of a physical object is used as a target to trigger an AR event and visualise the data that the user can not normally see. This technique can enhance/augment the shape of an object, present a three dimensional represenation, reveal a digital dashboard or show meta data and attribution related to the real worl object. Attribution can also be added to this AR view and edited to be shared to the community over the internet and synched in real life. Again this can have many many applications but in this paper we look at the GIS domain again to stay relevant to Ordnance Survey data and its customers.

Enhanced paper maps.

Printed maps as we know them are a merged view of many layers of topographical data about the land. Cartography is a technique to present this data using shapes, different line thicknesses colors. Map reading is a skill to be able to isolate all these layers and interpret the information. and even patterns.

Paper due to its convenience, versatility, security, cost and also the scale and reliability is still the favorited medium for presenting mapping information for large areas.

However, AR can be used to 'de-clutter' maps as it can show you only the information that you are interested in and hide the information that is not required.

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The other use case is where pattern of the map due to its' uniqueness is used as an AT target to reveal extra information that is not printed on the map such as weather, traffic or even temporal events such as concerts and groups activities.

This was developed and demonstrated in a collaborative project called Mapsnapper between the author and Southampton University computer vision research department which was featured in New Scientist in year 2006[3] and recently hailed by The Register in a featured article about Ordnance Survey during national map reading week October 2017.[4]

The methodology used computer vision algorithms such as SIFT features to create a geographically indexed dataset of map tiles with unique identifying vision signatures created by processing salient features in raster OS explorer maps. When the user takes a picture of the map, this is used for identifying the location and the points of interests are then returned and overlaid on the image of the map.

Another example prototype of a marker-based AR using cartographic features as a marker was a prototype iOS app made by the author to work with the Mars map published by Ordnance Survey. This was very successful in recognizing the map pattern and used Qualcomm's Vuforia technology. As the user points the camera of the device at the paper Mars map, an AR experience is triggered, and A 3D model of Mars is overlaid on top of the paper representation. The 3D model was produced by OS cartographic team using the elevation data from the MOLA instrument on MGS. Supplied by NASA/JPL/GSF. Resolution approximately 463 meters per pixel.

The original paper map sheet is a topographic base-map based largely on elevation data from satellite imagery and is printed at a scale of 1 to 4 million (1:4000000) and measures 980 by 840mm. It represents an area of Mars 3672 x 2721km which is similar in size to the United States of America (USA).

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3 https://www.newscientist.com/article/dn10416-phone-creates-interactive-maps-from-snapshots/

4 https://www.theregister.co.uk/2017/10/20/ordnance_survey_augmented_map_week/

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Fig. 10. An actual snapshot of the Ordnance Survey topographic Mars Augmented Reality app during a demo

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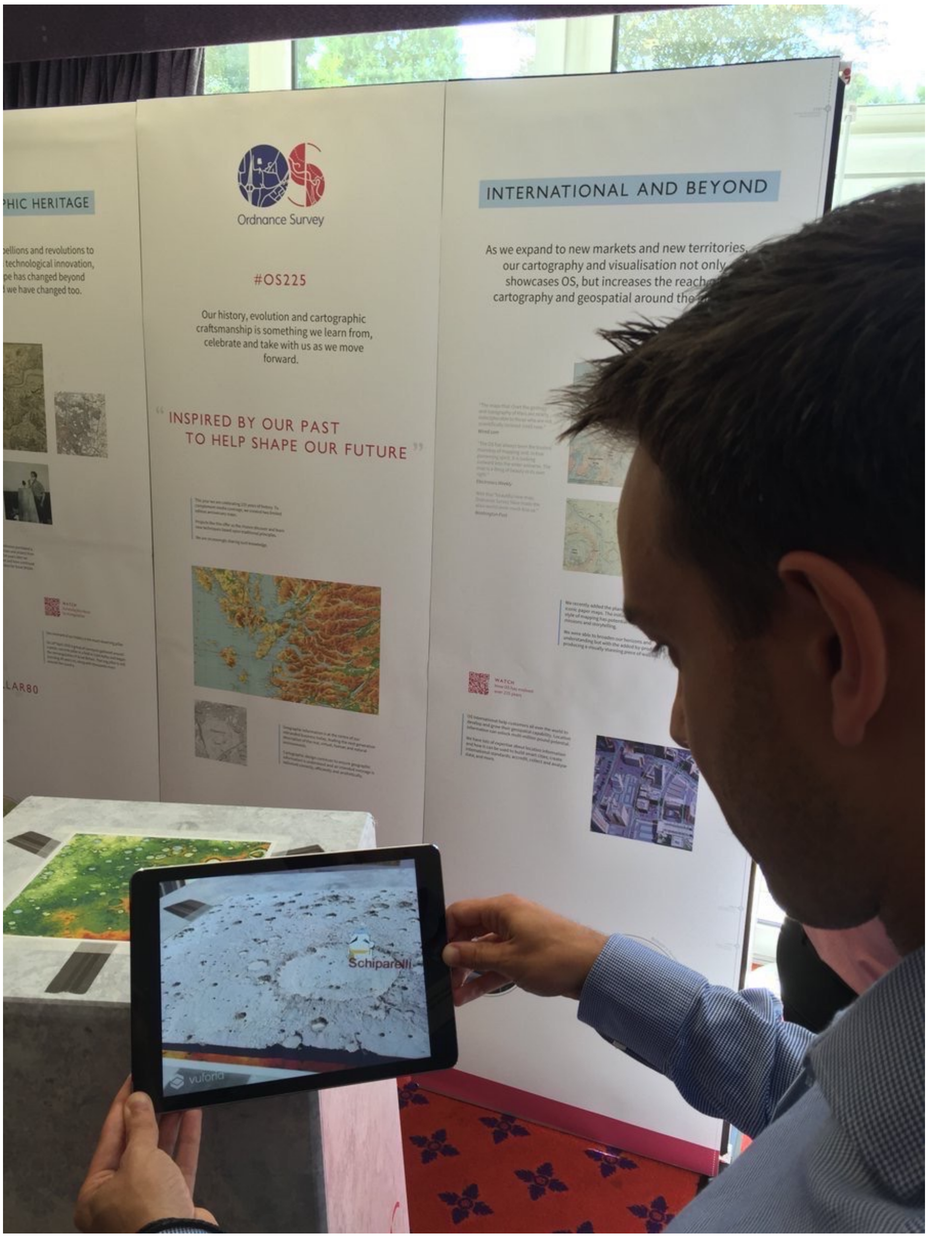

Fig. 11. A variation of Mars Augmented Reality app in action at an ESRI conference stand, where the maps creator cartographer Christopher Wesson pictured demos the app to the visitors

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Walking trails unlocking geospatial data with smart symbols.

Another concept the author is currently exploring with one of the OS sponsored startups is an interactive walking trail augmented reality app for kids and families exploring the wildlife of England and learning about the animals they reveal with the app. Unlike the location-based AR, the physical posters with pictures in woodlands are used as targets to unlock the digital content in this case the 3D animated cartoon animal and overlay them on top of the real-world sign. The app allows the kids to take a photo and currently features four animals with fact sheets included in the app.

Fig. 12. An actual snapshot of Pocket Pals Trail app running on iPhone showing an animated digital butterfly and the tree trunk hiding the physical sign behind it

2.3 Tabletop mixed reality (Hololens)

In this scenario, headwear is used for a hands-free AR experience where the user will see the digital content overlaid on real world through the clear lenses as holograms.

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OS has developed two prototype app for Microsoft HoloLens for tabletop placements of detailed 3D models as holograms. One is of Manchester University captured by high precision drone acquired aerial imagery on a tabletop. The use case for this is smart city dashboards where real time data can be overlaid on the model and incidents can be discussed in a disaster management scenario. An actual footage of the app can be seen YouTube channel `Here.`

The other demo features a 3D model generated using the digital elevation model based on OS Terrain 5 datasets of mount Snowden. An actual footage recorded on Hololens headset can be viewed `Here.`

One use case for the example above can be flood visualization and management in a multi-agency scenario where all users some in the room and some not all wearing Hololens can collaborate in a common mixed reality session to visualize and have a discussion around natural disaster management.

Another type of mixed reality prototype has also been developed for visualizing the buried assets in real world scale overlaid on real roads and surfaces. This would allow utility inspectors to asses where the current pipes are in the ground underneath if planning new assets or repairing existing ones. It allows them to dig the correct place and avoid damage to neighboring pipes and assets.

This would offer utility companies a new level of operational intelligence which can drive efficiencies and increase safety.

3 Virtual Reality and GIS usecases

Due to its closenss to a real life experience, Virtual Reality can be a very powerful medim for simulation and education.

Research has proved that VR certainly enhances learning. The brain absorbs information 33 per cent more effectively when in the immersive environments of AR and VR, according to Stansford University Virtual Human Interaction Lab researcher Jeremy Bailenson.

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3.1 OS Virtual Map Room

This Oculus Rift app has been developed with purely education in mind. The idea is based around gamifying a GIS task of interacting with geospatial data in an escape room scenario. The app was demoed to visiting school students on a GIS education day, where they were required to collaboratively solve a GIS task and find the key to exit the map room. The maps themselves are two-dimensional raster Ordnance Survey maps and points of interests and polygons are overlaid on the virtual tabletop.

Fig. 13. Actual snapshot of OS Virtual Map Room app on Oculus Rift

We continue to collect feedback from students to assess how they find the VR map interaction versus non-VR. Certainly, the level of engagement and participation of students has been witnessed to have been higher compared to previous years where VR was not used.

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3.2 Virtual Explorer House

In thsi example, the team created a virtual reality app that poulates the assets dynamically at run time by connecting to a live data set of in this case desk locations held by utilities at Ordnance Survey and places the virtual desk the locations they really are in the building and with the information about the desk number viewable in virtual reality. The aim of this demonstrator was to asses the methods in which geospatial data in this case desk with locations can be obtained from external sources and with unity creating assets in real time and placing them in a correct location. This is the basis for a dynamic virtual reality experience as opposed to fixed data. With a future in 5G networks becomign mainstream, the concept of untethered dynamic VR would be more than achieveable.

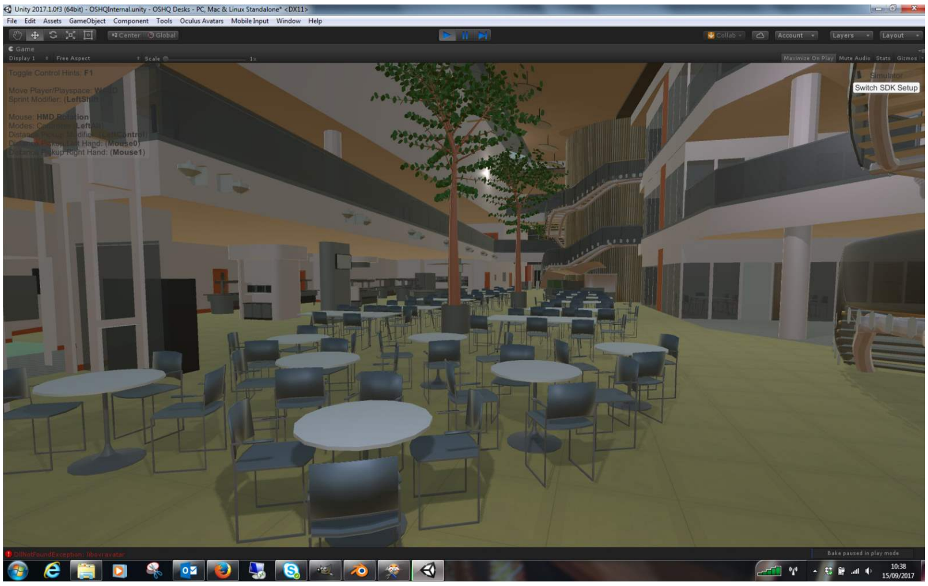

Fig. 14. Virtual Explorer House snapshot

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Fig. 15. A virtual tabletop experience featuring 3D mode of the Ordnance Survey headquarters

3.3 Digital Twins: Bournemouth VR for 5G planning

The aim of this demo was to use virtual reality for remote asset management and planning of a 5G network visualising the street assets and locations of the building. The powerful medim of immersive placement in a remote location adds an enhanced information retention, situational awareness and also a greater data consumption from peripheral vision. Overall the experience should be as if the user was directly flown in real life atop the city of Bournemouth to plan the network. Of course, virtual reality provides a more convenient, cheaper and repeatble alternative to a flight. It is also weather independant as aerial flights sometimes need to be cancelled due to poor visibility. The education angle could be that the task of planning the 5G network can be turned into a set of steps in a VR enviornment and trainee GIS analysts can use it as a learning tool and improve their skills.

In order to add a fun element to learning and also to showcase the detailed elevation model, OS branded beachballs are featured in the app where the user can pick up and throw them into the city. The app has been part of the VIP visits by ministers and geospatial commission to the building and received many good feedback for an interactive enviroment and the quality of the automatically generated 3D model jusst using oblique standard aerial imagery.

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Fig. 16. An snapshot of Bournemouth VR playing on Oculus Rift

This type of scenario assesses the role VR can play in immersive 360 visualisation of digital twins of cities for urban incident managament, urban planning and also remote asset planing and management.

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Evaluating Mixed Reality Collaborative Learning Environments: the MiRTLE+ Case Study

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Abstract. The rapid increment of using advanced technologies such as smart glasses, handheld and head-mounted devices have recently shown its efficiency and effectiveness in education. This paper uses MiRTLE+ model as a case study to evaluate the concept of mixed reality game involving remote and local learner in collaborative learning spaces. This aims to measure presence, immersion and learning outcomes. Four different learning game scenarios with two level of player background (Novice and Expert) were conducted using UNO game card. The results showed that learners presence and immersion in MiRTLE+ were significantly different from the presence and immersion of learners using traditional web-based platforms and very close to those of the control group who do not use technology.

Keywords: Human-Computer Interaction · Mixed Reality · Augmented Reality · Presence · Immersion · Learning Outcomes · Cards Games.

1 Introduction

In the Human-Computer Interaction (HCI) field, factors like presence and immersion have been studied theoretically and empirically to prove the effectiveness of mixed and augmented reality technologies for end users in such diverse sectors as health [3], military [9] and education [7]. In education, most of these empirical studies (e.g. [2] and [15]) have focused on measuring the impact of the aforementioned factors on students' interactions with their learning content. However, very few empirical studies have explored the effectiveness of these factors in relation to groups of students doing learning activities within collaborative synchronous mixed reality learning spaces. Learners and teachers using virtual environments typically have very limited interactions with their real teaching environments and the people within them. Thus, this case study focuses on developing and increasing the interactivity among remote virtual and real students in teaching environments. So far, however, there has been little investigation into

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how to increase the interactivity of remote virtual students in physical smart spaces based on the dynamics of interconnecting physical people and objects with their virtual counterparts.

In a previous paper [1], we proposed the MiRTLE+ architecture. It is considered to support the collaboration of small groups of people from different levels of background (i.e. novices and experts) and from different locations (i.e. distance and local) around learning tasks using mixed reality, augmented reality and virtual reality concepts, which makes its model design unique comparing to other mixed-reality approaches. Thus, the MiRTLE+, as it will be called in this paper, was developed into phases. In this case study paper we consider to explore the impact of different learning scenarios by using different interface devices (i.e. the use of tablets and PC screens), whereas the next phases will consider immersive augmented reality glasses and virtual reality head-mounted display in the future work.

Four different learning scenarios are structured based on user interfaces, locations (remote and local) and levels of expertise (novice and expert) as shown in Fig 1.

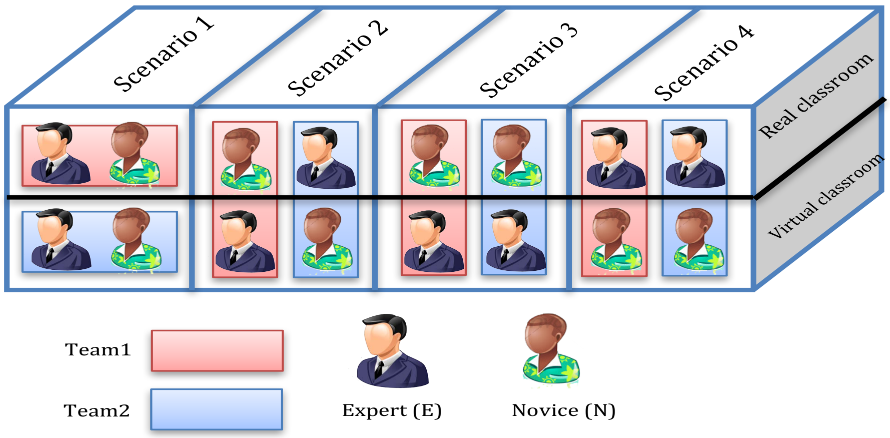

Fig. 1: Learning scenarios of phase one.

Moreover, the MiRTLE+ learning scenarios will be compared with our baseline control group (i.e. participants who will not use technology at all) as well as the web group (i.e. participants who will use a 2D web browser and Hangout software for collaborating in the learning activity).

In the following, we discuss this further, in six parts. The following part describes the background and related work. In the third part, the experimental approach and design are presented. The fourth part will demonstrate the results and analysis. Then, our results are discussed in the fifth part. Finally, the conclusion will be drawn.

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1.1 Research questions

Independent variables for our research questions in this paper are considered to be learning scenarios and users interfaces. Thus, this study will address the following research questions (RQs):

1. What are the differences of learning effectiveness depending on which learning scenarios or users' interfaces are used?
2. What are the differences of participants' sense of presence and immersion factors depending on which learning scenarios and users' interfaces?

2 Background and Related Work

2.1 Mixed Reality(MR)

Mixed reality (MR) (also called hybrid reality) is the merging of virtual and real worlds to create new spaces that accommodate and visualise virtual and real objects in real time and enable users to interact with them [16]. Milgram and Kishino [12] also define MR as a generic concept within the zone between real spaces and immersed virtual spaces. This zone is where graphical computer based objects exist in real space (augmented reality) and where real objects exist in virtual space (augmented virtuality), as shown on the Reality-Virtuality Continuum in Fig 2. The MR concept can be used as an advanced tele-presence method to connect the virtual environment with the physical environment [14].

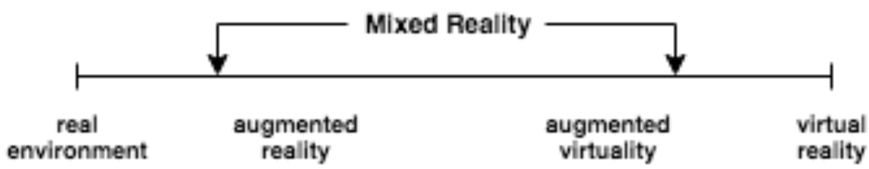

Fig. 2: Reality-Virtuality Continuum.

One another example of applying the concept of MR is the MiRTLE project. The MiRTLE (which was developed by the university of Essex [6]) was empirically designed using the Open Wonderland project, which is a popular open source software tool for creating 3D virtual spaces. The Open Wonderland project is a Java-based system that provides a purpose-built world targeting education, business and government applications. The MiRTLE project basically sought to allow remote students to virtually (in a 3D environment) interact with local students and their teacher. The system allows remote students to share programs, such as word processors and Internet browsers. The remote students' presence takes the form of avatars superimposed with their login names as shown in Fig 3.

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Fig. 3: MiRTLE avatars superimposed with their login names.

3 Experimental Approach

3.1 Subjects

Twenty-four participants voluntarily participated in the experiment, of which 16 participants were to use the MiRTLE+ platform, four participants were to use the web platform, and four participants were to be the control group. The participants were recruited from the University of Essex through an opportunity sample and signed a consent form. Twelve participants who had never played the Uno card game and did not know its rules were recruited as novices. Another 12 participants who had played Uno and knew its rules were recruited as experts. The participants were recruited in groups for our different learning scenarios. Each scenario had four participants playing in two teams. Each team had a novice and an expert player.

(a) Local participants, scenario 1 (b) A remote participant, scenario 1

Fig. 4: Participants in various MiRTLE+ learning scenarios

3.2 Tasks and procedures

We propose a simple learning activity task in which a group of students are asked to play a card game, which will have a number of rules and instructions. Usually,

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people prefer to learn these types of games by being able to practice with experts whilst playing a real game. In addition, the Uno card game is specifically selected because its rules are simple, and achieving the target does not take a long time, which fits with our experiments' time constraints.

During the setup phase with the participants, the pre-test for the Uno card game rules and the demographic questionnaire concerning each user's technology background were sent to participants via email and completed before starting any of the experiments. The experimenter assigned four participants, two experts and two novices, in each learning scenario based on their availability by using the Doodle website.

The Web learning scenario: For the web group, participants were also provided with instruction sheets. The instructions included the log-in procedures for the Hangout[4] application to enable a video call between participants. Also, it included how to start the game session through the web browser. Participants logged in from their office machines that were distributed around the university campus. One participant logged in from the iClassroom to follow up on the procedures established by the experimenter.

The control group scenario: The control group participants were all recruited to play the Uno card game on a table with four chairs in the iClassroom. They did not use technology at all. They were provided with a real Uno card game pack and instructions sheet (which included when they should discuss the game and the target to win the game). Experts were also given extra sheets for recapping the rules. Two video cameras were set up in the iClassroom to record novice participants play actions, the spent time for each session and discussions between the game rounds.

3.3 Data collection

Qualitative and quantitative data: Data for the main dependent variables (mentioned in the introduction of this section) were collected from (1) the Presence Questionnaire, together with the four factors related to presence identified by Witmer and Singer [17], namely, control, sensory, distraction and realism; (2) the Immersion Questionnaire (IQ), with its five factors identified by Jennett et al. [8], namely, control, challenge, real-world dissociation, emotional involvement and cognitive involvement; and (3) learning outcomes, which will be described further in the next paragraph.

Learning outcomes: In order to measure learning effectiveness, two methods were applied: pre- and post-tests for measuring participants' knowledge in playing the Uno card game and an error-based testing system to track novices playing as they played and learnt rules during the game task.

[4] https://hangouts.google.com/

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4 Results and Analyses

4.1 The experiment

As explained earlier, this study focused mainly on the differences between MiRTLE+ interfaces within various learning scenarios. Table 1 described the analysis of all scenarios. This table presents the means of all dependent variables (i.e. presence, immersion and learning outcomes) based on the interfaces used in each scenario by experts and novices.

Table 1: Descriptive statistics for scenario-based interfaces

	Scenarios interfaces comparisons									
	Scenario 1		*Scenario 2*		*Scenario 3*		*Scenario 4*		*Web*	*Control*
	r	*l*	*r*	*l*	*l*	*r*	*r*	*l*		
Presence	5.35	5.35	5.00	5.15	5.44	4.47	4.94	4.56	4.31	5.88
Immersion	3.88	3.88	3.88	3.82	3.92	3.90	3.86	3.98	3.51	4.24
Learning outcomes	10%	80%	30%	50%	45%	N/A	35%	N/A	35%	45%

Notes: r = remote users who used PC screen interfaces, l = local users who used iPad-based AR interfaces, N/A = not applicable for novices regarding the teaching variable or experts regarding the learning variable.

Scenarios comparison

Presence: The analysis revealed a statistically significant difference between the presence means in our scenarios determined by one-way ANOVA ($F(5,18) = 4.055, p = 0.0122$). To follow up the ANOVA results, post hoc test was carried out using Tukey's HSD (honest significant difference) test in order to make a pairwise comparison. The results showed that the difference between control and web group was statistically significant at 0.01 and the difference between control group and scenario one was statistically significant at 0.1.

Immersion: The ANOVA test was also carried out to test differences in the immersion level among the scenarios. A statistically significant difference was found between the MiRTLE+ scenarios, web and control groups ($F(5,18) = 2.924, p = 0.0419$). To follow up the multiple comparisons, the Tukey's HSD test was applied. The result showed that the difference between control and web group was statistically significant at 0.1.

Learning outcomes and scenarios differences: First, from the above table the learning gain scores that appear in percentage were quite similar among scenarios. However, scenarios 1, 2 and 3, in which novices used AR interfaces,

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present very convergent or similar scores (i.e. 45%, 40% and 45%, respectively) to the control group (45%), whereas the scores of novices who exclusively used VR PC screens (35%) were similar to those of novices who used the web scenario (35%). This could indicate that novices in scenarios that involve AR interfaces could have more knowledge gains than those in web or screen-based VR scenarios. However, as the difference was not statistically significant.

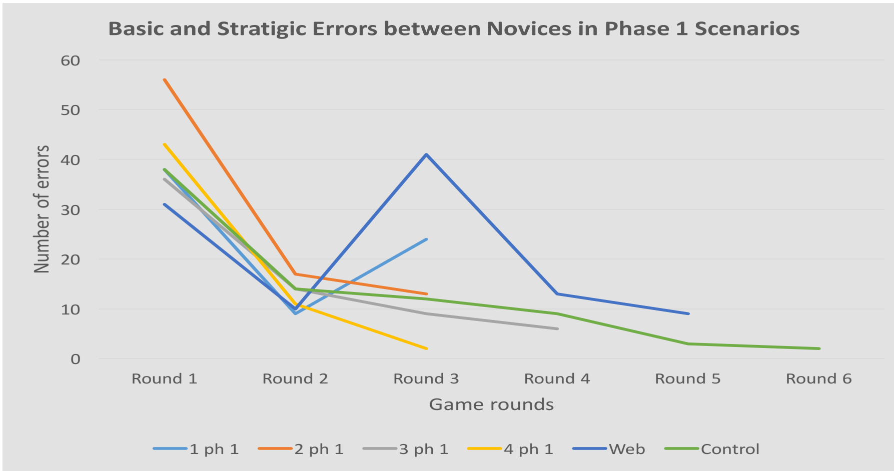

Fig. 5: Basic and strategic errors committed by novices in phase one scenarios.

By monitoring novices' errors from the database as shown in Fig5 below, we noticed that the number of novices' errors in most of the phase scenarios as well as the control group decreased from the first round to the last round (i.e. when the target is reached and the game is over), indicating that novices' knowledge of Uno rules improved with time. However, unexpected changes occurred in scenario 1 (i.e. 1 ph 1) and the web scenario. The participants' scores increased in round 3, possibly because of other factors (i.e. time, different cards and the novices' backgrounds).

Presence and immersion between scenarios: A deeper analysis was also carried out to reveal the differences between interfaces in the scenarios. As we defined in the above table, l stands for local users who used iPad interfaces, r stands for remote user who uses VR on screen-based interfaces, w is for the web platforms users through screen-based interfaces and c is for control group users (i.e. without using technology). We analysed the differences of presence and immersion variables between those four interfaces by using one-way ANOVA test as presented in the following table 2 on page 8 below.

The above table shows statistically significant differences among the interfaces for all three variables. To follow up, we applied the pairwise Tukey's HSD

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Table 2: ANOVA results for the study variables subjected to interfaces

	F	df	p-value
Presence	6.484	(3,20)	0.00449**
Immersion	5.321	(3,20)	0.00735**

* p <.05
** p <0.01

test and found a significant difference of $p < 0.01$ between c and w for the presence and immersion variables. Further, from the previous table 1 on page 6, the differences in means (with their standard deviations) for presence between the w interfaces 4.31(0.86) and the c group 5.88(0.11) were significant at 0.01, and the differences between the r interfaces 4.98(0.58) and the c group were significant at 0.05; in contrast, no significant difference was found between the c group and the l interfaces 5.12(0.40), indicating that the experiences of participants who used the l interfaces were closer to the c group than those who used the r interfaces.

5 Discussion

This section will discuss our results by answering the sub-questions RQ1, RQ2 and RQ3 which were reworded from our research questions presented earlier in the introduction.

RQ1: Is there a relationship between novices' learning outcomes and presence and immersion in phase one scenarios?
RQ2: Is there any difference in the participants' sense of presence and immersion depending on which learning scenario/activity is used?

Presence: The results demonstrate that participants felt spatially present in all MiRTLE+ scenarios (i.e. the virtual world and the augmented world), but did not perceive them as real. Surprisingly, a comparison of the mean scores showed a statistically significant difference between the web group and the control (real) group. However, the MiRTLE+ scenarios were not significantly different from either, although the means with their standard deviations were closer to the control group than the web scenario. This implies that experts and novices tended to be more present when they were interacted using AR and VR interfaces. One the experts explained this in the following words:

I used to play Uno in my iPad, but this experience is too creative. I can communicate with friends and can see their avatar which makes me feeling be there. Sometimes the sound is not clear but I still understand my friends.

A comparison of the presence means showed that the web interface was significantly different from the AR interfaces and the control group. That is, the web interfaces scored the lowest on presence, as originally hypothesised. Participants

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using the AR interfaces felt closer to reality than those who used normal PC screen interfaces. This empirical finding strongly supports the theoretical claim that the AR features of navigation, manipulation and sensory immersion might enhance the users feelings of presence [10]. Furthermore, a very strong positive correlation was observed between presence and novice learning outcomes, which supports this research outcome. De Lucia et al. confirmed that "presence and learning are strongly related: increasing presence also increases learning and performance" [4]. Witmer and Singer echoed this same sentiment saying, "it would be very surprising indeed if positive relationships between presence and performance were not found" [18].

Immersion: Similar results were found with immersion level in that a significant difference was found between web-based users and the users of AR-based interfaces as well as between web-based users and control groups. These results might imply that a more visual system interface with robust and interactive 3D graphics could elicit higher levels of immersion than an interface that is less visually attractive (i.e. when compared with the reality, the AR-based environments, the VR-based environments to the web-based platform). This supports the findings of [11, 8]. Furthermore, novices and experts using the same interface either an iPad or a PC screen (i.e. involving a similar 3D environment) reported similar feelings of immersion, as indicated by the similarity in their immersion means for the MiRTLE+ 4 scenarios. It is equally possible that participants in the VR and AR conditions were similarly distracted by the graphics as well as the novelty of the environment, and this may have cancelled out any difference in immersion levels between them.

RQ3: Is there any difference in novices' learning effectiveness depending on which scenario/activity is used?

Learning: In our experiment, novices within scenarios that involved AR interfaces had higher learning gain scores than those using the web-based platform or VE interfaces. Further, these scores were closer to that of the control group. Although the learning differences between the scenarios were not significantly different, possibly because of the mix of interfaces in each scenario, it is interesting to note that the AR-based interfaces led to better learning gains for novices than web-based interfaces. These findings seem to support this previous study [13].

A follow-up analysis of the novices' achievement in our error-based system showed a decrease in errors during the game rounds. This combined with the results of the pre- and post-tests validates the improvement shown by the novices in learning Uno rules. However, scenario 1 showed an increase in errors in round 3, although the it was less than round 1. Overall, this result may also be suggestive of an improvement in learning. A similar pattern was observed in the web-based group in round 3; however, the errors decreased dramatically after that round, suggesting high subsequent improvements. These achievement trends may be explained by different factors. Firstly, round 3 may feature new card scenarios

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that could be more difficult than those played earlier. Secondly, the playing time for round 3 was longer than that for the other rounds, which could generate new card game situations and support to the previous point. The third factor, which is also related to the time, is that the spent time on discussing Uno rules with the experts before each round needs also to be considered. In the web-based scenario, novices and experts had a longer time for discussion after round 3, which was not the case in scenario 1.

Given the longer playing time and discussion time before round 3 in scenario 1 and in the web-based scenario, it is likely that if this round was played before the other rounds, a decreasing trend, similar to the other scenarios, may have been witnessed. Nevertheless, according to Hamari et al. [5] learners hone their skills and build knowledge of the game rules (by decreasing the errors in our case) as long as they continue to play.

Although the results of the current study show significant differences between the study groups, some of them should be taken tentatively due to the relatively small sample size for some of these groups (e.g. grouping by scenarios). For this reason, while the results obtained from the interface and location can be said to be generalisable based on comparison with credited previous studies in the literature (e.g. [13]), those for grouping by scenarios should be interpreted rather cautiously as descriptive statistics without drawing further conclusions. Future research may consider focusing more closely on grouping by scenarios by repeating the experiment in each scenario.

6 Conclusion

This case study was produced to evaluate learners' presence, immersion and learning effectiveness by using our MiRTLE+ model. We found that novices using the MiRTLE+ learning scenarios showed better learning performance results and closer (although not significantly so) results to the control group than those using web-based platforms. Presence and immersion were positively related to learning outcomes in almost all learning scenarios. The participants' presence and immersion in MiRTLE+ were significantly different from the presence and immersion of participants using traditional web-based platforms and very close to those of the control group. Furthermore, the user interface played a key role in increasing and decreasing the levels of all mentioned factors to show that, compared to other VR and web-based variables, AR interfaces were highly considered to be the most influential variables to increase the users sense of presence and immersion, and their learning outcomes. We also concluded that although these technology interfaces are still under development and investigation, they have a high potential for effectiveness in learning through their application in collaborative MR learning spaces. However, we must also take into account their shortcomings (e.g. distractions while holding or cybersickness while wearing the interfaces), which continues to affect some users.

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Enhancement of Students' Soft and Hard Skills in an Interdisciplinary Immersive Learning Environment

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Abstract. This paper chronicles a study focused on students' perceptions of the development of soft skills in an interdisciplinary, immersive learning class. The project outlined for the course was collaborative and interdisciplinary, involving development of an immersive and interactive, multimedia exhibition for a special collection of artifacts. Upon completion of the course, students were surveyed to explore how the course design affected perceptions of the development of hard and soft skills, including creativity, critical thinking, and problem solving. Based on these findings, this paper also discusses how the structure of a specific learning experience affects students' perceptions of authority, collaboration, individualism, groupthink, motivation, and balance of structure in informal learning.

Keywords: Project-based learning, immersive learning, soft skills development

1 Introduction

During the past 20 years, most universities have implemented interdisciplinary learning structures to provide students with 21st century soft skills. According to [12] specific soft skills include critical thinking, teamwork, problem solving, collaboration, creativity, and innovation. Although the value of specific soft skills is dependent upon the environment or problem space in which they are applied, many scholars argue that soft skills are harnessed or enhanced through interdisciplinary collaboration. Interdisciplinary collaboration is defined as a student group comprised of "various disciplinary backgrounds" and as group work that applies student expertise to address complex tasks, projects, or problems [1]. To address both interdisciplinary collaboration and soft skills development, project-based learning (PjBL) models are also used by many university instructors. Project-based learning models allow students to apply their disciplinary skills, while gaining soft skills as they work in these collaborative projects.

Recent research on interdisciplinary, project-based classes primarily focuses on the enhancement of students' soft skills by collecting data and input from teachers. This includes observational notes and tests given to students. Test scores have demonstrated that interdisciplinary, project-based learning enhances most students' soft skills [16]. reported students improved test scores and demonstrated improved cogni-

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tion after participating in an interdisciplinary project. These tests focus on the effect of PjBL on students in the classroom, as well as their soft skills development and the importance of PjBL in preparing students for workplace responsibilities and expectations.

This paper reports student perspectives on the development of soft skills after completing an interdisciplinary, immersive learning class. The project was highly collaborative and interdisciplinary and involved development of an interactive, multimedia exhibition for artifacts from a special collection located in the archives of a mid-sized, Midwestern university. Students were surveyed to explore two research questions: **RQ1:** How does an interdisciplinary project affect student perceptions of the development of 21st century soft skills, including creativity, critical thinking, and problem solving? **RQ2:** How does the structure of a specific learning experience affect students' perceptions of authority, collaboration, individualism, groupthink, motivation, and balance of structure in informal learning? The goal of this case study is to provide an example of an interdisciplinary classroom structure in a collaborative learning environment focused on enhancing students' soft skills of the 21st century.

2 Review of Literature

Understanding the nature of project-based learning and the development of soft skills requires examination of several interrelated fields of study. This section works to define soft skills, examines how learning is enhanced through the development of these skills, and explores extant literature focused on student perceptions of soft skills development.

2.1 Defining soft skills

In contrast to technical or "hard" skills that are knowledge based, soft skills are the behaviors and traits used in environments and situations. Soft skills positively contribute to social interactions, work performance, and career opportunities. Additionally, the importance of soft skills depend on the field, environment, or audience [15]. According to [12], highly valued soft skills include critical thinking, teamwork, problem solving, collaboration, creativity, and innovation. These skills are relevant to many disciplines and industries in the workplace. The importance of soft skills continues to increase, becoming a focal point in work environments and classrooms.

Soft skills have become important criteria for employers, and soft skills complement employees' technical skills when tackling large projects. One survey of more than 250 technical leaders found that a lack of soft skills among employees is a major reason for project failure. The survey contends that soft skills paired with technical skills can to improve team collaboration and individual productivity. In turn, projects are more likely to succeed and increase profits [2]. Another survey of 49 business executives attempted to define the top 10 most important soft skills among respondents. Of the 512 skills mentioned, communication, courtesy, flexibility, integrity, interpersonal skills, positive attitude, professionalism, responsibility, teamwork, and work ethic were mentioned most often. These results demonstrate that businesses expect and prefer employees to possess certain soft skills as they enter the workplace,

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but that not all soft skills are equally desirable by employers [14]. With this demand for soft skills in the workforce, [15] argues that "educators have a special responsibility regarding soft skills, because during students' school and university time they have major impact on the development of their students' soft skills."

2.2 Learning structures and enhancement of soft skills

For several decades, interdisciplinary collaborative learning structures have been implemented in higher education to enhance the development of soft skills among students [3]. Interdisciplinary Collaborative Learning (ICL) provides the opportunity for people from different disciplines to "contribute insights from his or her discipline, and learn in similar ways from others" [7]. It also offers a way for people from diverse demographic and disciplinary backgrounds to work together and enrich learning and problem solving. ICL is built from principles of both Experiential Learning Theory (ELT) and Constructivist Learning Theory (CLT). Experiential Learning Theory (ELT) is "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" [8]. Constructivist Learning Theory (CLT) is "the idea that learners construct knowledge for themselves--each learner individually (and socially) constructs meaning--as he or she learns" [6]. Generally, interdisciplinary collaborative learning allows students to learn from experiencing, communicating, and participating in an action using both theories.

Project-based Learning (PjBL) emphasizes self-learning as students work on a project. The project includes interactive discussions, team cooperation, and practical activities to ensure students gain an understanding of content and organization [18]. Most often, teachers act as facilitators while students take on team roles. This allows students the opportunity to structure team roles, collaborate on problem-solving tactics, and enhance their soft skills by working with a diverse team. In 2011, a survey on PjBL and its effect on soft skills in the workplace measured the participants' perceptions of PjBL on five areas: teamwork, project management, communication skills, interpersonal skills, and problem solving. The study found that PjBL does contribute to the development of soft skills pertinent in the workplace and that employability skills can be learned both in the workplace and in the classroom [10].

Alternatively, Problem-based Learning (PBL) is a subset of PjBL. [17] described PBL as focused, experiential learning organized around the investigation and resolution of messy, real-world problems. Students are engaged problem solvers, seeking to identify the root problem and the conditions needed for a good solution, and in the process becoming self-directed learners. [5] interviewed five STEM Academy educators about the most successful practices educators can do to foster problem-based learning environments. They found that working in teams, organizing their thoughts, communicating with team members, solving a problem, presenting their findings orally, and evaluating their success through a written document were the most important and significant according to their interviewees. When these practices are implemented in a PjBL structure, students are required to work outside of their comfort zones by collaborating with a diverse team to work toward a common goal in unison.

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2.3 Student perceptions of soft skills

A student's self-efficacy, perception of learning, and self-regulation affect learning environments as well. In a study on self-efficacy and personal goal setting, researchers found that students able to self-regulate their learning experience were more likely to achieve specific performance goals [19]. A student's perceptions about any element in their learning environments will determine their overall motivation for that element. One example of self-efficacy and self-regulation is the relationship shown between the Internet and its user. [11] explain that students' perceptions and attitudes toward the Internet shape their motivation to participate in Internet-based learning environments. The Internet also allows for autonomous discussion in which people have the ability to participate as much or as little as desired. Multiple studies have shown that "students work collaboratively with colleagues to pool their knowledge and skills, share the results of their inquiry, engage in peer teaching, and ultimately solve the problem" [4]. Whether on the Internet or in the classroom, self-efficacy results from students' engagement in what and how they are learning and contributing knowledge.

3 Project Design

The project outlined for the course was collaborative and interdisciplinary, partnering 13 undergraduate students from seven majors (journalism, communication studies, history, fine art, English, telecommunications, and computer science), and 11 graduate students from three master's degree programs (media design, digital storytelling, and architecture) to develop an interactive, multimedia exhibition for artifacts from a special collection in the university's archives. Led by a faculty member from a media design graduate program, the project allowed students to explore innovative approaches to storytelling and to create multimedia presentations. Students also engaged a number of cutting-edge technologies for experimentation, including: a 7-foot by 5-foot interactive, touchscreen wall with 32 points of touch; a 55-inch flat-surface touch table with 80 points of touch and a 4K display; four iPad Pros + display kiosks; virtual reality gear for developing immersive multimedia experiences; and mobile devices for augmented reality development. Students were divided into five smaller teams, each focused on a different aspect of exhibition design. Teams were structured as follows:

Physical exhibition design: Graduate students from an architecture design build program led the development of designs for a physical exhibition. Their work included a virtual reality experience in which users can explore the exhibition in a virtual space, a physical scale model of the proposed exhibition, and a full-sized prototype for an augmented reality display, which represented one area of the larger exhibition.

Small-screen interactive multimedia storytelling: Interaction design students and writers developed four multimedia presentations for small touch-screens focused on different topics related to the collection of artifacts.

Large wall screen interactive collection: Interaction designers, researchers, and writers developed an experience for a large interactive wall screen that allows multiple

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users to explore artifacts from the collection in digital form.

Interactive table top design: Videographers, writers, and designers developed an interactive video series features guest speakers related to the collection. Users can explore video interviews with experts to learn more about the collection. This highly engaging series also allows users to customize the viewing experience to address the skills and ideas they care most about.

Augmented reality storytelling: Developers, programmers, and writers created a novel augmented reality experience allows users to uncover rich storylines associated with artifacts from the collection. Using a smart device, exhibition visitors can unlock digital content, including video clips, audio, animation and more to enrich and enliven the exhibition experience.

When necessary, the professor provided students with resources, tools, and lectures that would help them understand and connect the concepts pertinent to the activities outlined above. For example, the class explored interaction design principles, cross platform storytelling strategies, and research methods, to name a few. However, it's important to note that the interdisciplinarity of the class ensured that each project team included students who brought relevant skills and talents to the project. Because of this, hard skills and topical knowledge were secondary learning objectives. Rather, the primary learning objective for this course was to develop important soft skills, including critical thinking, teamwork, problem solving, collaboration, creativity, and innovation.

To facilitate this learning, the professor engaged students in collaborative brainstorming sessions, design thinking strategies, problem-based learning initiatives, and creative problem-solving activities. At the start of the semester, student teams engaged in design thinking sessions to foster creative ideation about how to approach exhibition design, storytelling, and technology integration. Additionally, each project team engaged in weekly scrum sessions attended by the professor to update project progress, assign new tasks, and discuss challenges and new ideas. Scrum meetings represent a common practice "used in agile project management that emphasize daily communication and the flexible reassessment of plans that are carried out in short, iterative phases of work" (Dictionary.com).

Likewise, the interdisciplinary nature of the course, as well as the collaborative team structure for class meetings required heightened communication among team members and with the professor and key stakeholders outside the class, such as library representatives and university administrators. To foster stronger communication skills, students were regularly required to prepare brief progress presentations for which specific ideas were required to be communicated. Furthermore, the interdisciplinarity of each project team was deliberately structured so that students would be forced to think beyond their individual perspectives, engage creatively with people from different backgrounds and areas of expertise, and communicate ideas in ways that everyone could understand, regardless of disciplinary background. Student teams were ultimately given the autonomy to make decisions for project deliverables.

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4 Methodology

To explore the efficacy of this approach to immersive learning, this study applied a mixed-methods strategy to address the aforementioned research questions. These methods were designed to measure students' perceptions of this interdisciplinary project. Participants included four graduate and 13 undergraduate students from majors outlined above. Student participants were enrolled in a class that spent 16 weeks collaborating on the special project described above. To understand students' perceptions of their interdisciplinary class structure and how the project affected their creativity, critical thinking, and problem solving, participants were given a survey and individually interviewed during the final weeks of class. The survey included 101 questions adapted from three independent surveys by [9, 17, 13]. These surveys measure the skills and relationships among participants within their working environments. Participants were also individually interviewed in 15- to 20-minute sessions. Interview questions were designed to understand personal perceptions about the development of soft skills.

5 Results

Data is grouped into categories that characterize student perceptions, including authority, mutuality, autonomy, self-esteem and self-efficacy, communication, collaboration, creativity, critical thinking, and problem-solving.

5.1 Authority: Perceived relationships with leaders and stakeholders

Survey Results. The majority of participants agreed that authority – both internal (the professor) and external (project partners) – effectively provided feedback and evaluations. Likewise, they responded positively to questions about their relationships with individuals and/or other student teams involved with the project. These findings also show participants strongly agreed that their ability to exert control, power, or decisions in the project were reinforced by both external and internal authority figures.[1]

Interview Results. This structure of authority was flexible, as some participants expressed an ability to execute autonomy in their work. However, depending on team dynamics, participants varied on their opinions about the authority roles within the project. P9, a graduate student team leader, said it was difficult to come up with assignments for her undergraduate charges. P8, an undergraduate student, said she initially thought undergrads would have more control over the project design, as she was told that this was a student-run project. Most other student participants said having a designated team leader was helpful. P5 was able to rely on the professor and team leader when needed. P2 said usually in group projects "everybody kind of divvy's up what they're good at" and having a team made it "really nice to know that we all had

[1] In the interests of space, a full set of bar charts that illustrate response averages for all survey questions can be viewed by visiting: https://bit.ly/2SBAdlT

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that point person to fall on instead of kind of just looking at each other like ‘oh what the heck do we do now?’”

5.2 Autonomy: How students view their individualism

Survey Results. Responses to questions about student autonomy indicate participants felt enabled to pursue individual goals and objectives while working toward the project’s mission. Overall, responses to survey questions show participants perceived a high level of autonomy both within their small teams and across teams. Students generally agreed that their individual contributions and ideas were valued and applied, small teams worked successfully to achieve team goals and meet overarching project goals, and communication among groups about their progress was satisfactory.

Interview Results. Three participants said they needed opportunities to show off their own skills during the project. Additionally, P8 said it was important to feel heard and appreciated and that individuals should be able to see their own work and efforts in the results of the project. These feelings contributed to participants’ overall feelings of importance. P2 expressed similar feelings but said it was “really cool” to see the results of everybody’s efforts come together in a tangible product.

5.3 Mutuality: How teams respect each other’s expertise

Survey Results. Survey results indicated that participants perceived a strong shared relationship between teams and team members, including high levels of understanding, respect, and support among teams and individuals while working toward project objectives. The majority of participants agreed that this mutuality – a high respect for one another’s expertise – was necessary in order for teams and individuals to achieve the project’s goals. Likewise, participants responded positively to questions about their teammates’ individual contributions and expertise as it related to the project. Findings also demonstrate that participants strongly agreed that it was important for teams to share information across teams to strengthen goals and objectives of the project.

Interview Results. Comments made by more than half of participants revolved around appreciation for collaboration with students with different expertise. P7 noted that interdisciplinarity doesn’t happen in a focused field where everyone is studying the same thing. A class that involves students from multiple majors, on the other hand, lays the foundation for a variety of ideas and fosters alternative forms of thinking. Several students said this helped them broaden their perspectives (P1; P2; P5; P6; P7). For example, P2 said that the interdisciplinarity provided by the project fostered a divide-and-conquer strategy through which teams got more done through the division of labor. Four participants saw this interdisciplinary collaboration as beneficial because it gave them opportunities to practice their own hard skills, as well as learn new hard skills from their teammates. However, this structure also created negative feelings. For example, some students felt there was an initial lack of clarity about their roles (P1; P2; P6; P8), as well as uncertainty about whether labor was equally

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distributed (P2; P6). Finally, P3, P5, and P8 expressed frustration about working with people who were assigned similar tasks as them.

5.4 Self-esteem and self-efficacy: How students view themselves

Survey Results. The majority of participants indicated high levels of self-esteem and self-efficacy while working on the project. In addition, participants reported that they appreciated the ability to work toward team goals rather than working individually. Although they were less focused on building lasting relationships with their classmates, students were generally committed to teamwork throughout the project.

Interview Results. Two participants who felt confident in their overall team contributions stated that they saw an increase in their productivity and time-management skills. They attributed this to how they perceived their team's reliance on each other and their team's reliance on other teams. P4 and P7 felt motivated to showcase their own trustworthiness by practicing new time-management strategies to increase their productivity. P4 stated that the project "has taught me the importance of (time-management), and in the last few weeks I actually bought a daily planner and marked out my hours; and I'm actually on time and getting stuff done now."

5.5 Communication: Verbal and nonverbal

Survey Results. Overall, results indicate that participants felt their team members communicated well with one another and with other teams. Likewise, the majority of participants agreed that communication – both verbal and non-verbal – among teams was necessary to effectively build and maintain working relationships. These working relationships also depended upon the levels of trust teammates had in one another. This trust was built through effective verbal and nonverbal communication among students within and across teams. Fig. 1 shows participants perceived there to be a high level of team reliance, trust, and mutual respect.

Interview Results. P8 was the only participant that expressed frustration over not being able to communicate problems with the professor through email or meetings. According to this participant, this lack of communication contributed to her confusion and lack of understanding about the project as well as her role in it. More than half of participants commented that they felt like sometimes they were "not on the same page" with their teammates or other teams. A few participants stated that their understanding of their roles, as well as the roles of other teams, did not make clear sense to them until the end when teams were brought together to present their work.

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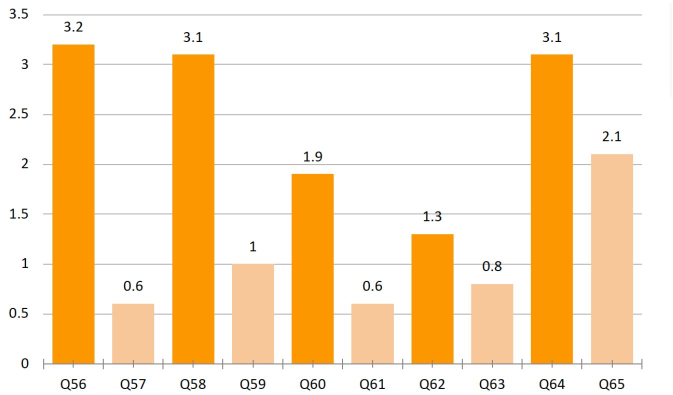

Q56 The individuals who represent my team are trustworthy.
Q57 Individuals on my team take advantage of other individuals that are vulnerable.
Q58 Individuals can count on everyone on my team to meet their obligations to the project.
Q59 Individuals can count on everyone on my team to meet their obligations to the project.
Q60 My team will work with other teams only if they prove they will work with us.
Q61 My team will find ways to punish other teams that do not keep their word.
Q62 If individuals treat my team unfairly, they will leave the project.
Q63 My team will pursue its own interests even at the expense of other teams.
Q64 My team has a duty to meet obligations to other teams/individuals.
Q65 Developing relationships with other teams/individuals is the most important part of collaborating.

Fig. 1. Ten questions explored students' perceptions of how communication

5.6 Collaboration: How students view collaboration among teams

Survey Results. Participants responded positively to questions regarding their teams' ability to work in cooperation with others to achieve goals. Generally, participants felt their teammates were well-trained, able to work with other teams, and able to accept ideas and work from all individuals. Fig. 2 illustrates the results of survey questions regarding collaboration among teams and individuals.

Interview Results. When asked: "What are some skills you have learned, gained or improved upon, by being on this project?", three participants said that it was challenging, at first, to learn how to collaborate with the different kinds of people an interdisciplinary project brings. However, according to P5, when obstacles arise in the project, having a collaborative team, with diverse skill sets, can create "collaborative problem- solving methods." P2 and P10 reported that their team relied either on other teams or their own teammates to accomplish their goals first in order for them to begin working on their own goals. P9 said having a diverse skill set can create a better product.

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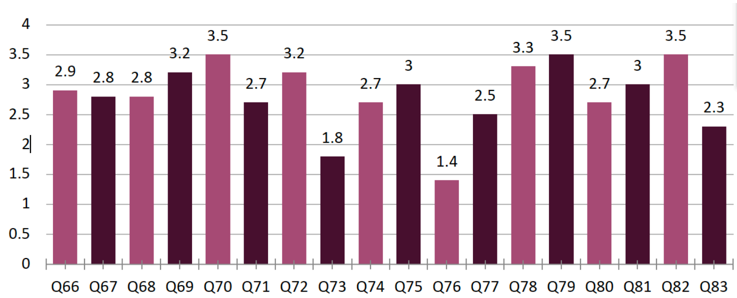

Q66 Individuals on my team are well-trained.
Q67 Individuals on my team are able to work closely with individuals from other teams.
Q68 Individuals on my team demonstrate a great deal of autonomy (freedom).
Q69 Individuals on other teams respect the work done by my team.
Q70 Individuals on my team are very positive about their goals and objectives.
Q71 Individuals on my team need to cooperate with other individuals
Q72 Individuals on my team are positive about their contributions and accomplishments.
Q73 Individuals on my team must depend upon the work of people in other teams.
Q74 Individuals on other teams think highly of my team.
Q75 Individuals on my team trust each other's professional judgement.
Q76 Individuals on my team have a higher status than individuals in other teams.
Q77 Individuals on my team try to understand capabilities, contributions of other teams.
Q78 Individuals on my team are extremely competent.
Q79 Individuals on my team are willing to share information, resources with other teams.
Q80 Individuals on my team have good relations with people in other teams.
Q81 Individuals on my team think highly of other related teams.
Q82 Individuals on my team work well with each other.
Q83 Individuals on other teams often seek the advice of people in my team.

Fig. 2. Eighteen questions explored students' perceptions of how collaboration affected team dynamics and project development.

5.7 Creativity: Individuality and expression

Survey Results. Participants expressed that the project design and outcomes fostered high levels of creativity. Average responses to questions about the degree to which the project required and allowed them to engage in individual creativity were high among participants. From these results, participants felt they were allowed and encouraged to assert individual creativity in order to meet the project's goals and objectives.

Interview Results. Participants did not explicitly express the implementation of creativity as a cultivated soft skill. Instead, they often connected creativity to the enhancement of hard skills like creative writing and design. However, some more subtly mentioned that they often needed to think of different ways to implement their skill sets in order to collaborate. P6 discussed how learning new hard skills from her teammates helped her think of other ways she could implement both her old and newly learned hard skills in other areas of her studies, interests, and future career options.

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5.8 Problem solving: Process of resolving issues

Survey Results. Participants expressed that the project design and outcomes promoted high levels of problem solving. The majority of participants strongly agreed that the project required and allowed them to engage in individual and team-mediated problem solving throughout various phases of the project.

Interview Results. Participants' answers varied when discussing problems their teams faced. This variance appeared to be determined by the student's perceptions of how well they thought their team collaborated and communicated. P8 expressed negative views about her team leaders, indicating that the lack of diversity in the team leader's skill sets made it difficult for her to understand the goals of the project or how her skills (different from her leaders) could be used. In comparison, multiple participants said they practiced and enhance their own hard skills and learned from the differing hard skills of teammates. P5 said: "I had help from (the professor) and I was able to reach out to (grad student team leader) ... It's mostly how I solve my problems…by reaching out and asking for advice and realizing I don't have to do everything completely 100% on my own because this isn't an independent project this is a collaborative project. So, you have to have collaborative problem-solving methods."

6 Discussion

Results illuminate how the project design engaged students in the practice and development of key soft and hard skills, as well as where the project design fell short. For the most part, surveys and interviews yielded similar results. However, it is important to note that while survey results demonstrated that students were generally positive about the experience, interview results revealed more detail about students' perceptions at various stages of the project. Thus, interview results provided a more holistic view of the positive and negative experiences students had over the course of a semester. Overall, three recommendations for the development and practice of project-based learning can be drawn from this research.

(1) Project-based and/or immersive learning should be designed to accommodate students from a variety of disciplinary backgrounds to ensure a collaborative environment in which students can complement and compromise together. Furthermore, when students from different backgrounds collaborate toward a shared goal, opportunities for them to learn from one another increase. For example, in the project outlined for this study, strong writers were able to learn new technology and design skills, while architecture students learned new storytelling skills [P1; P2; P6; P8]. This collaborative environment led students to rely on one another over time as they built relationships and formed an understanding of others' abilities. Ultimately, the collaborative environment not only fostered better teamwork, but it also allowed students to form new hard skills along the way. Thus, the development of soft skills – such as interdisciplinary collaboration and communication – led to the development of new hard skills – such as design or writing – and vice versa.

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(2) Instructors must foster an environment that equally allows each student to contribute and practice existing hard and soft skills in the context of the collaborative experience. The chance to practice soft skills in a project-based environment creates conditions that help students enhance these skills. P9 said, "I was able to practice my video editing skills and my video coloring skills. There was something that allowed me to spend more time on learning that skill because it was for a project and because there were people relying on it." However, when students were not given individual autonomy to practice their skills in ways that were meaningful to them, they often felt confused about how they fit in to the overarching aims of the project [P8]. Skills can still be enhanced when students are unsure of their project role but the student's journey developing these skills may be more difficult. When asked what skills she learned, gained or improved upon during the semester, P8 said that coming into the project, she thought her academic writing skills were strong. However, the project needed writers who were adept at a more conversational writing style. At first, this made it difficult for her to find her place in the storytelling team. After the project was complete, P8 said, "I think writing like a conversationalist is much more relatable. I can take that into a history perspective and say somebody is going to read something that I write and genuinely be interested in it. I think that's a big thing. You want to be formal in your writing and this project pushes you to be almost informal in a way. It is important, but you don't want to bore someone." This experience shows that although P8 found value in what she learned by the project's end, she struggled a bit more along the way because she felt that her existing skill set as a writer was not valued as much as skills exhibited by her teammates. Thus, instructors must form a strong understanding of the skills each student brings to the table so the project design can effectively accommodate and value their expertise.

(3) Emphasis must be placed on soft skill development as a core learning objective so that students are conscious of those activities as key requirements for success. Results suggest that for a project-based course to be successful, soft skills of collaboration and communication must be strong. Students must know from the start that they will be expected to solve problems and address project goals by engaging in frequent, respectful, and motivating dialogue. Furthermore, they should understand that their success in these areas will be measured and monitored as part of class assessment. P5 said when she experienced a problem with her writing, she was expected to collaborate with teammates and think critically about her approach, rather than try to solve the problem alone. P1 said collaborative problem solving required her to communicate ideas clearly so she could reach solutions that everyone agreed to. Students clearly knew that project success depended on how well they collaborated and communicated.

6.1 Limitations and future work

Often, large-scale, interdisciplinary projects involve fewer students. We acknowledge that the small number of participants is a limitation of this study. Future research could engage a greater number of respondents to provide more robust data about the intersections between hard and soft skill development in project-based courses.

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Using Educational Robotics as Tools for Metacognition: an Empirical Study in Elementary STEM Education

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Abstract: Despite that educational robotics (ER) are considered a novel learning tool that can support students in developing higher-order thinking skills, their role in promoting students' metacognitive thinking remains unclear. This work aimed at investigating the potential added value of ER in promoting students' metacognitive thinking in the context of elementary STEM education. One-group (n=21) pretest–posttest research design was used to examine the hypothesis that ER can serve the learning process as metacognitive tools. Data collection included demographic data, questionnaires investigating students' metacognitive thinking and in-situ metacognitive processes evident via visualizations and performance (or calibration) judgments. Results showed a statistically significant improvement in students' abilities to regulate their own cognition performing actions of metacognitive regulation such as planning, monitoring, and debugging strategies. Besides, while the analysis showed that students' ability to visualize a problem scenario was not differentiated, students' accuracy on performance judgments (prediction and postdiction judgments) was significantly improved.

Keywords: educational robotics; metacognition; problem-solving; STEM education

1 Introduction

Educational robotics (ER) are constructible and programmable high-tech devices which can be employed in education as an innovative educational tool, within a social constructivism and constructionism spirit, to support teaching and learning through hands-on activities in an inviting learning environment. During the last decade, a number of researchers and instructors have been frequently and fruitfully used ER as learning tools, in several contexts and disciplines, for the teaching of particular content knowledge in a field (e.g., mathematics and science [1]) or for supporting learning associated mainly with transversal skills such as problem-solving [2], metacognition (MC) [3], computational thinking [4], creativity [5], and collaboration [6].

However, despite the high attention emerged around this topic and the promising results from empirical studies, the evidence is not clear. Mainly, regarding the use of

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ER as tools to support MC the evidence is still ambivalent and fuzzy. Several studies that investigate the potential impact of ER activities on students' metacognitive thinking do not use validated measurement instruments [3]. Moreover, most of the previous works have used qualitative approaches to evaluate the outcome of ER activities in MC [7]. A holistic perspective on the issue of promoting MC via ER is still missing from the literature. All in all, research in the field of ER and their potential impact on students' metacognitive thinking is still in its infancy.

The present study aimed at examining the potential added value of ER activities in students' metacognitive thinking in the context of elementary STEM education. A one-group pre-test post-test research design was used to examine the hypothesis that ER can serve the learning process as metacognitive tools, supporting and promoting students' MC. Three research questions framed this investigation:

- RQ1: Are there gains in students' metacognitive abilities?
- RQ2: Which elements of MC improved?
- RQ3: Are there gains in students' abilities in mathematical problem-solving?

In the rest of the manuscript, we present the theoretical framework of this work, previous related studies, the methodology, and the results. We conclude with the discussion section and the interpretation of the findings.

2 Theoretical Framework

2.1 The role of metacognition in the learning process

Over the past years, there has been a growing interest among researchers in the study of MC [8]. MC is defined as "thinking about thinking" [9] and refers to meta-level knowledge and mental actions used to steer cognitive processes [10]. While several conceptualizations about MC exist, researchers widely agree that MC can be divided into a knowledge component and a skill component. The knowledge component is the "knowledge of cognition," and the skill component is "regulation of cognition." Knowledge of cognition is an individual's awareness of cognition and includes three subcomponents: declarative (knowing about things), procedural (understanding about strategies and other procedures), and conditional (knowledge of why and when to use a specific strategy) knowledge. Regulation of cognition indicates an individual's actions or mental activities to control their own cognition and includes three types of control: planning, monitoring, and evaluating [11]. Planning refers to goal setting, activating previous knowledge, and determining time. Monitoring comprises the self-testing skills to control learning and can be used to identify problems and to modify learning behavior when needed [12]. Evaluation relates to assessing the outcome and procedures of one's learning.

Over the past years, MC was recognized as one of the most relevant predictors of accomplishing complex learning tasks [13]. Researchers have shown that students with superior metacognitive abilities are better problem solvers [14], they know when and how they learn best, apply strategies to overcome obstacles [9] and regulate their own cognition. Furthermore, many studies have already been conducted to show that through metacognitive training, students' ability to solve mathematics problems im-

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proves [15]. The present study examines the hypothesis that ER can serve the learning process as metacognitive tools, supporting and promoting students' MC.

2.2 Educational Robotics and constructionism

The theoretical approach behind ER draws mainly on the theoretical perspective of Papert's [16] constructionism. As a pedagogical philosophy, constructionism states that students can learn when they are actively engaged in building some type of external artifact that they can reflect upon and share with others. The construction of the artifact itself drives students to acquire their own knowledge. One of the first constructivist tools was the Logo programming language developed by Papert as an implementation for Piaget's constructivist theories. ER can be considered as an extension of Logo and turtle graphics involving the programming of physical objects. Students interact with robots as a physical object (although the programming is happening digitally) and employ their knowledge and skills to solve real-world problems by challenging their existing knowledge, generating and experimenting their solutions [17]. From this perspective, ER is a constructivist tool which provides students the freedom to investigate their own interests while studying content and simultaneously applying metacognitive and problem-solving skills [1, 3].

3 Background work

3.1 Metacognitive Skills in Educational Robotics Activities

Empirical research records positive outcomes from the implementation of several ER projects providing evidence on the potential of ER to enhance students' metacognitive skills. While some studies have revealed that ER activities contain a variety of metacognitive experiences, only three studies appear to have reported a significant positive impact on learning [3, 7 and 8]. On the other hand, other studies failed to present positive results on the matter [18].

In an attempt to investigate the process of building and programming a robot as a metacognitive one, La Paglia et al. [3] found that ER activities can indeed allow students to monitor and regulate their learning. Keren & Fridin studied how ER can support the teaching of geometric thinking and help to promote students' metacognitive skills in kindergarten [19]. The authors found that students' performances on metacognitive assignments were improved while they worked on ER activities. More recently, Atmatzidou, Demetriadis, and Nika [8] conducted a quasi-experimental study with primary and secondary school students to investigate the development of students' metacognitive and problem-solving skills in ER activities performing different levels of guidance (strong and minimal). According to their findings, strong guidance had a positive impact on students' metacognitive and problem-solving skills.

In the authors' own previous work [7], a micro-level examination of elementary school students' discourse was conducted to identify the elements of collaborative knowledge construction and the role of the technology in an ER learning environ-

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ment. The results made evident that MC, along with questioning and answering, were prevalent elements of collaborative knowledge construction discourse around ER.

4 Methodology

This work employed a one-group pretest–posttest research design to examine the effectiveness of ER activities in improving students' MC.

4.1 Participants and Procedures

The sample of this study was 21 primary school students (N=21, 4th graders) in a public elementary school in Cyprus (13 girls, 8 boys) who participated in ER activities during a period of two-months. Two children were students with special educational needs and motor impairments (1 boy and 1 girl), and only one student had previous experience with programming and ER. Before the study, all the ethical approvals from the Ministry of Education and consent forms from the students' legal guardians were obtained regarding the data collection.

The participants were divided into five groups of 4-5 students of different genders and abilities (as perceived by their teacher). Particularly four groups of four students and one group of five students were formed. Students participated in eight sessions (80 minutes each) of ER activities (one session per week) in a typical classroom setting over a two-month period (as in Fig.1), during April and May of 2018.

Fig. 1. Classroom setting from an introductory lesson

Designing the technology-enhanced learning experience was a task undertaken by a teacher and an educational technologist. As presented in Table 1, the first two sessions were introductory lessons with preparation activities to help students get familiar with the EV3 environment. During this phase, essential programming details associated with this environment were described to them by presenting examples (directional commands, sensors, loop, and wait for). The next six sessions were STEM problem-solving activities; students should program a robot using a tablet or a computer to solve different problems according to the instructions and conditions of the activity (see Table 1).

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Table 1. The eight sessions of the course (80 minutes each)

Sessions	Tasks
Session #1 Introductory	a) Introduction to the learning objects of the curriculum. b) Opening the software, writing and saving a program, connecting the tablet or the computer to the brick with Bluetooth, running a program. c) Controlling the EV3 Motors (start programming motors); start, to finish, backup to start; start, to finish, turn around, back to start.
Session #2 Introductory	Using EV3 Sensors (start programming sensors); ultrasonic sensor, touch sensor, color sensor, and gyro sensor.
Session #3	Program your robot to move forward exactly 1.20m using (a) rotations, (b) degrees and (c) seconds.
Session #4	a) Program your robot to turn exactly 90 degrees using a gyro sensor. b) Program your robot to move on a square using a gyro sensor.
Session #5	a) Use the ultrasonic sensor to stop before hitting a wall. b) Program your robot to move forward by pressing the touch sensor until the ultrasonic sensor is 10cm from the wall. c) Program a robot that can move into the classroom without hitting any objects.
Session #6	a) Program your robot to say “green” when seeing a green object and “red” when seeing a “red” object. b) Program your robot to move forward when seeing a green tape and stop when seeing a red tape.
Session #7	Program your robot to move a block from one square to the other using the medium motor (cargo deliver attachment).
Session #8	Design a maze using objects from the classroom and program your robot to solve the maze without touching any objects.

We followed a low coercion approach for students’ metacognitive training. Typically, in every session, the students were given a worksheet with tasks of increasing difficulty. The worksheets were structured to support students on technical aspects but not to lead or guide them in solving the problems. The teacher acted as a facilitator, supporting student’s thinking in the form of hints, prompts and feedback without providing any answers. He often prompted students with questions such as: Why are you doing it? What are you doing? He prompted students to externalize representations of metacognitive thinking and problem-solving procedures verbally.

The groups followed a typical problem-solving cycle, without any formal prompting from the teacher and without any previous training to do so. A typical problem-solving cycle of an ER activity as undertaken by the students included three major steps: (i) understanding the problem – teammates read and defined the problem, (ii) plan a strategy – teammates proposed ideas and planned together, (iii) executing of a plan – students used the robot to execute; their strategy was reconsidered based on the robot’s performance (i.e., teammates evaluated the outcome).

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4.2 Data collection and instrumentation

Data was collected via a profile questionnaire on demographic data and two assessments measuring individual metacognitive awareness, as presented below.

Profile questionnaire. Before the learning activities, students answered an individual profile questionnaire. This questionnaire recorded demographic data (such as gender and age) and learners' experience with programming and ER.

Metacognitive Awareness Inventory [MAI]. We used the MAI instrument [20] as pre- and post-assessment, to assess the development of children's metacognitive thinking. The MAI questionnaire was given to all participants before and after the learning experience. Due to low reading levels, the questionnaire was read aloud by the teacher i.e., the teacher read each statement to the whole class, students answered, and when he was sure that all the students completed an answer then he proceeded to the next question.

MAI questionnaire is a 52 items self-report instrument consisted of multiple items which can assess metacognitive awareness in two factors -- knowledge of cognition and regulation of cognition. The participants answered these items by indicating their degree of agreement with each statement, on a 5-point Likert scale, ranked from 1: strongly disagree to 5: strongly agree. The first factor, "knowledge of cognition" consists of 17 items and can be classified into three subscales: declarative knowledge (knowledge about self and strategies), procedural knowledge (knowledge about how to use a strategy) and conditional knowledge (knowledge about when and why to use a strategy). The second factor, "regulation of cognition" (35 items) consists of five subscales: planning (goal setting), information management (organizing), comprehension monitoring (assessment of one's learning and strategy), debugging strategies (strategies used to correct failures) and evaluation (evaluation of performance after a learning experience). The reliability and validity of the MAI have been recorded in several previous studies (e.g., [21, 22]). For example, Baker & Cerro [21] found that MAI had a strong internal consistency for the "knowledge of cognition" (Cronbach's alpha = .88) and "regulation of cognition" (Cronbach's alpha = .91) scales.

Visualization and Accuracy Instrument [VisA]. VisA instrument was given to all participants before and after the learning experience to further investigate the development of students' metacognitive thinking. VisA combines students' prediction judgments, postdiction judgments, and visualizations to assess online MC and particularly the combination of metacognitive monitoring and regulation which are interrelatedly used during problem-solving [15]. Students responded in four mathematical problems. In each problem students were asked to divide their solutions into four steps: (a) read and rate their confidence in solving the problem correctly (prediction judgment), (b) draw a sketch to visualize the problem (visualization), (c) solve the problem, and (d) rate their confidence for having found the correct answer (postdiction judgment).

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Mary plants rosebushes along a path to her home. The path is 27m long. She plants a rosebush every 3m on both sides of the path. She also plants rosebushes at the beginning of the path (on both sides). How many rosebushes does Mary need?

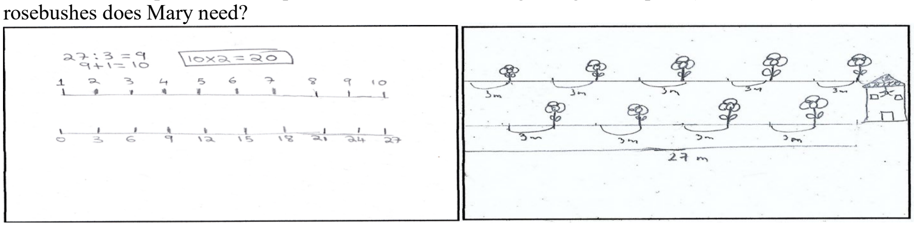

Fig. 2. Example of students' artifacts from post-VisA administration; schematic visualization with mathematical features (left) and pictorial with mathematical features (right).

The scoring procedure was simple. Students got one point for each correct prediction or postdiction judgment and zero points for each uncertain or incorrect prediction or postdiction judgment regardless of whether they had solved the problem correctly or not (i.e., if a student predicted that he could solve the problem and indeed did it, he got 1 point; or if he predicted that he could not solve the problem and indeed didn't, he again got one point). For the visualizations, students got zero points if they made pictorial or irrelevant sketches without showing any important aspects or relationships of the problem, they got 0.5 if their sketches were partly pictorials with some schematic or mathematical features and they got one point if their sketches were primarily schematic visualizations with mathematical features (see Fig. 2). The maximum score for each student was 12 points (4 problems x 3 points each). The first 30 visualizations (17.9%) were evaluated with two judges until a consensus about scoring rules was reached. Reliability was high (agreement over 90%) and, therefore the first researcher finished the scoring procedure alone.

Pre-post mathematics test. For assessing mathematical knowledge gains, we used the data from the four problem-solving tasks from the two administrations of the VisA instrument. We also looked for the correctness of their solutions (not their judgments and visualizations). Each correct task was scored with 25 marks, and the maximum possible score was 100 marks. The four tasks were adapted from the released 4th-grade assessment questions from previous studies of Trends in International Mathematics and Science Study (TIMSS).

5 Findings

5.1 MAI Questionnaire

First, Cronbach's coefficient alpha reliabilities were computed for the MAI scales, both for pre- and post- administrations; the scales had strong internal consistency for pre and post (Cronbach's alpha >.81). Then, un-weighted mean scores were calculated for scales and subscale. Paired-sample t-test analysis showed statistically significant differences on "regulation of cognition" [$t(21)= -7.83$, $p< .001$] with students exhibiting higher levels of "regulation of cognition" in the post-test ($M=4.02$;

SD=0.21), compared to the pre-test (M=3.70; SD=0.29) with large effect size (Cohen's d = 1.71). Instead, there was no statistically significant difference in "knowledge of cognition", t(21) = -.61, p = .55 from pre-testing (M=3.68; SD=0.46) to post-testing (M=3.72; SD= 0.32). With respect to the subscales of "regulation of cognition", the results demonstrated statistically significant differences with a large effect in three of the five subscales: Planning [(t(21)= -9.28, p= .000, d = 2.05], Comprehension Monitoring [t(21)= -3.65, p= .002, d = 0.80)] and Debugging Strategies [t(21)= -6.97, p< .001, d = 1.52] (see Table 2).

Table 2. Comparing pre- and post-MAI scores for each variable.

Variables	Pre-test M(SD)	Post-test M(SD)	t-test Statistics (Effect Size)
Knowledge of Cognition	**3.68 (0.46)**	**3.72 (0.32)**	**t(21)= -0.61, p= .55**
Procedural Knowledge	3.79 (0.30)	3.83 (0.50)	t(21)= -0.38, p= .71
Declarative Knowladge	3.55 (0.59)	3.59 (0.57)	t(21)= -1.30, p= .208
Conditional knowledge	3.78 (0.69)	3.85 (0.48)	t(21)= -0.36, p= .73,
Regulation of cognition	**3,70 (0.29)**	**4.02 (0.21)**	**t(21)= -7.83, p< .001 d = 1.71**
Planning	3.47 (0.59)	4.01 (0.44)	t(21)= -9.28, p< .001 d = 2.05
Comprehension Monitoring	3.79 (0.64)	4.18 (0.39)	t(21)= -3.65, p= .002 d = 0.80
Evaluation	3,77 (0.60)	3.98 (0.36)	t(21)= -2.63, p= .016
Debugging Strategies	3.74 (0.64)	4.26 (0.44)	t(21)= -6.97, p< .001 d = 1.52)
Information management strategies	3.75 (0.42)	3.80 (0.45)	t(21)= -1.17, p= .255

5.2 Students' visualization and accuracy (ViSa)

Once again, the scales had strong internal consistency for pre and post (Cronbach's alpha >.80). Paired t-test analysis indicated that students improved their performance from pre to post-testing; this difference was statistically significant [t(21)=-2.96, p<.005)] with medium effect size (d=0.797). Furthermore, the analysis showed a statistically significant increase in students' accuracy on prediction judgments and postdiction judgments (Table 3) from pre-testing to post-testing with medium effect size (d=0.65 and d=0.70 respectively for both variables). However, there was no statistically significant difference in students' visualizations from pre- to post- testing.

Table 3. Comparing pre- and post- VisA scores

Variables	Pre-test M (SD)	Post-test M(SD)	t-test Statistics (Effect Size)
Visualization & Accuracy	2.03(0.66)	2.33 (0.59)	t=(21)= -3.65, p= .002, d= 0.797
Prediction	2.33 (0.73)	2.71 (0.64)	t(21)= -2.96, p= .008, d=0.65
Visualization	1.43(0.88)	1.45 (0.72)	t(21)= -0.204, p= .84
Postdiction	2.33(0.73)	2.81 (0.68)	t(21)= -3.21, p= .004, d=0.70

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5.3 Learning Gains

A total pre and post-test score was computed for each participant, by summing up the correct answers and adjusting to 100. A paired-samples t-test was conducted using students' data from the two administrations of ViSa. The analysis showed a statistically significant increase, $t(21) = 2.65$, $p = .016$, from pre- (M=59.52%; SD=16.73) to post-testing (M=67.86%; SD= 19.59), with medium effect ($d = .58$).

6 Discussion

Despite the widespread use of robotics in education, their role as a metacognitive tool remains ambivalent. This study investigated the hypothesis that ER can serve the learning process as metacognitive tools, supporting and promoting students' MC in the context of elementary STEM education. Prior studies mainly observed metacognitive behavior in ER activities. To our knowledge this is the first investigation of the matter of MC via ER using a quantitative dataset and therefore, it represents an extension of previous work in the area.

Four significant breakthroughs have emerged in the present study. In accordance with prior empirical studies [e.g., 3, 7, 8] our research has provided evidence supporting the positive impact of ER activities on students' metacognitive thinking (RQ1). Our teaching procedure can be considered as a low coercion approach for students' metacognitive training. In contrast with the study of [8] which they found an improvement on students' metacognitive skills only in “strong guidance” groups, we found that MC can also take place with a minimal guidance approach. This finding further emphasizes the instrumental role of the technology in supporting students' metacognitive processes. The improvement in students' metacognitive thinking is seen as a collective result of the technology use, group work, teacher's interventions and the nature of the activities. However, we think that the role of the technology was instrumental since it enabled a spontaneous 3-stages problem-solving process (understanding the problem, planning, executing & evaluating) which can be considered by itself as a metacognitive learning protocol.

The collection of evidence of students' metacognitive processes by assessing students' judgments of their own performance (calibration), demonstrated that there was a statistically significant increase for students' accuracy on prediction judgments and postdiction judgments from pre-testing to post-testing (RQ1). The ability to judge one's performance has been conceptualized as an expression of metacognitive monitoring [23]. We, therefore, confirm previous findings about the positive impact of ER activities on students' abilities to monitor their own learning [1, 7]. Perhaps, that is because ER activities are based on procedural knowledge and engage students naturally in the process of exploration for solving a problem; yet, further research is needed to fully understand what elements of ER contribute to students' metacognitive thinking.

Furthermore, we found that ER activities have no impact on students' abilities to visualize a problem scenario. The latter contradicts to the previous finding of students' improvement on performance accuracy as someone would expect students to

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improve their visualizations. However, we know that the accuracy of performance judgments gives information into a limited part of metacognitive processes (only in monitoring by looking forward or backward about a solution plan for a problem). Also, to visualize a problem scenario is an activity that may need further skills or something that may require a longer time to be improved.

Moving a step forward, our study provides evidence that ER activities have a greater positive impact on three regulatory subcomponents of MC such as planning, monitoring, and debugging strategies (RQ2). These subcomponents are related to "regulation of cognition," and ER seem to tackle these aspects of MC well. This finding can be considered as crucial knowledge for educators who see their elementary students struggling in solving multi-step problems. Training these aspects of MC can help their students become more effective in solving multi-step problems in several disciplines and in general, to become more effective problem-solvers. Since a low level of guidance was applied, this improvement cannot be explained beyond the role of ER as "scaffolding embedded technological tools" [24]. These findings are in line with previous work by the authors [7] showing that students' discourse over ER activities included a large volume of regulatory and self-control elements such as metacognitive monitoring and planning.

Last but not least, in agreement with the prior work (e.g. [25]), the present study demonstrated a statistically significant increase on students' ability to solve logical-mathematical thinking problems from pre to post-testing (RQ3). It should be noted that our ER activities were not specifically aimed at improving students' abilities in mathematical problem-solving; instead, they were more about STEM and programming concepts. Therefore, it becomes evident that positive results in mathematical problem-solving can be documented via an interdisciplinary approach to ER activities in elementary education, capable of expanding the curricular space [17].

Depside the encouraging results of the study, some limitations of this work are also important to note. First, the study is based on a small sample size, although comparable with relevant studies in the literature [3, 7, and 8]. Second, the sample was drawn from a population of convenience. Third, the duration of the study (two-months) might have caused a maturation effect in the study, linked to the students' development of MC. Future research could replicate this study with a larger (and preferably random) sample of participants, whilst aiming for a control group helping to address a possible maturation effect.

7 Conclusion

This study provides empirical evidence on the added value of ER for learning. We examined the hypothesis that ER can serve the learning process as metacognitive tools, supporting and promoting students' MC. Our results suggest that ER activities can improve students' metacognitive and mathematical problem-solving skills. Specifically, the study demonstrated that: (a) students developed their metacognitive and problem-solving skills through ER activities, (b) students' accuracy on performance judgments was significantly improved, as yet another piece of evidence of metacogni-

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tive development, (c) regulation and self-control components of MC such as planning, monitoring, and debugging strategies were activated more than knowledge components of MC, (d) students' abilities in mathematical problem-solving were significantly improved. Given the encouraging results of the study, one might suggest that ER activities can be a vehicle to the development of MC skills in elementary education, although further research is needed to support this argument. We hope this work will motivate further research in the area of educational robotics for metacognition and learning.

Acknowledgments

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Job Interview Training in Virtual Reality: Evaluation in Laboratory Settings

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Abstract. This paper presents a concept, a prototype design and evaluation results of a virtual reality application for job interview training. We used rapid prototyping to develop several industry-specific applications that provided a rich presentation of occupations, targeting a specific group of young job seekers, including high-school students and unemployed. Each application included a job interview training component, developed using 360-degrees videos and simple scenario branching techniques. In addition, considering the results of intermediary evaluations, we developed a generic industry-independent job interview training application with a realistic scenario. The prototypes were evaluated by several groups of primary users and experts. The data were collected using questionnaires and interviews. The results indicate a generally positive attitude towards the concept job-interview training, both as part of industry-specific applications and as a stand-alone exercise. In the paper, we discuss the potential of job interview training in virtual reality for career guidance and fighting youth unemployment and various practical and technology considerations.

Keywords: Virtual Reality, Job interview training, 360-degrees videos.

1 Introduction

For many young job seekers today (young unemployed and high-school students), technology is a natural part of life, while traditional career guidance services and their channels of communication 'lag behind' digitally. They often rely on text-only presentation modes and basic training methods, so young people feel uncertain about the path they should choose. Entering work life can be frustrating and stressful, going through choosing a profession, searching for vacancies and attending job interviews. Therefore, there is a need to explore new and more efficient ways to communicate with and train young job seekers, as well as to facilitate engaging and safe working experiences. Virtual reality (VR) can provide an alternative, engaging and cost-effective and supplement to traditional career guidance. In this paper, we report results of a study exploring this relatively new application area of immersive technologies.

We report evaluation results of applying 360-degrees videos (hereafter called 360-videos) for job interview training. These results are a part of a larger study, where we introduced a concept of 'Immersive Job Taste' – capturing experiences in the workplace (e.g., daily operations, typical tasks or job interviews), enriching them with contextual

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information and making them available to the job seekers [1]. Such immersive experience aims to allow the user to train in unfamiliar situations, thus mastering the same real-world situations. The main question we investigate is how immersive technologies can help to activate job seekers, increase their interest in and understanding of workplace processes, and their knowledge and attitude towards job interviews.

Immersive technologies are being deployed for workplace training by several industries, for example, healthcare [2], construction [3] and manufacturing [4]. Different types of VR job interview simulations have been successfully used in the past, but mostly for specific target groups. For example, several articles report the use of VR for job seekers with disabilities, for example mental health issues. As early as in 2011, a study already reported a successful use of VR for job interview training of people with psychiatric disability [5]. Two more recent studies report increase of confidence and job interview skills [6] and that training in VR increase interviewing skills and trainees' obtaining a job offer [7]. At the same time, using VR available through head-mounted displays (HMDs) may lead to high eyestrain, which although still provide a better affordance for learning than a regular computer screen, as reported in [8]. Technologically, job interview training simulators can be implemented using different approaches, technologies and equipment. For example, it includes using multiple 2D video recordings, viewed on a flat computer screen, as in [7] or a simulated 3D environment with an interviewee character, as in [5] and in [9], or a simulated 3D environment available via an HMD interface, as in [10]. An alternative approach for creating immersive experiences is using 360-videos that can be watched both on a flat screen and in HMD VR. Our motivation for choosing the HMD-based 360-video mode for job interviews was two-fold: providing a relatively inexpensive but realistic and immersive recreation of the stressful situation that the job interview generally is and aligning job interview with the main Immersive Job Taste concept in VR.

The job interview training prototypes we present in this paper have been developed in two phases of a research project. In phase 1, we used rapid prototyping and low-cost techniques to map user needs. We developed and evaluated three applications for Google Cardboard: for health care, office work/startup and fish farming industry. Each of the three applications included a short industry-specific job interview experience. In the second phase of the project, we developed and evaluated a stand-alone industry-independent job interview training application InterviewVR. This application has been developed for Google Cardboard but evaluated on Samsung GearVR HMD. Local industries and public authorities provided materials for the study and advised on the job search process and recruited participants to evaluate our prototypes.

2 Design of Prototypes

Job Interview Experiences as Part of Immersive Job Taste. The job interview components were included in each of the three prototypes we developed in Phase 1 of the project (Fig. 1). All three apps were developed for Google Cardboard and contained (in addition to the job interview experience), interactive representations of workplaces, with simple gaze-based navigation. The job interviews were filmed using Samsung

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Gear 360 camera. The resultant video files had the resolution 4096x2048 px and later compressed to 1920x960 px. The job interview in all three apps followed a simple scenario scheme: 1) an introduction of the interviewer(s) and the workplace; 2) few questions about the interviewee's background and interest in the profession; 3) an important question with three text-based answer options; 4) three different reactions of the interviewer to the answer options; 5) a summary with tips for a successful job interview in a specific profession. In 2) and 3), the interviewee asks a question and then 'listens' to the answer of the user for some time before continuing to the next question.

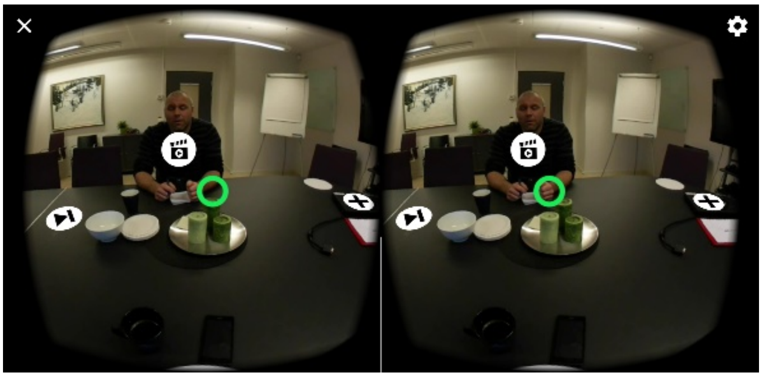

Fig. 1. Gaze navigation through the job interview (icons appear between questions)

The InterviewVR app has been designed to provide a generic immersive experience of a job interview with training functions, to function as a supplement to the industry-specific Immersive Job Taste simulations. In this application, we also used 360-degree videos, but improved several aspects based on the feedback received during the evaluation of the earlier prototypes. We filed using Ricoh Theta camera. The video files had the resolution 3840x1920 px, which we kept in the application. We recorded the sound from two sources. The ambient sound was recorded by the 360-camera, while the voice of the actress was recorded using an additional wireless microphone.

We significantly improved the scenario, both in the number of questions and branching methods. The InterviewVR simulation is based on a scenario that contains 12 main questions and 14 additional comments or questions that appear optionally depending on the answers to the main questions. All questions or comments were 360-filmed from the point of view of the user. In the scenario, the user takes the role of the job candidate and goes through a typical job interview. The app does not provide much guidance and instruction on how to perform at a job interview. Instead, the user is immersed into this situation and has to react to it by answering questions from the interviewer.

It is possible to record sound of the answers provided by the user, to make the experience of situation more realistic and to allow self-assessment and reflection by enabling a playback of the entire interview. While the user is speaking, a short 360-video clip with the interviewer actively listening is being looped.

In the design of the app, we did not use speech recognition and analysis, but still tried to make the experience personalized and realistic. We included / excluded some

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of the questions (videos) based on several multiple-choice questions the app asks before starting the interview (e.g., about education and work experience) and based on the duration of the answer (e.g., if the answer time is shorter than a certain value a follow-up question is added). We also had questions where the user was given a hint in the form of three possible directions for developing an answer (Fig. 2). In these situations, the scenario develops further based on the chosen direction.

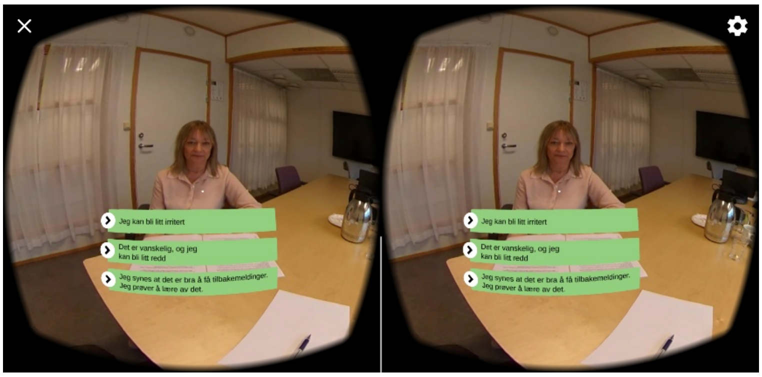

Fig. 2. Possible directions for developing an answer

After the user completes the interview, an option to play it back becomes available. The locally stored sound recordings of each answer are played over the same videos.

3 Evaluation

3.1 Research Design, Study Settings and Data Analysis

The primary target group of the study is defined as young job seekers, i.e. individuals aged 18 to 25 who are using welfare services, and are in most cases unemployed. Secondary target groups included high school students, job seekers of different ages and different welfare professionals. Each data collection session included a presentation of the Immersive Job Taste concept, testing our prototypes by the participants, and collecting feedback. In both phases, the questionnaire included three sections. The first section contained 10 questions about background. The second section contained 20 Likert scale questions about the specific apps and three open questions. The topics we evaluated included: user friendliness of the app (4 questions), usefulness of the app (4 questions), and possible future extensions (3 questions). The third section evaluated the Immersive Job Taste concept, which is outside of the scope of this paper, but reported in [11]. We used the same or similar questions in the individual and focus group interviews in all data collection sessions. In some of the data collection sessions, we used shorter versions, excluding some of the questions. The apps have been gradually improved between different sessions, so the results cannot be fully merged together.

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All data were collected in lab settings with one of the developers assisting the participants in testing apps. Not all the participants answered all questionnaire questions. To analyze the data from individual interviews and focus groups, the project employed a method similar to theoretical sampling as it is described in Grounded Theory [12]. Individual interviews with young job seekers during phase 1 were analyzed using thematic analysis and thematic mapping [13].

3.2 Results

Job Interview Experience in Workplace Simulations. The questionnaire given to the participants (17 job seekers and 8 welfare professionals) of the final evaluation of phase 1 contained two statements on the usefulness of the job interview experience in each of the three apps: Q1. I could benefit from this app to feel safer at a job interview; Q2. The job interview in the app seemed realistic considering what questions were asked. Table 1 below presents the results of the answers to these questions for the fish farming, healthcare and office/startup applications.

Table 1. Usefulness of job interview experience in phase 1

	Q1 Fish	Q2 Fish	Q1 Health	Q2 Health	Q1 Office	Q2 Office
Strongly disagree	6%	6%	11%	0%	9%	13%
Disagree	17%	6%	0%	16%	18%	9%
Neither agree or disagree	11%	13%	16%	11%	23%	39%
Agree	56%	69%	58%	42%	45%	35%
Strongly agree	11%	6%	16%	32%	5%	4%
Number of responses	18	18	19	19	22	23

In the third part of the questionnaire, we asked one more general question related to the job interview. The statement "Such apps can make me more confident and prepared for a job interview" was evaluated more positively. From 17 participants who responded, 18% replied fully agree, 47% – agree and 35% – neither agree or disagree.

At the focus group interviews, the participants expressed concerns about the scenarios of the job interviews in the apps. It was noted that sometimes the interviewers were "rude", but the interview scenarios were also "realistic": "*It made you feel like he wanted to hire someone and was actually interested. It was more comfortable then. But not that comfortable, it's always scary at an interview…*" (job seeker, individual interview). One job seeker claimed that VR-interview training would have been useful for him a year earlier when he "*struggled a lot with anxiety, I think it would have been useful to calm my nerves before big interviews*" (job seeker). The welfare professionals were optimistic: "*Job interviews is a unique situation [...] but to be able to prepare, to have experienced it with such a tool [VR], that would help a lot*" (Welfare professional).

The participants thought it was a "cheap" solution that the interviewers asked a question, and one should answer with their own voice during a pause between questions. Many did not realize that they were supposed to talk in the pauses between questions.

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The part of the job interview simulations where we used a branching scenario were evaluated very positively. The participants highlighted that it was useful to get feedback on what you answer, though it was noted that it was too obvious what was right and wrong answer and wished to have several answer alternatives to choose from.

Job Interview training with InterviewVR. In phase 2, the questionnaire data show a very positive attitude towards the app by both job seekers and welfare professionals. We used two statements to evaluate the usefulness of InterviewVR app: Q1. After completion I had a better understanding of what a job interview entails (only for job seekers); Q2. The job interview seemed realistic considering what questions were asked.

From 13 job seekers answered Q1, 69% selected strongly agree, 23% – agree and 8% – neither agree or disagree. From 23 job seekers answered Q2, 48% selected strongly agree, 43% – agree and 9% – neither agree or disagree. From 21 welfare professionals answered Q2, 62% selected strongly agree, 33% – agree and 5% – neither agree or disagree. None selected disagree or strongly disagree for both statements.

The data from the focus groups supports the positive responses to the questionnaire as job seekers have been more optimistic to the usefulness of the app towards the end of phase 2: "*If you are able to sit there [in VR] sincerely and answer well, then you'll probably be able to do it in a real job interview as well*" (job seeker). Some respondents considered the app potentially useful for them (not just for someone, which was the most common opinion in phase 1): "*I've probably been to four-five hundred job interviews and gotten four-five hundred 'no', so maybe I can use this to understand why I keep getting rejected*" (job seeker).

Two specific features were discussed in detail. Multiple choice (interviewer asking a question and user choosing one of three written answers) was viewed as too easy and did not let the user come up with their own answer. Replying orally (interviewer asking a question followed by a looped 'reaction' video where the user could answer) was viewed as awkward and did not give the user feedback, which was considered essential. This failure to incorporate feedback resulted in lack of "*interview feeling*". Multiple choice was preferred because feedback was considered of highest importance.

Further Development. The main features desired in the job interview simulations were increased realism and feedback possibilities. The participants wanted to know when they had done something right or wrong in the simulation.

For the InterviewVR app, it was suggested to increase the realism by creating several industry-specific interview scenarios instead of a single generic one. The participants also wanted the simulation to be adjustable to the skill level of the user with varying degree of difficulty (e.g., progressively stricter time restraint and feedback on tasks/questions). They suggested having a tutorial mode and having the option to turn "hints" off. The ideal simulation according to the participants should allow the user to talk with voice and get feedback on his/her answers, giving the users the same stressful feeling as during a job interview. A suggested improvement was to have the user answer a recorded question and then have a human trainer from behind the scene choose between two or more suitable pre-recorded responses. It was also suggested that with the

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current version of InterviewVR it would help to agree in collaboration with a welfare professional on a profession or position beforehand and answer questions accordingly.

4 Discussion, Conclusions and Further Work

The study presented in this paper is highly cross-disciplinary and is in the intersection of the fields of VR, education, advisory science, psychology, and professional industries, made possible by a unique collaboration between academia, public sector and private companies. We demonstrated that relatively low-cost VR simulations made for experiencing job interview or for training job-interview skills can be a useful tool for the young job seekers and can help to mitigate some of their challenges. While there have been projects exploring workplace training and interview training in VR, little has been done to develop the solutions for young unemployed, something we consider as our contribution, as well as integrating job interview training with workplace simulations in VR as a part of the Immersive Job Concept.

Our study showed the importance of feedback during job interview training, especially on the consequences of the right and wrong choices to enable the users to learn from their mistakes for a more realistic and experience. The industry-specific scenarios were considered more realistic and potentially more useful, though their realism has been achieved at a cost of direct questions and (subjectively seen by some participants) rude feedback. The generic scenario designed with the welfare professionals was seen by the job seekers as better developed, but less realistic and too generic. Designing a scenario involving both industry and public authorities appears to be a good alternative.

For the immersive job interview training to be widely adopted, welfare personnel and k-12 teachers need to be trained to setup VR equipment and use the apps. This highlights the need for intuitive use interfaces, built-in guidance, easy installation and minimum required maintenance. The limitations of the study presented in this paper most importantly include a relatively small group of primary users and the fact that all evaluations have been done in laboratory settings.

The real-life evaluation outside of the lab is already ongoing and aims to explore how the job seekers and welfare professionals can handle the simulation with limited technical assistance, how much the simulation is used over time and if the using the simulation has an effect on the transition to work life. There is a need to further develop a coherent methodology, standards and templates for simplifying the development of the job interview simulations for different target groups, different languages and for industry-specific scenarios. This includes finding the optimal method for content development. While 360-video allows relatively cheap content production and provides a realistic experience, it lacks interactivity that is especially appreciated by the younger audience. A combination with 3D animations could be the optimal solution. Another alternative is to consider a non-immersive mode (flat screen) for the simulations based on 360-videos, which is the standard in most Google Cardboard apps. This would allow to address cybersickness and improve accessibility. Other technologies for increasing realism and improving feedback include speech recognition and other AI elements.

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Immersive Virtual Reality as an Authentic Learning Activity in Problem Based Learning: A Case Study of Elementary Students' Learning Behaviors

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Abstract. Problem-based learning (PBL) has become increasingly popular in K-12 education. It has also presented educators and designers with the challenge of providing authentic resources to students. One possible solution is the use of immersive virtual reality (IVR) as an authentic resource. This case study sought to elicit the perspectives and observed learning behaviors of elementary students using IVR in their PBL-based STEM class. The emergent themes suggested elementary students view IVR as a valuable authentic resource. Observed learning behaviors indicated elementary students can make observations and draw conclusions from IVR content.

Keywords: hypothetical model of immersive cognition, ICAP framework, immersive virtual reality, problem-based learning, student collaboration

1 Introduction

Originating from medical schools, Problem-Based Learning (PBL) has expanded to K-12 students. A key element of PBL is the authenticity of the problem itself, which is needed in order to provide positive learning experiences to the students (Scott, 2014). This authenticity of task continues to be a struggle in PBL designs (Savin-Baden, 2016). One possible solution is to incorporate immersive virtual reality (IVR) into the PBL cycle. IVR is a mobile device-generated scene that simulates the real world through the use of 3D 360˚ visual stimuli and Head Mounted Displays (HMDs) to fully immerse the user in the virtual environment (Xie, 2010). To date, research on IVR in instruction has been limited to memory recall (Bailey et al., 2012; Rupp et al, 2016) and possible abstract learning activities and experiences (Ahn et al., 2016; Passig et al., 2007) with collegiate aged students. IVR could potentially be utilized as an authentic PBL learning context to make a problem scenario more realistic.

The purpose of this descriptive case study was to understand elementary students' views and perceptions of IVR's impact on their engagement with and describe their learning behaviors in a collaborative PBL-based STEM class. This study addressed the following research questions:

RQ1: What are elementary students' perceptions of using IVR in their PBL-based STEM class on their engagement with the content?

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RQ2: What characterizes students' cognitive and collaborative behaviors when using IVR in their PBL-based STEM class, including:
- RQ2a: Learner-to-content interactions
- RQ2b: Learner-to-learner interactions
- RQ2c: Types of questions students are asking
- RQ2d: Types of observations students are making
- RQ2e: Other observed learning behaviors

2 Theoretical Framework and Literature

2.1 Problem-Based Learning

The use of authentic problems in PBL positively impacts and deepens the learning experience for students, leading to higher levels of engagement (Scott, 2014). When problems are directly connected to real-life situations, students are more likely to feel a sense of ownership and motivation to learn (Dole et al., 2017). Using PBL in the classroom can lead to higher levels of student understanding (Firdaus et al., 2017) and promote student empathy with the content (Grosseman et al., 2014). Adding a non-immersive virtual environment to elementary students' PBL experiences showed growth in their questioning skills (Hung et al., 2014), implying technology positively impacted learning in a PBL setting (Dondlinger et al., 2015). 2D video has also been found to provide an authentic learning context as an instructional hook and research source (Aronis, 2016).

2.2 The Hypothetical Model of Immersive Cognition (HMIC)

According to the HMIC proposed by Ladendorf et al. (2019), IVR potentially combines the analysis of strong visual stimuli with embodied memories to deepen the learning process and learner engagement. It is proposed that the visual stimuli activate multiple channels in the brain, bypassing the working memory, and bringing both cognitive and embodied memories to the forefront from long-term memory. IVR allows users to experience a deeper sense of presence over a desktop computer or mobile device alone due to the 3D-360˚ view (Ladendorf et al., 2019; Rupp et al., 2016). The first-person point-of-view heightens this sensation by allowing the user to take on a semi-live position within the IVR content (Scoresby and Shelton, 2011). It is hypothesized that IVR could pull both cognitive knowledge and embodied memories of physical sensations, potentially creating a more engaging and motivating learning experience (Ladendorf et al., 2019).

3 Methodology

3.1 Site and Participants

This descriptive case study was conducted at a Midwestern K-5 elementary school that serves students aged 5 to 11. All students receive a daily 30-minute STEM-

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focused PBL class. Eight 4th grade students, five boys and three girls between the ages of 9 and 10, participated in this study. Six participants were White, one Hispanic, and one Asian and all were native English speakers.

3.2 IVR Experience

The IVR experience was implemented into a previously developed PBL problem scenario: "Our local zoo needs to revamp their habitats and audience experiences. What habitat designs and audience experiences can you recommend to the local zoo representative?" Participants researched an animal and habitat, wrote a final report, and engineered a model of their proposed habitat. IVR was used as an authentic source.

Participants used the school's IVR kit which consisted of 24 iPod Touch devices, 24 Vibe viewer HMDs, and 2 iPad devices. The IVR experience lasted three days. Participants were introduced to the IVR kit and explored a zoo habitat on day one. Participants were given a research sheet specific to their chosen animal with IVR resources to explore on days two and three.

3.3 Data Collection

Observational data was video recorded and transcribed for conversations and movements. Participants were interviewed individually one week after the IVR experience for 20-25 minutes each using Seidman's (2013) 3-part interview methodology as a framework.

3.4 Data Analysis Procedures

All transcriptions and student artifacts were coded over three phases. The ICAP rubric was used to analyze the participants' cognitive and collaborative behaviors identified in RQ2 (Chi and Wylie, 2014). The rubric was edited to include the IVR behaviors of movement, choosing content, observations, and questioning

Table 1. ICAP Rubric (adapted from Chi and Wylie, 2014, pg. 221)

Learning Behavior	Description
Interactive (dialoguing)	Debating with a peer about the justifications based off IVR experience; discussing similarities and differences between IVR experiences with a peer
Constructive (generating)	Explaining concepts from the IVR experiences in their own words; comparing and contrasting IVR content to prior knowledge or other IVR content; asking questions beyond clarifications
Active (manipulating)	Manipulating the IVR by choosing experience, moving 360˚, looking around; interacting with the IVR content by reaching out, walking, or talking; asking clarifying questions; making verbatim or summarizing observations of the IVR scene
Passive (receiving)	Watching IVR with no movement, verbal questions, and verbal observations made

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3.5 Data Validation

A second coder was utilized to establish inter-rater reliability (IRR) at r=81.15% using Miles and Huberman's (1994) percentage agreement method. Participants also reviewed the emergent themes in a focus group setting.

4 Findings

Two main themes emerged from the data analysis: IVR content and lesson structure impacted participants' perceptions of their engagement (RQ1, RQ2a, RQ2b), and the participants' interactions with the content, each other, and the types of questions and observations indicated the level of engagement when compared to the ICAP framework (RQ2a-e).

4.1 IVR Content and Lesson Structure Impacted Peer Interactions

Purpose of IVR in the Instructional Design. The participants indicated they wanted to utilize IVR experiences for the purpose of inquiry. They wanted to explore and discover answers with IVR content they have never seen and use the experience to develop their own understandings. The participants viewed IVR as the vehicle for the content, but not the central focus of their learning.

Participants felt they wanted IVR used at specific times during the instructional sequence. One participant, Emily stated multiple times she should have preferred to start with the IVR as an instructional hook versus a new resource in the PBL cycle. "*I think that when we flip those two, the research we're going to have to read it anyway so it wouldn't have made a difference. Cause me and [my partner] found the basics everywhere and in the VR*." IVR as an instructional hook would have given Emily more focus for the upcoming research. Placing the IVR in the middle of the research process led to feelings of disengagement and boredom. *"…we would have learned more if we started from the introduction…yeah, you kind of get to look at the area and the zebras and feel like you get to know it…it's the same stuff we already saw like the stuff that we have the same info for, like from every website.*" Emily also indicated multiples times they were behind on research and the IVR set them further back. While other participants did not corroborate this statement in interview, all agreed with this theme during the focus group.

IVR's Impact on Student-Student Interactions. Six of the participants indicated they would want to utilize IVR with a partner again. These six relied on their partners for troubleshooting and sharing observations. Participants were observed physically moving their partners' bodies and heads towards a detail they had observed. The participants and partners exhibited a sense of excitement that fed off each other. If one partner was excited, the other became interested and immediately began looking. The participants also wanted to share what they were observing and receive immediate feedback. If the partner was not available, the participant reached out to a new person to share. Some participants went so far as to seek out the teacher just for the sake of sharing the IVR experience.

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Two participants cited specific frustrations with their partners that would lead them to not want one again. In one case, Adam's partner left him multiple times to be with other groups and view different animals, leading to frustration an unengaging experience. In a second case, Laura was frustrated with her partner who was not adept at using the IVR goggles and confused by the content. Laura had to redirect her partner, troubleshoot, and explain the content multiple times. Her partner was not allowing Laura to dive as in-depth into the IVR content and hindered her learning.

4.2 Learning Behaviors with IVR

Movement in IVR. Observed movement included 360˚ head and body movements, reaching out and walking (see Table 2). The manner and speed in which the participants moved their heads and bodies to view the 360˚ content changed as the experience progressed and new content was introduced. Participants used fast head and body movements with new IVR content and slower movements with previously observed content. Reaching out or attempting to walk towards the objects was not as noticeable in subsequent viewings. Their focus changed from taking everything in as quickly as possible to looking at a few specific details in additional viewings.

Table 2. Movements

	Students	Times Observed
Reaching	6	19
Walking	8	43

Observations, Questions, and Conclusions during the IVR Experience. Participants made two distinct types of observations during the IVR experience: in-the-moment while immersed (ITM) and after-the-fact without IVR (ATF) observations. ITM observations were clarifications and immediate wonders while ATF observations were reflective and pointed out specific details (see Table 3).

Table 3. Observation Style Comparison

In-the-Moment Observations	After-the-Fact Observations
Oh wow! Look at that! Oh my god, I see the leopard! Wait, where am I? I'm on a rock! Leopard!	So we need glass around the enclosure. Lots of space in there. And benches. A lot of enclosure. Yeah, because when you think about it there are a lot of enclosures. They close off the giraffes, the elephants, all the animals.

Included in the observation count in Table 4 were questions participants asked. Participant questions were focused on gaining clarity in what they were observing such as, "What is that?", and "Where am I?" and not asking deeper questions about the content.

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Table 4. Observation Count

Observation Style	Observations	Percentage of Total Observations	Conclusions Drawn
In-the-moment	327	68.99%	20
After-the-fact	147	31.01%	48

A chi-square test of independence was performed revealing a moderate relationship between the categories at *a*=.05 (X^2(1, N=542)=40.437, $p < .001$) and a low effect size using Cramer's *v*=.273, suggesting that there were many more ITM observations when compared to ATF observations (see Table 4). Participants were able to draw conclusions verbally from both styles. ITM and ATF observations that resulted in conclusions did not differ in style or details. More conclusions were drawn with ATF observations, indicating the need for time outside of the IVR experience to reflect. Questions were used as observations and clarifications.

ICAP Analysis of Learning Behaviors. Learning behaviors were analyzed using the ICAP framework. "Observations and questions" were participant observations of and questions about the IVR content. "Movement and interacting with IVR" were moments participants physically moved, looked around 360˚(see Table 5).

Table 5. ICAP Analysis

Student Activity	Interactive	Constructive	Active	Passive
ITM and ATF Observations & Questions	47 9.92%	47 9.92%	380 80.16%	0
Moments of Movement and Interaction with IVR	0	0	229 96.22%	9 3.78%
Total	47 6.60%	47 6.60%	609 85.53%	9 1.26%

A chi-square test of independence was performed to analyze the frequencies and relationships between the ICAP levels and student activities, revealing a significant relationship at *a*=.05 (X^2(3, N=712)=69.894, $p < .001$). A medium effect size was detected using Cramer's *v*=.313. Only 9 instances of passive receiving were found, where participants watched the IVR content with no movement or verbal observations. These moments occurred immediately after participants had been actively looking around the IVR environment and found the specific detail to stop at.

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5 Discussion and Implications

Elementary students perceived IVR as a useful tool in PBL. They preferred IVR videos to static scenes, supporting Aronis' (2016) study of traditional video as a vehicle for authentic learning in PBL activities. The participants perceived IVR as having a place in PBL possibly as both an instructional hook and primary source. Hung et al. (2014) found similar results with non-immersive VR used for scaffolding and support. Instructors and instructional designers must be purposeful in the incorporation of IVR in PBL learning activities, paying attention to the placement of the resource in the PBL cycle.

The participants made both ITM and ATF observations and were able to draw conclusions from both observation styles. More conclusions were drawn with ATF observations despite the fact that fewer ATF observations were made. This suggests the time outside of the IVR environment was necessary for participants to reflect and draw conclusions. Despite participants showing frustration when told to leave the IVR environment, the number of conclusions drawn were higher when participants were not immersed compared to full immersion. The time given for review and reflection could possibly yield more generation of conclusions. When observations and movements were combined, only 1.26% of the observed learning behaviors were rated as passive, which was done after participants had manipulated the scene to find a detail to focus on, implying that learning with IVR is naturally active. While IVR inspires active learning behaviors, it does not seem the behaviors will be higher-level. Instructional scaffolding is needed to support students in this endeavor (Hung et al., 2014).

5.1 Limitations and Future Research

Only eight participants were used in this case study at one site. The IVR resources in this study were limited to mobile applications available from the school district. The study was also limited to PBL as the instructional design.

Future research should be conducted on the impact of authentic IVR content on students' responses. Content designers would also benefit from research comparing students experiencing new IVR content versus previously learned material on content understanding and engagement. Research should also focus on IVR content and instructional designs that support students in inquiry learning behaviors. Finally, future research should expand on active learning with IVR.

IVR has the potential to provide an authentic learning activity in PBL and other learning designs. The field of literature needs to continue to expand, and to include the voices of learners form all ages. It is through their voices that K-12 educators and content developers will be able to truly meet their needs with IVR technology.

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Virtual Reality STEM Education from a Teacher's Perspective

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Abstract. Maroon is a virtual laboratory designed for learning experiences with virtual reality setups. It provides access to various simulations and experiments to learn and understand better physics. In a first study, the experience is evaluated with 14 prospective physics teachers to identify and discuss the potential of the setup for the classroom. In this study, we found that the experience was described as highly engaging and promising as it makes the content more interesting for learners. However, also the need to provide specific VR learning in educational institutions, as well as proving pedagogical scenarios to support collaborative learning were identified.

Keywords: Virtual reality, STEM education, VR, Interactive Simulations

1 Introduction

Traditional STEM (Science, Technology, Engineering, and Mathematics) education often presents STEM fields as a collection of formulas. Therefore, students are memorizing facts instead of understanding the underlying phenomena. As a result, students often describe STEM fields as *boring and complicated* and failure rates are very high [9]. Instead of reciting formulas, students should be able to experiment with hands-on and interactive experiences [13]. Teaching models that encourage conceptual thinking in classrooms through interactive engagement and the use of visualizations, simulations, and hands-on experiments can support learners to understand the scientific phenomena [4].

However, for many schools and other educational institutions, the provision of hands-on exercises and examples poses a challenge. Experiment setups are often very complex and expensive. Therefore, learners can only conduct a limited number of hands-on experiments and also only for a short period. This leads to a higher demand for digital learning experiences. Additionally, the new generations of learners require flexible and engaging learning environments, which help them to focus, which are motivating, and also let them explore the learning content.

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In previous studies [10–12], we have presented and evaluated Maroon, a virtual reality (VR) physics laboratory to learn physics through interactive simulations and visualizations. We have compared the different version of Maroon using different VR technologies and have shown that this form of learning highly engages learners. Especially the room scale VR version supporting the HTC Vive environment was described as highly engaging and immersive. However, working with a room scale environment in a classroom setting poses various challenges, such as the needed space, the setup, and missing pedagogical concepts on how to introduce this experience in a classroom. Therefore, in this paper, we want to shed light on the experience of the other side of the learning experience: the teacher's perspective. We present a first study with 14 physics teachers to find out more about challenges, requirements, and potential options and scenarios on how to integrate a room scale VR experience into a classroom environment.

2 Related Work

Digital learning experiences to support interactive learning and engage students are becoming increasingly important for the classroom and can be used to support active learning approaches [6]. In particular, in fields such as physics, animations, visualizations, simulations, and virtual experiments can help learners to understand the phenomena [5]. Computer-based interactive simulations are usually cost-effective, safer, and take less preparation time when compared to traditional experiments [15]. However, designing learning tools for generations becomes increasingly challenging. They require engaging and flexible learning tools. For this purpose, the use of game-based systems, as well as virtual reality based systems have been shown as promising tools to engage learning but also increasing learning outcomes.

Bonde et al. [1] presented a gamified digital learning laboratory for biotech education. In a study testing this gamified laboratory, they found that this environment can significantly increase the students' motivation and their learning outcomes when compared to traditional teaching methods. Also, the use of virtual reality environments has been shown to enhance, motivate, and stimulate the learners' understanding of various phenomena. These environments have been shown as particularly successful in helping learners to understand events and elements when traditional instructional learning has been shown as inappropriate or difficult. The application of virtual reality in physics education has shown already very early as a promising approach [8]. Loftin et al. described in 1993 an early version of a digital physics laboratory for a virtual reality learning experience. In recent years, a new peak of virtual reality technologies, which are more affordable and also more immersive [3], gives new options and chances to bring virtual reality education to schools and other educational institutions. Additionally, tools such as the game engine Unity make it easier to develop different simulations and experiments for these devices and make both the learning, but also the development open to a broader audience.

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3 Maroon

Maroon is a three-dimensional virtual laboratory and learning management system supporting learning experience supporting the interaction with virtual reality devices. Maroon is designed as a virtual laboratory room with different experiment setups. When users approach an experiment, they get teleported into a new scene, where they can work with the experiment (see Fig. 1). We developed Maroon with the game engine Unity3D[4] and designed it similar to a first-person game.

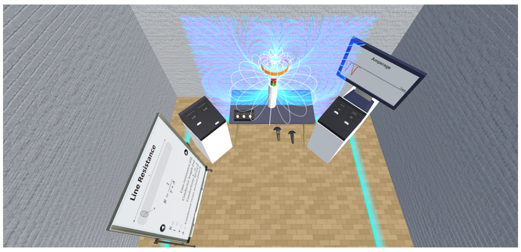

Fig. 1. Screenshot of an experiment room

The main version of Maroon supports different forms of interactions. On the one hand, Maroon can be used in a web browser with the own PC using the mouse and the keyboard to interact with the virtual world. On the other hand, it is also designed to be used with virtual reality devices such as the HTC Vive, the Oculus Rift, or mobile VR solutions (with the own smartphone). The different versions of Maroon were already introduced and evaluated in different studies [10–12]. These previous studies focused on evaluating the experience with these different virtual reality devices. In these studies, we compared room-scale VR experiences with the HTC Vive and mobile VR experience with mobile phones. We found that the room-scale VR experience was described as more engaging and more immersive. However, the HTC Vive environment also poses challenges, such as the needed space, the setup, and missing pedagogical concepts on how to introduce this experience in a classroom. Therefore, in this paper, we present a first study with a focus on evaluating learning and teaching perspective from a physics teacher's perspective to find out more about challenges, requirements, and concepts how to integrate Maroon in a classroom environment. For this purpose, we focused on evaluating the overall experience, as well as the experience with two different physics experiments: one experiment illustrating Faraday's Law and one experiment illustrating Huygens' Principle.

In the *Faraday's Law* experiment, a small magnet and a conducting non-magnetic ring (coil) are positioned on a horizontal axis. Users can grab the magnet and move it along the horizontal axis. When the magnet is moved through

[4] https://unity3d.com/

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the coil, a current is induced. The current is displayed on a graph on a monitor on the right. The user can also feel the acting force through haptic feedback in the controller. In a panel on the right, the user can change the coil's mass, the resistance, and the magnet's dipole moment.

In the *Huygens' Principle* experiment, users can learn about diffraction. The experiment shows a basin filled with water. In the basin, a slit plate is placed, which allows users to observe the interference pattern generated by diffraction. Users can move the plate to the left or to the right and can also change the plate by grabbing it, throwing it away, and taking a different plate with more or fewer slits from the shelf to their left. On the control panel, users can change wavelength, wave frequency, and the propagation model. Users can also change the wave colors to enhance the visualization.

4 Evaluation

To understand better the value of the virtual reality learning platform *Maroon* for educators, as well as their needs and concerns, we conducted a qualitative user study with 14 prospective physics teachers. We designed the study with a focus on (1) experience and engagement, (2) usability, and (3) learning value from the teacher's perspective.

Setup The VR evaluation setup is a portable testing setup and consists of a Laptop, an HTC Vive[5] head-mounted display, the two base station, two controllers, and two tripods for the lighthouses. For the room-scale setup, an area of at least 2m x 2m is necessary. For this evaluation, we set up two HTC Vive room-scale experiences in one room. Both HMDs were captured with only two base stations. All participants were in one room and able to watch the others interacting with the environment to simulate an in-classroom learning experience. Test users did not wear any headphones so that we were able to interact and talk to them during the study.

Material and Procedure We recruited 14 student teachers of the teacher's study program. The participants filled out a 30-item pre-questionnaire to get information about their demographics, their experience with VR technologies, and their experience with educational tools. We familiarized all participants with the test environment and the VR setup. After giving a short introduction, we explained the different tasks and equipped them with the HMD. The first task was to interact with Faraday's Law experiment. The second task was to interact with the Huygens Principle experiment. After finishing all the tasks, we asked the participants to fill out the post-questionnaire. The first part of post-questionnaire consists of open-ended questions about their experience in the virtual laboratory and their opinion of the laboratory as a teaching tool. The second part consists of a 22-item scale with Likert scale questions between 1 (fully disagree) and 5

[5] https://www.vive.com/

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(fully agree) about their motivation and experience in the virtual laboratory. We used the Computer Emotion Scale [7] to assess their emotion towards learning the new software. We used the System Usability Scale (SUS) [2] to evaluate the participants' satisfaction with the usability of the virtual laboratory.

Participants All 14 participants (11m, 3f) were in a student teachers program for physics education. The prospective physics teachers were aged from 21 to 28 (M=23.43; SD=1.72). We asked each participant to rate their experiences using a Likert scale between 1 (low experience) to 5 (high experience). All participants rated their experience with computers with 3 points or higher (M=3.4; SD=0.65). No participant rated the experience with virtual reality higher than 3 (M=1.39; SD=0.63). 7 participants stated to have used a VR device before. 6 participants have used the Oculus Rift before, only one the HTC Vive. 13 participants stated to use simulations for teaching. When asked about digital learning tools they use they named the e-learning platform Moodle, videos, simulations, the learning games from Kahoot, physics simulations from Phet, and physics simulations using the smartphone from phyphox[6]. All 14 participants stated that they think that VR is a promising way to teach physics through experiments. When being asked what they expect from a VR experience as a teacher the following items were listed: a new form of teaching, more engaged students, active and interested students, better understand through visualizations. They also mentioned that it is important that the tool is easy to use, that students cannot hurt someone or can destroy something, and a new form of teaching.

5 Results

Experience and Engagement All 14 participants rated the experience as engaging and motivating. To assess the participants' emotions while interacting with the VR lab, we used the **Computer Emotion Scale** [7]. The four emotions happiness, sadness, anxiety, and anger are assessed by asking the participants to rate 12 items on a Likert scale between 0 and 4. The results reveal that participants have significantly stronger positive emotions representing happiness (AVG=3.11; SD=0.54) and perceive very low emotions referring to sadness (AVG=1.0; SD=1.04), anxiety (AVG=0.82; SD=0.28), or anger (AVG=1.03; SD=0.29) while interacting with the VR experience.

Usability Only one participant described issues with the interaction with the experiments and with the user interface. The other 13 participants described the experience as very intuitive and self-explaining. We used the **System Usability Scale** [2] to assess the usability of the VR experience. The SUS is a 10-item standardized questionnaire on a Likert scale between 1 (not agree) and 5 (fully agree). The environment received an acceptable SUS, which is above average

[6] https://kahoot.com/, https://phet.colorado.edu/, https://phyphox.org/

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(SUS = 68+) but also indicates room for improvement. The participants rated the overall usability of the system with 70,628 points out of 100.

Learning Value from the Teacher's Perspective Many participants mentioned that it would be helpful to add audio tracks to each experiment, which explain the concept of the phenomena and the effect when changing any parameters of the experiment. Participants mentioned that the VR Lab makes the content more interesting, fun, and engaging. However, when being asked if they think the VR Lab makes the content easier to understand, the answers were very mixed. Especially elements such as the visualizations the engaging and interactive interaction with the experiment, and the many options to interact with the experiment very rated as very positive. They suggest adding an audio track or other forms of explanations directly to the experiment. Additionally, one participant suggested adding the assignment protocol directly into the scene.

Use Cases The teachers were also asked to describe ideas and scenarios on how to use the VR lab in schools. Several participants mentioned the introduction of experiments which they are not able to perform in schools because they are not visible, too dangerous, or too expensive. Examples included acoustics or optical experiments. They would use in lab courses or as a project instead of using it as part of the traditional classroom experience. Also, one participant was concerned that students would see the experiments as a game instead of a learning experience.

Qualitative Observation During the evaluation, we collected qualitative feedback to be able to identify challenges, options, and use cases of the setup.
"What did you like?": When asked about what they liked about the virtual laboratory they stated that it is showing *"physical phenomena which are usually invisible"*. They liked that it is very interactive, user-friendly, and playful elements. One participant mentioned that one feels "as a part of the experiment". Several participants also mentioned that the virtual reality setup engages to experiment, explore, and research.
"What did you not like?": Participants mostly mentioned technical difficulties and dangers. This sometimes includes technical disruptions when other participants were standing in front of the base stations (sensors) and dangers through the cables. Additionally, participants mentioned that they did not like the feeling that others were watching them. One participant mentioned a feeling of dizziness. No participant felt nausea.
"Would you use it for teaching?": Most of the teachers mentioned that they would use it for teaching but also noted several requirements and limitations. This especially includes the needed space, the needed setup time, and the costs. Additionally, teachers mentioned that especially the first interaction with the VR setup might be challenging because students will be very excited and distracted by their first experience with VR and will not concentrate on the experiments.

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6 Discussion and Limitations

The results of this evaluation reveal that teachers would use VR technologies in the classroom. However, in the current state, they would prefer to use it on dedicated "project days" instead of making regular use of the technology. Their main concern hereby is the setup time. In the current experiment setup, the VR setup is designed to be mobile and requires a setup and calibration time. This issue can be solved by integrating VR setups in dedicated "VR Laboratories" or "VR Rooms" in each educational institution.

The qualitative observation and feedback we got from the participants also indicate concerns that the use of room scale VR with large student groups (e.g. 20 - 30 students) might be overwhelming and students would start to misuse the technology instead of focusing on the learning content. The need to develop specific pedagogical strategies was identified. For a future study, we are developing different pedagogical strategies to involve student groups in the whole learning process. Students can work, for instance, in groups of three. While one is working with the experiment in VR, the other two can give him or her instructions from the assignment sheet. This sort of collaboration was identified as a valuable tool to engage also in other VR experiences such as the VR game Keep Talking and Nobody Explodes[7]. Experiment assignments can be designed in a way that they would be only able to solve them while working together. This scenario would also be supporting the concept of collaborative learning, which has been shown to help learners understand the learning concepts [14].

All participants in this study were very young prospective teachers. All of them were 28 or younger. Their openness towards the use of new technologies might be higher compared to teachers who are already used to work with traditional teaching methods for many years. However, we also believe that introducing new learning technologies to prospective teachers is an important strategy to bring such innovative technologies to schools and other educational institutions.

7 Conclusion

In this paper, we presented a qualitative study with 14 prospective physics teachers to understand better their needs when working with a virtual reality setup to teach in classroom settings. The VR setup was described as a tool, which can enhance the students' engagement and help to get them interested in the topic. However, we also found that especially the room scale setup, which requires setup time and a dedicated space poses challenges. We were able to identify the teachers' need for a fixed setup (e.g., in a dedicated VR learning lab in the school), where they do not need to set up and calibrate the VR devices themselves. Additionally, we identified the need to define and evaluate various pedagogical models supporting collaborative learning in VR. Collaborative setups, which require students to work together on the assignment (one in the VR

[7] https://keeptalkinggame.com/

DOI: https://doi.org/10.3217/978-3-85125-657-4-14

experience, two from the outside) by talking to each other can help to overcome various issues and help them to learn together.

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Adult Learning Sign Language by combining video, interactivity and play

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Abstract. One in every six persons in the UK suffers a hearing loss, either as a condition they have been born with or a disorder they acquired during their life. 900,000 people in the UK are severely or profoundly deaf and based on a study by Action On Hearing Loss UK in 2013 only 17 percent of this population, can use the British Sign Language (BSL). That leaves a massive proportion of people with a hearing impediment who do not use sign language struggling in social interaction and suffering from emotional distress, and an even larger proportion of Hearing people who cannot communicate with those of the deaf community. This paper presents a theoretical framework for the design of interactive games to support learning BSL supporting the entire learning cycle, instruction, practice and assessment. It then describes the proposed design of a game based on this framework aiming to close the communication gap between able hearing people and people with a hearing impediment, by providing a tool that facilitates BSL learning targeting adult population. The paper concludes with the planning of a large scale study and directions for further development of this educational resource.

Keywords: Virtual Reality; Adult learning; Serious Games; Games based Learning; Video Learning; British Sign Language.

1 Introduction

British Sign Language (BSL) is a complete visual-gestural language with a unique vocabulary, construction and grammar believed to be used by 151,000 of the UK population, 87,000 of these are Deaf [1]. Increasing the number of Hearing people to learn a sign language, would drastically reduce the barriers, discrimination, and plain ignorance that Deaf people face every day. Learning a visual language like BSL could be well supported by the use of highly visual resources, such as video or a rich graphical environment. Shepard and Cooper [2] and Mayer and Gallini [3] made the connection between visual clues, the memory process, and the recall of new knowledge.

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Virtual reality (VR) holds exciting prospect to accommodate the needs of people with hearing disabilities [4] [5] [6] as it supports high motivation, it allows for a greater control over one's environment, it facilitates repetition and self-pacing. To further motivate and engage the learning process and stretch knowledge retention and skills, VR can be coupled with gamification [7], which is the application of game-design elements and game principles in non-game contexts. Game play stimulates brain activity, demonstrating retention of information and engagement that result to effective cognition [8].

The paper presents a background review of games that have been created to support learning BSL highlighting their use to train or assess, their success in fulfilling their intended purpose and the technologies they have been used to support those. Section 3, suggests a theoretical framework to be followed for the creation of an interactive game to support learning BSL combining the whole cycle of learning, instruction, practice and assessment. Section 4 presents a proposed game design addressing this framework making use of VR technology, coupled with Gestures recognition by a Leap Motion Controller and gamification. The paper concludes with directions of future work targeting to evaluate the validity of this proposed educational resource.

2 Related work

Several existing BSL educational games, using 2D technology and relatively low interactivity, target users who already hold some knowledge of the sign language aiming to engaging them in activities to practice their knowledge. "*Sign language test"* [9] is one such game, that shows an image of a sign and 5 options to choose from. *"Finger Spelling Game"* [10], displays a series of signs and asks the player to recognizing the whole word. "*Signing Time Kids"* [11] is a memory matching game with a countdown timer. Some other games attempt to teach novice players a sign language. Like *"Sign the alphabet"* [12], a learning by doing multiple choice game that displays a BSL sign and asks the player to recognise the respective letter. Answers are revealed as the game is played, users can be guessing, but their score is reduced. Similarly, *"What is this Letter Sign"* [13], alternates between displaying a written letter and three signs for the user to choose from, there is no scoring, but players are congratulated when providing a correct answer. The *"GreenBeanies App"* [14], provides a short story with clickable words that trigger a short video playing the sign for the word performed by a person. *"Sign my World"* [15], is a mobile 2D video game to aid deaf children to learn the Australian Sign Language (Auslan) and familiarize with the appearance of common nouns and verb signs. It contains a number of interactive objects that when clicked, an image and word are displayed, as on a flash card; followed by the video of the Auslan sign for that object.

Game technology combined with sign language recognition encourages deaf children to practice the American Sign Language (ASL) in an enjoyable way. Such an example is *"CopyCat"* [16]. To play children wear coloured gloves with wrist-mounted accelerometers and interact with a computer vision recognition system.

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"Virtual Sign Game" [17] [18], is a game for learning the Portuguese sign language (PSL) that combines 3D, Kinect and gloves technology. The player controls a synthetic character that interacts with objects and non-player characters aiming to collect several gestures from the PSL that are performed by those characters helping the player to visualise and train existing gestures. *"MemoSign"* [19] aims to foster and promote the vocabulary acquisition for Deaf and Hard of Hearing (DHH) learners in both signed and spoken languages. MemoSign combines, Memory Match Game and avatar technology that render sign notations content in visual-gestural modality.

3 Theoretical framework

To create an educational resource that marriages advanced technology combined with game elements to successfully support learning BSL an instructional scaffolding approach in learning [20] is proposed. This is the "the systematic sequencing of prompted content, materials, tasks, and teacher and peer support to optimize learning" [21]. Similar to scaffolding used in construction, the educational resource, that can be an 3D interactive game, puts in place temporary support structures to assist learners in the process of learning the BSL alphabet. It tailors the learning process to the needs of individual learners by enabling a self-paced exploration of the immersive environment. The structure of the scaffolded instruction implemented takes place in three levels:

- ***Level 1 – learn – the game and the individual do it***
  The game demonstrates how to communicate using BSL in videos. The videos provide a realistic depiction of BSL alphabet and are embedded as objects in the game environment. The learners explore the environment to uncover the hidden objects and watch the videos. Additional scaffolds (i.e., repetition of a BSL gesture and a video inventory) enable learners to master individual BSL letters.
- ***Level 2 – practice – the individual does it***
  In the practice stage individual learners demonstrate their mastery of the BSL alphabet by practicing recognising the BSL alphabet.
- ***Level 3 – assess – the individual is assessed***
  Once learners feel confident with their mastery of BSL, all scaffoldings are removed, and they can assess their knowledge by playing a game against a virtual enemy.

Fig. 1 presents the structure of the scaffolded instruction implemented in the game.

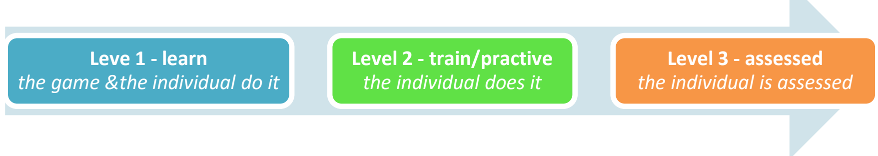

Fig. 1 The scaffolded instruction implemented in the 3D interactive game platform

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4 Signum Battle - the 3D interactive game platform

4.1 The game design

Genre. The Signum Battle is a third person hybrid action – adventure – educational game, aiming to teach BSL alphabet in a fantasy mythological world. The player/learner takes on the role of a hero/explorer who needs to complete several learning quests to advance through the game. Adventure genre games usually require the player to solve a problem, but without much action happening, by action we refer to encountering drawbacks in the form of enemies or battles. Action genres constitute mainly of action derived activities and the game play is very much based on the player using their reflexes and being in a heighten state of alertness to fight enemies. Problem solving is essential for constructing links between information to reinforce learning. In addition, negative and positive reinforcement strengthen the motivation for learning which is supported by the combination of action and adventure genres respectively.

Game demographic. The target audience of this educational game is people that learn sign language later in their life. Taking into consideration that after Level 2 of the game there is suggestion to mild violence per the Entertainment Software Rating Board the band in which the game fitted best I s E10+ [22].

The lore. The review of educational games to teach sign language revealed that none of the existing games have an engaging story and/or engaging environment usually found in popular games. Therefore those educational games come across as uninteresting. The backstory of the Signum Battle is that mermaids have used their enchanting song to lure humans into the sea, the survivors left in this fantasy world lived because their lack of hearing has empowered them to be immune to the mermaid's chant. The mermaids have become aware of their limitation and have summoned walking sea creatures, minions, to come into land to protect their territory and the humans they have trapped. A young heroine has stumbled into this world and decides to go on a mission to help them. To do so she needs to pick up the skills and magical powers of this language to attack the minions, reach the mermaids lair and rescue the humans. The language to be learned is the BSL. The backstory is used to: provide a framework for a mission based game structure; and help the players submerse themselves in a game they experience "Suspension of disbelief" [23] in order to be entertained. Furthermore, it was important to tackle the subject of deafness in an inclusive and non-patronising way. Thus, deafness is presented as positive and empowering element in the story of the game. This has been the case in many superhero stories; as for Marvel who included a deaf super hero in their comics, which according to Callis [24] for deaf children this pop culture representation is affirming. Hence, the people of this game world survived the evil song of the mermaids which lured men to sea, because they were immune due to their lack of hearing.

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Game controls. The game is controlled by mouse clicks to move around and interact with objects in the environment. Gestures, using a leap motion controller, are used to practice the signs that have been learned or make selections in level 2. The keyboard is used to recognise signs. This game aims to be inclusive; therefore it includes audio, but is not reliant on it. Audio is used to engage able hearing players, but for every sound que there is an equivalent visual feedback.

The game environment – looks interesting and engaging reflecting the magical theme of the backstory. Hence the story unfolds in a forest where stone ruins (see Fig. 1(a)) where added to reflect the destruction that had come before.

4.2 The game Levels & mechanics

Level 1 Learn. Level 1 familiarises the player with the BSL signs. Signs drawn on stone tiles like ancient hieroglyphics are scattered in the environment among the forest ruins for the player to discover (see **Fig. 1**(b)), supporting exploration, engagement and immersion in the game. Picking up a sign activates a video that plays out the corresponding gesture for that letter, then the sign is added in an inventory. Players can open the inventory and play the signs as many times as they need to be confident that they know it. Currently, only 8 signs of the BSL alphabet have been implemented.

At this level the game mechanics used is exploration, discovery and collection of signs to advance to the next level. There is no time constraint, rewards or penalties. Once all the letters in this level have been collected the players can proceed to level 2.

(a) (b)

Fig. 2 (a) The forest environment in level 1 where the players collect the BSL signs; (b) inventory of the collected BSL signs and video playing the sign gesture.

Level 2 Practice. In Level 2, players transition from an open environment to a closed sheltered area (see **Fig. 2**(a)) where they can practice at their own pace the signs they have learned. The system prompts the player to correctly recognise the corresponding BSL sign of letters they have learned in Level 1 (in a form of a multiple choice questionnaire). Players select one of 3 cubes that appear on a table top in the training room using the leap motion (see **Fig. 2**(b)). Initially it was planned to use a BSL recognition algorithm for Leap Motion, but this was too difficult due to the use of two hands while creating gestures. The letters are presented randomly until the players perform

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well, indicating they have learned the signs. There is no time constraint, rewards or penalties at this level. When the players feel confident they can progress to level 3.

(a) (b)

Fig. 3 Level 2 (a) The sheltered environment for practicing the signs; (b) The user recognizing the BSL signs using a leap Motion controller.

Level 3 Assess. Level 3 is the battle level where the player's recognition of the BSL signs is assessed. To win this level the players have to correctly recognise the BSL signs shown on top of the enemy/minion by hitting the respective key on the keyboard see **Fig. 3**. Correct recognition of the BSL signs keeps the enemy in distance (see **Fig. 3** right image), while failing to recognise them reduces the players' health, that after few wrong attempts dies and the level starts again. There is no time constraint at this level, the players play as long as they can last. Speech recognition could support faster identification of signs. However, selecting the respective key of a sign on the keyboard might serve learning better, as it helps the conceptual connection between letters and signs.

The enemy in Level 3 was inspired by a collection of sea monsters. The enemy is bigger than the player's avatar and fearsome to add to the fear factor of the game [22].

Fig. 4 The battle, the players have to correctly recognise the BSL signs shown on top of the enemy/minion by hitting the respective key on the keyboard to keep the enemy away.

4.3 The technology

The game has been implemented in Unity. For the environment and textures we used, 3DsMax and Photoshop have been used, while for the game characters, Adobe Fuse

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CC and Mixamo (an online tool with an extensive library of animations that can be attached to 3D characters). Gestures are recognized by a Leap Motion Controller.

5 Conclusions & future work

This paper presents a first attempt of providing a valuable resource to support people to learn the BSL alphabet in an enjoyable and effective way with the use of video coupled with advanced technologies and gamification. The resource uses a scaffolding approach in learning, putting in place temporary support structures to assist students in the process of learning and tailoring the learning process to the needs of individual learners by enabling a self-paced exploration of the immersive environment.

The paper presented the design of the first version of the prototype. Low usability of an educational resource's interface may have a major impact on it learning educational potential [23] [24]. Thus, at this stage of design and development of the Signum Battle we aimed to discover and improve user experience (UX) issues before proceeding with testing related to its educational validity. For this purpose we use virtual world (VW) heuristics evaluation [25]. Currently the prototype undergoes through further updates to address the VW heuristics evaluation results and resolve usability issues before proceedings to a comparative study engaging a large number of users to evaluate its educational validity of this resource, as well as user satisfaction.

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Immersive Learning Experiences for Understanding Complex Systems

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Abstract. Complexity is core part of our lives. Aware or not, people need to understand and communicate complex ideas and perspectives. Understanding and communicating complexity can be facilitated through interactive simulations. Doing so in the physical world is often impractical, however. Users and developers are overloaded with information and ambiguity, costs are prohibitive, and unsupervised physical simulations raise safety concerns. Novel immersive technology might hold the key to transforming how we tackle understanding and communicating complexity. In this position paper, we propose empowering user agency and perception to take part in complex learning experiences and create their own, combining two factors: enhanced visual and spatial context provided by location-awareness, immersive environments, and somatic, embodied agency; and enhanced cultural and social context by leveraging as input methods the rich semantics of cultural-social gestures and rituals. To deem the feasibility of this argument, we propose developing two culture-aware prototypes, one for the Confederated Salish and Kootenai Tribes in Montana, United States, and another for a Western Europe cultural context.

Keywords: Complexity · Complex systems · Complex learning · Immersive environments · Emergence · Culture · Context · HCI · Gestures

1 Introduction

Stephen Hawking once said he thought the 21st century would be the century of complexity [5]. The world is an extremely complex place and has been rapidly evolving for some decades, comprised of complex and interconnected systems, creating novel challenges that call for a new way of thinking. Ecosystems, societal issues, politics, weather, and the human body are examples of such complex systems. They are complex – not to be confused with chaotic – in the sense that

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they act in interdependent and unpredictable (non-deterministic) ways. A key concept that makes complexity diverge from chaos: emergence. Simply stated, some features that emerge in large systems cannot be traced down to lower components, causing uncertainty to be inherent. Examples of such properties are the behaviours of water or of a bird flock. Even if initial conditions of individual birds or water molecules are known, the behaviours seen afterwards – of the whole – cannot be predicted directly (*e.g.*, flight formation, surface tension); rather, they have emerged from interactions of individual system components. Complex systems, or the study thereof, may hold the key to our understanding in this regard. Complexity science replaces the reductionist paradigm with a more holistic approach. Thus, the process of learning about complexity, which the literature traditionally calls Complex Learning [10,13], poses specific challenges.

This paper argues why Complex Learning and its challenges might be eased through the combined used of immersive environments and context-aware, culturally-leveraged learning experiences. It concludes by outlining a proposal for subsequent validation of this idea, developing two immersive learning experience prototypes, one for the Confederated Salish and Kootenai Tribes (CSKT) in Montana, United States, and another one for a cultural context in Western Europe. The expectation is that users, through these prototypes, are empowered to understand and communicate complex concepts and ideas.

2 Complex Systems

There is no single, formal definition of complex systems. Complexity, by itself, has several definitions proposed by authors with different backgrounds, objectives, and research perspectives, which led us to reflect on its interdisciplinar nature. Apparently dissimilar systems can share important commonalities both in structure and behaviour, so it should be possible to find universal or more fundamental laws by which their properties are governed [11]. Emergence is often described, originally by Aristotle, as "the whole is something besides the parts" [2]: the collective phenomena at a higher level are not the simple sum of the individual behaviours or characteristics of the constituent elements – a composite whole [6]. This is also called synergy, such as the division of labour of the ants or sounds' destructive interference. Complexity is associated with the intertwining and inter-connectivity of the constituent elements of a system and the surrounding environment [8, 11]. By extension, the definitions of complex systems [6,8,10,11,21,23], typically based on ideas from authors such as Holland, Funke, and Dörne, agree that a large number of elements, interacting at various levels, result in the emergence of a new level of organisation: self-organisation. Thus, there is a hierarchical structure with all these levels effecting each other. They are interconnected and interdependent on each other, and it is not possible to completely isolate a whole system or reduce the whole thing to one level. The very emergence of order, out of apparently chaotic or noisy behaviour is a manifestation of complexity. The coexistence of order and noise and their interweaving appearance is the complexity. Thus a complex system is a spe-

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cific type/class of system with properties that lead to emergence, namely: *(a)* multiple constituent elements, relations, and levels of hierarchy; *(b)* exhibiting non-linearity and phase transitions, that is: joining two things does not necessarily mean that the result is simply the sum of the properties of the individual elements, and occasions where a minimal change of a value, through feedback loops, can trigger large systemic effects [11]; *(c)* connectivity, as a driver of complexity, meaning the system's is topologically a network; and *(d)* autonomy, variability, and adaptation, as enablers of self-organisation and evolution.

3 Complex Learning

Learning is nonlinear, adaptive, and constructive [6] – indeed learning is itself a complex process. Therefore, learning about complexity is the application of a complex process (learning) to a complex concept (complexity). The resulting hypercomplex system is thus a challenging and distinctive social cognitive process [10]. This nature has traditionally been expressed in the literature as "complex learning", despite its ring of pleonasm.

Little wonder then that teaching complex concepts is challenging for teachers, communicating complex concepts and ideas is challenging across intercultural contexts, and even societal clashes may arise from lack of common understanding. Several efforts have been carried out attempting to understand and explain the phenomena. One particular aspect is that often teachers cannot put themselves in the cognitive status of the novice student, no longer remembering the difficulties themselves faced when learning the same topic. This is called the curse of knowledge bias or hindsight bias [9]. In this regard, Ifenthaler argues [10] that effective learning environments for complex knowledge domains should target three attributes: *(a)* understanding complex systems; *(b)* developing adaptive expertise; and *(c)* acquiring soft skills such as collaboration (*e.g.*, peer-learning– to tackle the aforementioned curse), communication, and task coordination. The literature on this problem includes learning theories such as Complex Constructivism [6] and Connectivism [20]; instructional strategies such as the 4C/ID model [13] or the Complex Problem Solving (CPS) process [8]; and focused aspects such as the aforementioned hindsight bias or the importance of feedback and repetition [22].

These proposals hinge on planning and providing circumstances and processes within the context of learning environments in support of complex learning, where the learner interacts (exerts agency) and perceives the outcome. The underlying perspective is that our personal mental models, states, constructs, or entities (depending on the theoretical lens on knowledge) change, not only by self-reflection and inner interactions over time, but by interaction with the physical world. Our agency and perception in this interaction are heavily influenced by prior knowledge and worldviews (dependent on social interactions and culture). The outcome then impacts subsequent agency and perception.

However, providing complex learning experiences/interactions in the physical world is often infeasible. Not only due to monetary issues or the risk they may

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entail (*e.g.*, simulation of catastrophes/accidents), but also because of their dynamic complexity, the presence of confounding and ambiguous variables, and the fact that feedback is often misinterpreted or surfaces with a time delay. If this occurs, the number of iterations of these cycles decreases and consequently slows the entire learning process, including the ability to accumulate experience, test hypotheses and improve [22]. Back in the early 80s, Papert and Schön suggested a way they deemed feasible to carry out and create such experiments, through simulation spaces or virtual worlds. According to these perspectives, the main benefits of using immersive learning experiences (*i.e.*, virtual, augmented, mixed and cross reality, in present terminology) in the field of complex knowledge, are: *(a)* the removal of aspects that are peripheral to the experience, isolating it the most; and *(b)* having greater control over the variables, so that the learner can exert agency with complete, accurate, and immediate feedback. One such example was presented by Ifenthaler [10], and combines the benefits of mobile learning, virtual learning environments and augmented reality.

4 Learning in Context

Though often overlooked as trivial or shared common ground [19], context shapes learning through the surrounding environment, particularly through social interactions and culture [22]. It is also considered one of the challenges of complex learning due to its situativity in real life contexts [10]. Virtual learning environments from complex concepts should thus leverage the context of the surroundings (*e.g.*, physical, social, cultural) – becoming situated learning environments. Technology can enable interaction with culturally-rich social immersive environments [7, 10, 16, 19] but this also leads to new challenges concerning their use, design and development. Currently, such environments are not authentic contexts for most everyday complex situations. This occurs for numerous reasons; from immersive environments not being tangible (for the most part) to failing to reflect the importance of the social dimension [7]. To tackle these challenges different authors [3, 7, 10, 19] propose methods, models, and recommendations for analysis, design, and engineering of context, combining technical dimensions with cognitive theories and educational processes. The challenge of tangible interaction in particular has seen a recent spike due to wide interest in gestural input modalities in mobile devices, the so-called natural user interfaces (NUI), leading to renewed interest in the wider approach of multimodal interaction. The "natural" allegation of NUIs has been criticised, due to the high level of artificiality it entails [12] and even for the fact that most such "natural" interfaces do not follow basic principles of interaction design [17]. They imply the learning of a set of predefined gestural commands by users – rather than the other way around, *i.e.*, the interfaces accepting whatever commands users would already deem "natural". For instance, one can consider the interaction with current head-mounted devices such as HoloLens, Oculus Rift, HTC Vive and, more recently, Magic Leap. Switching between these devices typical interfaces requires learning different arrays of gestures/commands using one's hands or joysticks.

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This ignores the cultural and social dimensions of context. The proposal below establishes a relation between human-computer interaction studies and anthropology, leveraging it to make systems that are more context-aware. Previous studies [1,14,15] present preliminary contributions on the potential and feasibility of creating a cultural layer abstracting the interaction processes and elements (*e.g.*, gestures and other somatic aspects) from its system control effects (commands) – the shamanic interface. Critically, recent results point towards the use of cultural-aware gestural emblems for interaction resulting in better remembrance and lesser command input errors than using gestural emblems that are not cultural-aware [4].

5 Proposal and Future Work

The proposal herein is part of an ongoing research effort with the overarching goal of empowering non-experts to understand and communicate systemic concepts and ideas.

We hypothesise that a significant contribution can be achieved by an innovative combination of two factors: *(1)* enhanced visual and spatial context provided by location-awareness, immersive environments, and somatic, embodied agency; *(2)* enhanced cultural and social context by leveraging as input methods the rich semantics of cultural-social gestures and rituals.

The expectation is that a computation system tapping this combination will enable users to understand complexity better, by exerting agency and perception within the enhanced visual-spatial context, exploring the interconnected concepts and data. The enhanced socio-cultural context of input methods aims to support more powerful and diverse semantics for that agency, thus contributing to a deeper perception and from there, better *understanding*. And that non-expert users can better *communicate* their complex concepts and ideas, due to being empowered by the more powerful semantics of agency and the enhanced visual-spatial context, and thus create representations of those ideas that are dynamic experiences in their own right, which can be explored by third parties. To appraise the feasibility of this proposal, leveraging early results aforementioned [4], we plan to develop two cultural-aware immersive learning experience prototypes, one for the cultural context of the Confederated Salish and Kootenai Tribes (CSKT) in Montana, United States; and another for a cultural context in Western Europe (yet to identified). Besides serving as validation artefacts and constraints for the concrete rendering of this proposal, the complex concepts communicated by the dynamic experiences created by the users can be explored mutually and contrasted with the level of understanding achieved via more traditional means. The basic concept for the CSKT prototype stems from a story told by a Pend d'Oreille elder, Luli's Journey [18], about Canadian geese migrations. The goal is to empower users to *understand* the emerging nature of the geese V-shaped flight formations (*i.e.*, complex flight dynamics), and for them to *communicate* the insights people obtained in the past from observing the birds (*e.g.*, weather patterns)–see Fig 1.

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Potentially, extending it to wider topics such as climate change and its effects on the food chain, urban planning, ecology, entrepreneurship, psychology, among others. Following the rationale above, the CSKT prototype should use immersive technology and somatic interaction in the visual-spatial context of the Flathead Indian reservation (*cf.*, *factor 1*), and enable interaction through sociocultural-aware gestures and emblems. *E.g.*, switching to bird's eye view using a 'sky' gesture or changing the current season between winter and summer, reflecting that through landscape changes within the immersive environment (*cf.*, *factor 2*).

Fig. 1. Sample illustration on flight formation from Luli's Journey [18].

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Virtual Reality as a Medium for Remote Class Participation

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Abstract. We discuss the potential of Virtual Reality as a medium for distance learning, with a specific focus on remote access to a class. We also describe a proof of concept of a remote classroom participation system. Our proof of concept mirrors what happens in a classroom into a generative virtual reality, taking into account a potentially low bandwidth data connection. We discuss how ours, or similar VR systems, help to bridge the gap between the efficiency of online and face-to-face education, and how it makes remote classroom participation more accessible.

Keywords: virtual reality · immersive learning · remote classroom

Introduction

Since 1968, when Ivan Sutherland built the first virtual reality head-mounted display (HMD)[1], the new-in-kind immersive medium he created found applications in engineering, big data exploration, entertainment, gaming, medicine, architectural visualizations, and many other domains. A domain that greatly benefits from the proliferation of virtual reality is education. Many immersive educational experiences had already been explored and evaluated.

In this work, we discuss a potential of Virtual Reality as a medium for remote classroom participation. First, we discuss the current issues with remote learning and how these issues can be addressed using virtual reality. We argue that virtual reality medium can effectively bridge the gap between face-to-face and remote learning. Second, we present a novel generative immersive system that allows a remote student to actively participate in a face-to-face class. To the best of our knowledge, no previous work presented real-time virtual classroom environment generation, where face-to-face instruction performed in a physical environment is simultaneously mirrored in virtual reality, so that remote student takes part in it.

Issues with Remote Learning

Over the last thirty years, the rise of the Internet and educational multimedia resources democratized access to education for remote students. However, as

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indicated in various studies [2], remote learning is not always as effective as face-to-face learning.

According to Jonassen et al., the lack of a direct teacher-to-student and student-to-student interaction, “cannot be understated” [3]. Some students can efficiently learn only through interaction with an instructor [4]. It is because, for many students, interpersonal communication is an essential component of effective learning; without it, the learning process is negatively affected [5].

Another negative consequence of the lack of direct communication between the teacher and the student is a difficulty in identifying and supporting students who are at risk of not mastering learning objectives [6]. This issue negatively affects course retention and increases course failure rates.

Online instructors attempt to mitigate the lack of direct instructor-to-learner interaction by recognizing “a unique opportunity for social networking and the development of peer support networks to fill this instructional void” [7]. Another approach to address the solitude of remote learning is to encourage – and support with technology – peer review and peer feedback. However, prior research shows that peer review and peer feedback is not as effective as the review and feedback provided by the instructor [8].

In contrast to remote learning, face-to-face classroom instructor frequently improves both the delivery style and the content of the course based on in-class interactions with students. Real-time classroom response systems, such as NetClick [9], support this approach with the use of mobile devices or classroom technology. In online courses, the instructor may not have timely access to the student feedback. Use of analytical and statistical tools for collecting the student feedback is insufficient in an remote learning context, because it misses on the important *non-verbal* feedback immediately available to the face-to-face instructor. For example, facial expression and body posture of a student may inform the face-to-face instructor about the lack of engagement, but is invisible to the online instructor.

Another criticism of remote learning is that, while distance education promises equitable access to education, many parts of the world still do not have sustained infrastructure to support broadband Internet connection [10]. According to a U.N. report [11], it will take another 125 years to bring land-line broadband Internet to all households in the world. The *digital divide* [12] affects not only developing countries, but also many communities in the US [13]. While in the recent years the digital divide is shrinking due to the fast proliferation of mobile Internet access [11], the coverage and the speed of the mobile data connection [13] is often insufficient for the traditional multimedia-based online education [10].

Prior studies advocate designing online courses in a way that ensures content accessibility. Online education should not only provide participants with the opportunity to take part but also consider the role that unreliable infrastructure might play in undermining the availability of online resources [3]. It is argued that to improve the availability of online courses in underdeveloped areas, the course should be designed to use as little bandwidth as possible. Yet, it is difficult

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to do so in practice. For example, some excellent learning content comes only in a form of audiovisual recordings. Providing the same content in textual form is not an adequate solution, because some students learn more efficiently when using audiovisual learning materials rather than relying solely on text-based materials [14].

Use of Virtual Reality in Education

Virtual Reality has been used in education and training since it was invented. At first, virtual reality has been used for educational purposes in the context of military training, followed by surgery training [15]. Virtual campus tours and experiences were implemented for CAVE systems and head-mounted displays as a means for encouraging pursuing a college degree. Experiments in persuasive virtual reality (where persuasiveness can be considered an educational goal) were also performed, showing that VR is a strongly persuasive medium. VR games, virtual reality tourism, VR documentaries, VR arts exhibits, and galleries, or VR performances, while not having educational objective per se, do constitute a learning or self-development experiences.

Immersive environments were also developed for language learning, science, and engineering, distance learning, or for virtual campuses as meeting spaces for students and faculty [16]. Sometimes, classes were held in 3d virtual environments. These systems did not usually use head-mounted displays, due to their high cost of the hardware at the time. More recently, a number of virtual field trips were designed for K12 education in biology, natural sciences, music, or arts.

Immersive technologies increase accessibility of computer systems across one dimension while limiting its accessibility across another dimension. On one hand, the spatial input often used in virtual reality requires full body mobility (for navigation and exploration) or hands mobility (for selection and manipulation, for example, using the virtual hand metaphor). On the other hand, virtual reality allows learners to transcend the limitations of physicality, e.g. location, individual physical abilities, or safety concerns. Consequently, in VR-aided learning co-located and the remote learners utilize face-to-face and remote learning modes not as a consequence of their physical location, but in a result of their, and the instructor's, choice. The choice of learning mode can be therefore informed by what serves best to achieve learning outcomes, rather than what is possible. This paradigm shift: applying learning mode that is most efficient for a given learning outcome, is what makes VR-aided learning a *disruptive* technology for education.

VR-aided learning also has a potential to positively impact the society, by responding to the need for life-long learning, attenuating learning barriers, and reducing costs of attaining educational goals. VR-aided learning directly supports equitable access and diversity by enabling disadvantaged groups to take full advantage of learning opportunities that may be otherwise inaccessible to them.

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Bridging face-to-face and remote learning

We believe that while immersive technologies will play an increasing role in both online and face-to-face learning, they also have the potential to address many of the issues with remote learning. To support that claim, we design and implement a prototype of a system that brings the online instructor and the remote student back together. The system also addresses the issue of low-bandwidth Internet connection. We call our prototype system Uni*VR*esity.

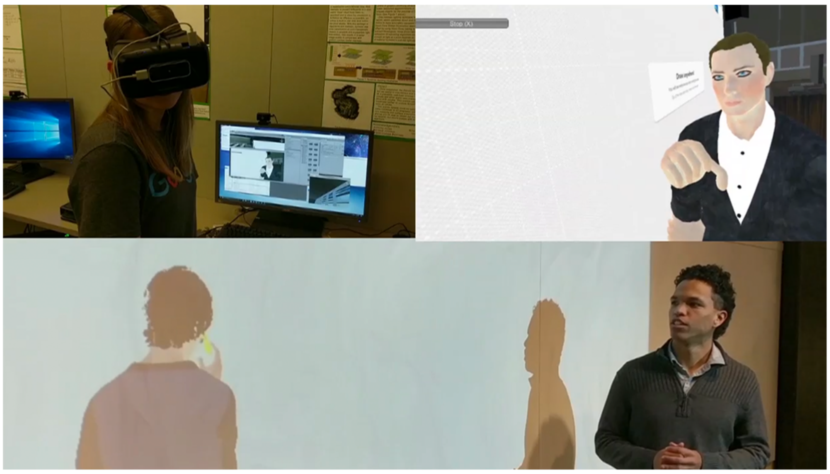

Fig. 1. A remote-student looking at the avatar of a teacher in VR, and the teacher looking at the avatar of the remote student projected onto the whiteboard.

Uni*VR*esity allows a remote student to connect to a virtual, procedurally generated classroom. The classroom is a real-time representation of what is happening in an ongoing, face-to-face classroom. When the face-to-face instructor speaks in a real classroom, his voice is transmitted over the network to the virtual classroom. At the same time, the avatar representation of the instructor is being animated, enriching the voice communication transmitted from the real classroom with animations of synthesised movement, facial expressions, and gestures. The animation synthesis is instructor's voice-driven.

To enable remote student access, the teacher opens an app on her laptop or mobile device. There is no need for any specialized equipment in the classroom. The role of the app is to broadcast the teacher's voice to all connected remote students.

The remote student joins the class by starting VR application and using a class-unique code provided by the teacher. Once connected, the student participates in the class.

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The communication between the remote student and the instructor is two-way. A remote student can ask questions, which will be heard by the class and the instructor. The instructor or classmates answers are heard, and visualized, in the virtual world the remote student is connected to.

In our prototype implementation, animations of the teacher's avatar are not pre-recorded but are generated in real-time from the voice of the teacher. The quality of the voice-driven animations is far from sufficient in the presented prototype. However, we actively research animation synthesis techniques that have a potential to improve the quality of the body and the facial animations in future implementations of the Uni*VR*esity system. In the future, we plan to use Uni*VR*esity system as a platform for development and testing of new models of relations between human voice and motion, drawing upon theories of human communication.

Interactive Whiteboard as a Shared Interaction Surface

The interaction between an instructor and a remote student can be facilitated beyond voice if the classroom is equipped with an interactive whiteboard or an interactive projector. In this case, the app enables using the interactive surface as a proxy connecting the virtual and the real world. Anything that the instructor writes on the interactive whiteboard is reflected, in real-time, on the virtual whiteboard the remote student sees in the virtual world. Moreover, the remote student can be called to the whiteboard, in which case he is represented in the physical classroom as an avatar visible on the interactive whiteboard (Figure 2). Movements of a remote student are animated based on the student's voice and spatial input. For example, when the student draws on the virtual whiteboard, her avatar draws on the interactive whiteboard in the physical classroom. The student's avatar can also face the instructor and the classroom, for example, to ask her peers a question.

We experimented with four low-cost spatial input devices for remote students: Leap Motion, Oculus Touch, a smartwatch, and a custom-designed bend sensor. Based on experience from previous projects, we know that Leap Motion with Orion SDK can provide freehand interaction and high-quality animation of the student's hands. However, positional precision errors that the device is prone to may make it difficult to precisely draw on the virtual whiteboard. Thus, we may decide to trade freehand interaction for precision and switch to Oculus Touch controller. Based on our previous experience with the device, the controller provides seamless, precise tracking at the cost of less accurate mapping of hand animations. To support mobile-based virtual reality interaction for a remote student, we also plan to use an off-the-shelf smartwatch as a spatial input device for smartphone-based HMDs. We will use smartphone-based 3D pointing and navigation techniques published previously [17, 18].

Supporting mobile-based access to our platform is important for the equitable access considerations; mobile-based VR is forecast to proliferate much faster than the desktop-based VR [19].

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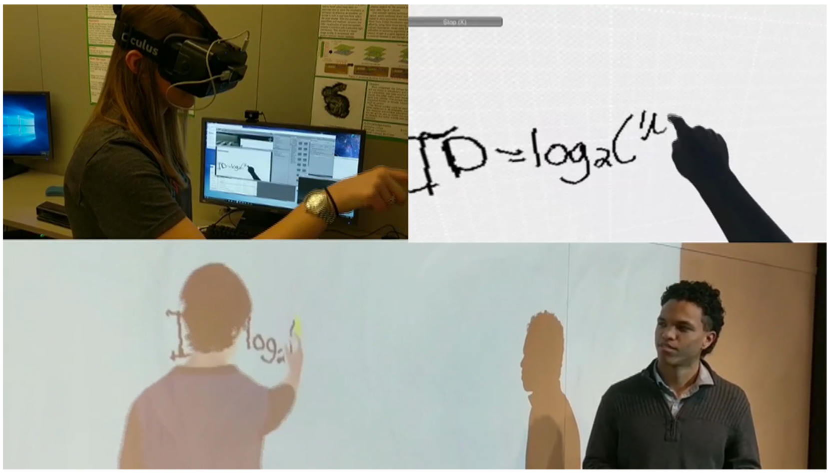

Fig. 2. A remote student writing on the virtual whiteboard, while her avatar is simultaneously writing on the interactive whiteboard in the class.

Addressing Low-Bandwidth Constraint

By generating, rather than transmitting, virtual reality environment that can run on the remote student VR device, we remove the requirement for a broadband Internet connection. The data transmitted between the classroom and the remote students consists of voice only. In the version of our prototype, where the interactive whiteboard is used, the transmission additionally includes the position of the teacher's and the remote student's cursor. No other information needs to be transmitted over the network.

User Feedback

To date, the system under development was evaluated in informal tests within our research group. The user responses to the system were overly positive. Users pointed out that the interaction with an avatar of a teacher is more interesting than a voice or videoconference connection. Also, younger users expressed a request to be able to modify their avatar, if presented to the class. One common criticism of the system was the quality of gesture and face animation - an area of improvement that we are aware of and actively work on. To make any claims about systems efficacy as a remote learning tool, a formal evaluation of the system is required and is planned in a near future. Currently, we are developing an online platform that will serve as a sandbox for pedagogical studies in efficiency and accessibility of virtual-reality-based class participation. Using the platform, we plan to perform two types of long-term evaluations in the future.

In the first type of study, we are interested in understanding how virtual-reality-based class participation compares to traditional remote learning and

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face-to-face participation in class. Our goal is to identify a set of requirements and design principles that VR-based class participation must conform to, to match the learning outcomes of face-to-face pedagogy.

We will perform the study by dividing online students into two groups: one using traditional online resources and the other participating in face-to-face instruction using our remote access system. This setup will allow us to compare learning outcomes of three groups of students: online students who use traditional distance learning means, online students who participate in face-to-face class using our system, and traditional face-to-face students.

We will repeat the pedagogical efficiency study over the period of a semester – a timeframe corresponding to an iterative improvement in the development of the platform – as well as platform integration of the animation synthesis models and algorithms.

The third type of study we are planning to perform is a quantitative plausibility experiment. We understand Plausibility as a component of presence. We adopt the deconstruction of presence postulated in [20] into the concepts of Place Illusion as *being there*, and Plausibility, which is the illusion that events in the virtual environment are really happening.

Summary

In this position paper, we argue that Virtual Reality is a medium that has a potential to be used as a medium of choice for remote classroom access. We also presented a proof of concept of a system which does not require specialized equipment in class, yet delivers virtual reality representation of that class to a remote student. We believe that in near future students will be able to choose on a daily basis whether they want to participate in face-to-face learning in person or as an avatar, and that choice will not negatively influence their learning outcomes. We also believe that immersive systems have a potential to have a transformative impact on remote learning. Virtual Reality can be used to bridge the gap between the virtual and the real – or between the online and the face-to-face learning.

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Development and Evaluation of a Virtual Reality Game

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Abstract. With the ever-expanding digital gaming market and the ever more sophisticated and affordable Virtual Reality (VR) apparatus, it has been possible to apply these technologies in different areas beyond research. In education, the development of VR has grown significantly evidencing contributions to the teaching and learning processes. In Brazil, only a few research groups have developed projects that involve the development of VR for education due to technical difficulties and high costs. This article presents the development and evaluation of an VR game to support the learning of neuroanatomy. The results of the evaluation suggest that the game created is easy to use, even by inexperienced subjects in VR, and is potentially useful for teaching and learning processes. In addition, the game was considered fun and did not cause discomfort, which is common in many RV applications. Considering the results of the questionnaire on the feeling of presence, a high average was obtained (5.8), and for three of the six questions, averages above 6.1 were obtained on a scale of 1 to 7, with 7 representing the real sensation of being present in a certain place. In addition, through the open questions, suggestions for improvement have been provided for the next versions of the game.

Keywords: Virtual Reality; Educational Games; Neuroanatomy.

1 Introduction

The digital gaming market is a key player in the global media and entertainment industry and, according to Netscribes Gaming Market Research, is expected to grow significantly by $ 323.91 billion by 2023. At the same time, Virtual Reality (VR) software and hardware are increasingly sophisticated and inexpensive, allowing them to be applied in different areas, beyond research, such as training, therapy, marketing, and entertainment [2]. According to the International Data Corporation (IDC) report, global RV spending is expected to reach $ 17.8 billion by 2018, an increase of almost 95% over 2017.

According to Burdea and Coiffet [4], VR is a computational application in which users can interact with three-dimensional virtual digital environments, which reproduce

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existing or imagined situations involving the senses such as sight, hearing and touch. For Slater, VR is able to create the user's sense of being transposed into a three-dimensional virtual digital world and provide a visceral and immersive experience, although this does not always occur.

The applications of VR in education are many and there is a consensus of its benefits in the teaching and learning processes. Among the possible benefits are the possibility of expanding the perceptions of the five senses, representing more than the real state of affairs, greater engagement with the student, appropriation according to each person's rhythm, exploration instead of deduction, active learning, interacting and facilitating a global analysis and their interrelationships. The available technology and cost limitations will define the type of application to be developed in each case [5].

In addition, VR used in education in a playful way, can enhance learning through the exploitation of information, for example, proposals as clues in an immersive game, favoring the development of desired skills. [6].

In the health area, VR has been used in the simulation of surgeries, mainly for operative training of video-laparoscopic surgery, in the preoperative planning and in the intraoperative support. The images of virtual digital models have the advantage of being able to evaluate the organs three-dimensional, to observe the internal structure of the organ, to evaluate the relations between the organs with their topographies and to produce selective visions of the body. In addition, there is no time limitation for use [7].

Currently in Brazil, only a few research groups have developed projects with VR application for teaching and learning in the medical field due to technical difficulties and high cost. However, some proposals are emerging to minimize the difficulties of developing and maintaining the required systems and programs. In addition, skilled human resources, involving interaction between different areas, are being prepared for optimization and democratization in the use of this technology in teaching and learning processes [8].

Thus, this article aims to develop and evaluate VR applications to support the teaching and learning processes of neuroanatomy in order to minimize the need for management of real anatomical parts. In addition, to provide an innovative and engaging experience for the learning of neuroanatomy that allows the development of pedagogical activities with low cost, both in the classroom context, with the use of virtual reality glasses, as at home, with the use of and your smartphone.

2 The game

For simple gameplay, with few commands and rules, the first version of the game was based on puzzle games. The puzzles to be solved can test various player skills, such as logic, strategy, pattern recognition, sequencing and part-whole relationships. Games in this category involve a variety of logic and concept challenges, occasionally adding time pressure and other elements of action [8].

The game takes place in a futuristic virtual digital room, in which the brains (frontal lobe, parietal lobe, occipital lobe, temporal lobe, cerebellum, corpus callosum and brainstem and diencephalon) are randomly arranged on a table (Figure 1a). The main

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purpose of the game is to assemble the brain by joining the arranged parts, whose colors are also randomly defined with each game. The randomness of position and color of the pieces aims to maintain the challenge between matches, minimizing the possibility of solution by mere memorization of colors and positioning. Players visualize a brain as a reference and use virtual 3D virtual hands to pick up the parts by rotating and translating each part to make the fit between the parts until the whole is complete (Figure 1c). The parts being held by the player through the virtual 3D virtual hand change color as a way to provide visual feedback to the user (Figure 1b).

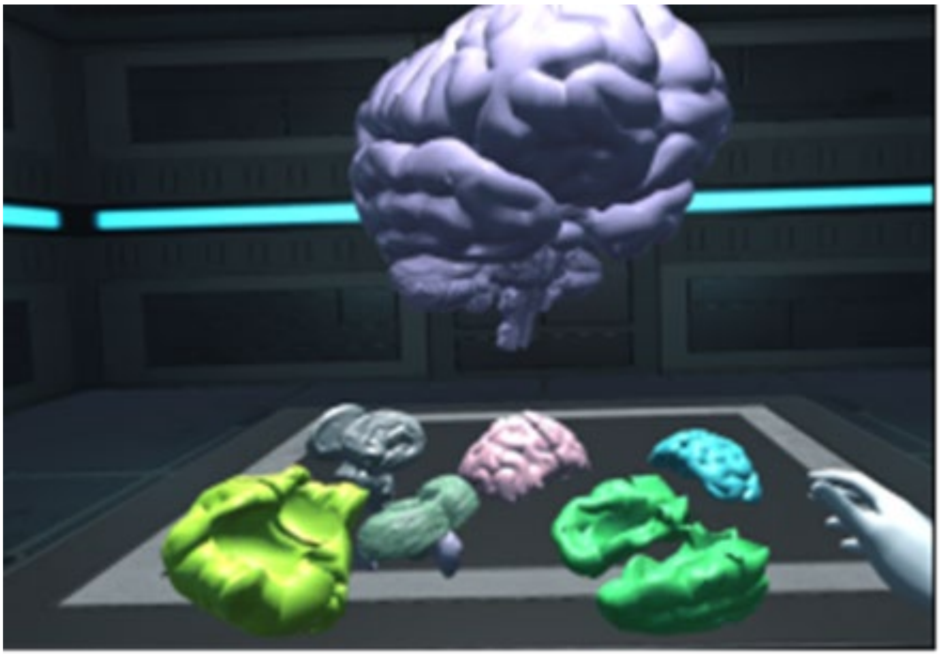

Fig. 1a. Parts to be assembled

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Figure 1b. Partial assembly

Figure 1c. Full brain

3 Evaluation

In order to carry out a first evaluation with users, the game was used by a group of 10 students from courses in health and education at a university in the south of Brazil. The

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objective of the evaluation was to identify limitations and potentialities of the game, as well as to obtain suggestions that could contribute to future versions.

3.1 Participants

A total of 10 people participated in the evaluation of the game, being 6 men and 5 women. The age range was 17 to 20 years (M = 21.8 SD = 4.8). Among the participants, there were eight students of the discipline of Neuroanatomy, two of them from the undergraduate course in Physical Education, one from Physical Therapy and five from the Psychology course. In addition to these, a student of the Social Sciences course and a master's degree in Education participated in the evaluation. As for vision problems, six subjects had no vision problems, one had only astigmatism, one nearsightedness, one astigmatism and myopia, and one with astigmatism and farsightedness.

As for the video game experience, the participants evaluated themselves on a 5-point Likert scale, 2 of whom considered themselves to be very inexperienced, 5 inexperienced, one with medium experience, one experienced and one very experienced. Regarding the VR experience, the majority of participants considered themselves to be very inexperienced, with only one participant self-rated experienced in VR. As to previous knowledge about neuroanatomy, 2 considered themselves very inexperienced, 6 inexperienced, one with medium experience and one experienced.

3.2 Materials

The game was developed at Unity3D and for evaluation a Dell XPS 8900 computer with 3.6 GHz Intel (R) Core i7-7700 processor, 16 Gb RAM and NVIDIA Gforce GTX 1060 6GB graphics card was used. For the visualization we used the Oculus Rift CV1 and for the interaction the Oculus Touch controls.

3.3 Procedure

The procedure used followed a typical protocol of evaluation with users. It began with a general explanation, followed by the signing of the informed consent form and the term of use of the image. Subsequently, a questionnaire was applied to characterize the participants and, shortly thereafter, the virtual reality glasses and the controls were adjusted in the participant to begin the test (Figure 2a). After completing the game, each subject answered a questionnaire, with open and closed questions, to evaluate the experience. Through a 5-point Likert scale, participants expressed their opinion about ease of use, fun, utility, and possible discomfort caused by VR. Already on a scale of 7 points, each participant answered 6 questions from the SUS questionnaire about the feeling of presence in the game [9]. In addition, participants recorded their understandings about the potentials and limitations of the game in open-ended questions. All matches were recorded for further analysis of player behavior by a camera attached to a tripod to the left side of the player (Figure 2a).

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Figure 2a. Student playing with the Oculus Rift and Oculus Touch controls.

Figure 2b. Graduate student using the game and the teacher and classmates watching and commenting on the game on the big screen and TV.

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4 Results and Discussion

Participants answered questions about the ease of play, the degree of fun (I had fun playing), possible discomfort caused by VR (I felt discomfort playing), on a 5-point Likert scale, varying between fully disagree and fully agree. Also, on a 5-point scale, the participants expressed their opinion on the usefulness of the game in relation to the possibilities of use for learning neuroanatomy, ranging from little useful to very useful.

As can be seen in figure 3, the game was considered easy to use (M = 4.0), even though the majority of the participants had no previous VR experience, and potentially useful (M = 4.3) for the teaching and learning process of neuroanatomy. In addition, the game was considered fun (M = 4.7) and did not cause discomfort (M = 1.9), commonly known as cybersickness in VR. Ease of use is potentially associated with the intuitive and natural way of picking up and dropping parts, provided by the use of the Oculus Touch controls, which control virtual hands. While the fun is possibly associated with the immersive experience provided by Oculus Rift and the fact of learning to play.

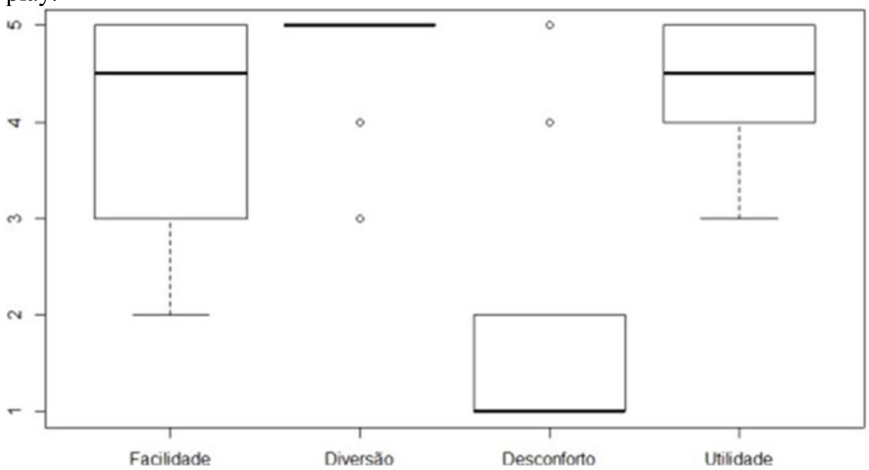

Figure 3. Bar chart referring to ease of use, fun, discomfort and usefulness of the game. The bold lines are the medians and the boxes are interquartis bands.

Considering the results of the presence questionnaire (Table 1), a high average was obtained (5.8), and for averages out of the six questions, averages above 6.1 were obtained. The SUS scale ranges from 1 to 7, with 7 being the real sensation of being in a certain location.

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Table 1: Average SUS questions on presence

SUS Question	M
1. Indicate how much you felt about the environment virtual.	6.5
2. State how much the experience seemed to be real.	5.8
3. Do you remember the virtual environment more like photos you saw or more like a place you visited?	6.1
4. During the test, your strongest feeling was being in the room where it is now or in the virtual environment?	6.1
5. Consider your memory of being in the virtual environment. What is the similarity of this memory to the memory from other real places you've been to today?	4.6
6. During the experiment, at some point you thought was really in the virtual environment?	5.0
Average SUS	**5.68**

About the potentialities of the game, it is possible to emphasize that the participants valued the experience of manipulating the parts of the brain, considered very close to reality. The verisimilitude of the virtual pieces in 3D gave confidence to the players allowing to relate the knowledge acquired previously, with the new information worked in the context of the game itself. Participants stated that the game can aid in learning neuroanatomy in a different, engaging and easier-to-understand way. When questioned about how they felt during the game, participants reported that they felt as if they were actually in another environment, a calm environment that facilitates concentration, and one participant reported that it felt like a real practical class. Among the reports, these were the most striking: subject A - "I felt as if I were actually somewhere else, as if the pieces were actually falling or making some sound"; subject C - "As if in fact it was in another environment"; subject E - "Comfortable and easy to play. It's fun to piece together and interact with the elements of the game "; guy G - "It was a fun experience, I felt a bit confused because the hands were not mine." On what each participant learned from the game, answers were obtained such as "I learned the parts of the brain", "certain positions of some structures that did not exactly remind me of their place", "Where the parts of the brain are located", besides of some records about learning the VR itself, which is the first experience for most of the participants. As in the experiments developed by Schlemmer [6], the game was understood by the players as a technology that potentiates the learning in neuroanatomy due to the possibilities of handling the anatomical parts in VR, as well as the opportunity to restart whenever necessary, recognizing and exploring the relationships of the anatomical structures and the knowledge involved. In this way, the player is allowed to learn through experimentation, interacting with the object of study, in the construction knowledge. Still, immersion in the game provided the engagement of the players who felt instigated to solve the puzzle. In this way, the immersive environment served as a triggering factor for the exploration and search for the solution of the proposed problem. The possibility of manipulating structures and their relationships enabled the emergence of knowledge in many players, generating skills that had not yet been generated before immersion in VR. From this, there is interaction and complementarity of the previous knowledge of neuroanatomy and the

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proposal of the game in VR, not being an end in itself, but with potentiality to complement the competences of the player.

As for the limitations, some difficulties related to the fitting of the pieces, the lack of sound in the virtual 3D virtual environment were recorded, not being able to undo the pieces already in place and on the precision to get the parts of the brain with virtual hands. In addition, it was recorded that the internal view of the parts is not adequately comprehensible.

In the last open question, in which the participant was invited to register comments, criticisms or suggestions, the following comments stand out: "I felt very comfortable during the game, learning this way stimulated me to want to know more about it", "It was "I think it's going to be very good for students who have no idea what these pieces are, it's easier to understand," "I suggest more information about what has and what is happening in the game (such as sound, writing, animation and / or effect ", and" it would be interesting to be able to move the reference brain for better orientation " .

5 Final Considerations

This study aimed to develop and evaluate an application of VR to subsidize the teaching and learning processes of neuroanatomy in higher education Some of these comments corroborate results obtained in closed questions, as well as suggest important improvements for the systematic use of the game in the teaching and learning processes of neuroanatomy. All suggestions are being analyzed and considered for future versions of the game, which is intended to be used as learning technology for neuroanatomy in the coming semesters, providing an innovative and engaging experience for students. A total of 10 students evaluated the game and the results suggest that the game is easy to use, fun and potentially useful and engaging for the teaching and learning processes of neuroanatomy. Participants felt strongly present in the virtual 3D virtual environment, developed for the game, according to SUS questionnaire, and valued the experience of manipulating the parts of the brain, considered very close to reality. Regarding the limitations, there was difficulty in the fitting action, lack of sound, the name of the pieces and low internal visualization of the pieces. In the next version of the game, it is intended to create clues that contribute so that the players can assign greater meaning to the functions and relations of each mounted segment. In the future, players will be able to make use of a virtual digital library to seek subsidies and broaden the process of meaning.

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Mobile Augmented Reality in Science Teaching: an analysis of the pedagogical usability with pre-service teachers

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Abstract. This article presents the results of a pedagogical usability evaluation with pre-service teachers about an application for Science teaching developed with educational resources in augmented reality. The evaluation of the application was carried out through a quality evaluation model of educational software for Science teaching, considering the Pedagogical, Science Teaching, and Usability aspects.

Keywords: Science Teaching · Pedagogical Usability · Pre-Service Teachers · Mobile Augmented Reality · Mobile Learning.

1 Introduction

Augmented reality (AR) was recently addressed in the report presented by the New Media Consortium [2]. In this context, it is possible to note that research on AR in education is evolving quickly [1].

A variant of AR technology is the Mobile Augmented Reality (MAR) technology [3]. Mobile devices are indicated to have a positive impact on both teachers and students in that it positively affects the duration of their attention, learning and training tenacity, and their attitudes towards collaboration and interaction [8]. MAR initiatives have been making inroads in the training and learning domain, as learning approaches can be virtually accessed using the ubiquitous mobile devices, in which learners can access learning materials and contents anywhere, anytime on their mobile devices [6].

It is important to emphasize that the construction of educational applications with technological resources related to MAR also needs to be articulated from a pedagogical point of view. Christensen et al. [5] point out that in parallel to the use of the computational resources offered by this type of environment, the present focus on the educational side, which must be articulated by the teacher, becomes essential and must be carefully established and organized.

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Among the various points to be considered when projecting and constructing a MAR approach is how the design of the environment will be interconnected to its educational objectives. It should be clear the form and context in which each learning situation will be applied. According to Lakkala et al. [7], this could be called pedagogical usability, i.e., correspondence between the systems design and the educational environment, situation, and context in which it will be used.

The pedagogical usability of a system and/or learning material is also dependent on the goals set for a learning situation by the student and teacher [9]. Regarding the pedagogical usability criteria for digital learning materials, the most common pedagogical usability features are learner control, possibility for cooperative or collaborative learning activities, explicit learning goals, authenticity of learning material and learner support (scaffolding) [10].

Chiu et al. [4] explain that physical laboratory experiments in science enable students to interact with observable scientific phenomena, but students often fail to make connections with underlying molecular-level behaviors. Virtual laboratory experiments and computer-based visualizations enable students to interact with unobservable scientific concepts, but students may find it difficult to connect with actual instances of the phenomenon observed.

The purpose of this article is to investigate how the pedagogical usability of MAR educational resources is seen by teachers in training in science teaching. In order to do so, experiments were carried out using MAR educational resources for the teaching of sciences and applied modules of a pedagogical usability evaluation questionnaire to infer the results from this experiment, aiming at answering the following research questions (RQ):

- RQ1: What are the pedagogical aspects related to the use of MAR educational resources in Science Teaching?
- RQ2: How do pre-service teachers perceive the use of MAR educational resources in Science Teaching?
- RQ3: What is the opinion of pre-service teachers about the usability aspects of MAR educational resources in Science Teaching?

2 Methodological Procedures

2.1 Research Design

Participants attended two on-site meetings in an IT lab of the educational institution in the second semester of 2018. The meetings lasted one hour and forty-five minutes each. In the first meeting, the participants were introduced to the avatAR UFRGS app. The test coordinators helped the participants install the MAR app in their smartphones.

The second meeting was characterized by the use of the avatAR UFRGS app. The participants were instructed on how to use and interact with the science simulations, settings and variables configurations to play and interact with the AR simulations. At the end of the second meeting, after participants had interacted with the app, a user experience analysis questionnaire regarding this type of approach was applied.

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2.2 MAR app for Science Teaching

The avatAR UFRGS app is an educational technology that provides students with interactive simulations developed in MAR. In the app, students have access to various educational resources, where they can visualize micro and macroscopic physical phenomena and interact with multimedia resources such as images, videos, 3D objects and simulations.

In relation to the pedagogical potential of the MAR app, some of the available resources for students to interact with are visual simulations, access to multimedia resources, interaction and storage of experiments in the students inventory, as well as access to the experiments without the need to connect to the Internet.

The avatAR UFRGS app was used to provide participants with the visualization and interaction of educational simulations, which enables students to change parameters and verify the changes that result from their actions. The content that participants had access to during the meetings was about basic Science, where they were given the orientation to visualize the experiments, interacting with the simulations, and checking the associated multimedia resources.

2.3 Participants

The participants of this research are pre-service teachers studying for the Degree in Natural Sciences offered by the Federal Institute of Rio Grande do Sul, in the discipline of Information and Communication Technologies in the Teaching of Natural Sciences (40 class hours). Although the course is located in the field of Natural Sciences, this course aims to present to the student teachers how technology can be used in teaching in the context they are inserted and, therefore, being considered an appropriate discipline for this experiment to be carried out.

Nineteen student teachers participated in this study and the demographic profile of the participants is: 14 female (9 in the age group of up to 29 years old and 5 in the age group between 30 and 50 years old) and 5 male (all up to 29 years of age). All participants reported having a smartphone and/or a tablet to install the avatAR UFRGS app, as well as Internet access. As previously mentioned, this course presents to students new possibilities of using technologies in their teaching practice, however, the participants had not yet had contact with technological resources of MAR or with the app used during the experiment, having some knowledge about this area.

2.4 Tools and Collected Data Analysis

By the end of the second meeting, a test was applied to the nineteen participants, comprising thirty multiple-choice questions related to their first impressions while using the AR app, considering that none of them had ever used this kind of technology before. The answer options were placed according to the model proposed in the Likert scale, defined as follows: Fully disagree; Partially disagree; Indifferent; Partially agree; and Fully agree. It is important to highlight that the creation of the forms was made using the Google Forms app.

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The questionnaire comprised thirty multiple-choice questions (each question provided an optional open-ended question for participants to write a justification for their answers) to gather information about their opinion on the use of the AR app, difficulties and advantages identified during the experiment. The data collection instrument used was PECTUS (Pedagogy, Science Teaching, Technology, and Usability), which consists of a model of quality evaluation of educational software for science teaching composed of four dimensions of evaluation: Pedagogy, Teaching of Sciences, Technology, and Usability [11]. For the evaluation of the pedagogical usability of the avatAR UFRGS app, only the Pedagogy, Science Teaching, and Usability dimensions were used. Finally, a qualitative analysis of the results was performed based on the descriptive statistics of the results obtained through the PECTUS collection instrument.

3 Results Analysis

RQ1: What are the pedagogical aspects related to the use of MAR educational resources in Science Teaching? In order to answer the research question on aspects of pedagogy related to the use of the AR app by the teaching professors, ten pedagogical attributes of educational software quality were evaluated in science teaching: Affectivity, Flexibility, Cognitive Load, Conceptual Reliability, Collaboration Support, Objectivity, Teacher Support, Student Control, Motivation, and Accommodation of Individual Differences. Each of these attributes is defined in Table 1, presenting the average (Avg) of the answers obtained with the participants and their standard deviation (SD).

Analyzing the results of the evaluation module related to Pedagogy aspects, we can observe that the global average was 4.27. This value characterizes the MAR app positively for this requirement, since the teachers recognize the affectivity (average 4.1) and flexibility (average 4.5) of the app. However, student teachers understand that the MAR app offers a relatively high cognitive load for a learning resource (average 3.6), although it presents good evaluations in conceptual reliability (average 4.2), collaboration support (average 4.3) and objectivity of the app (mean 4.4). The MAR app also presented good performance in the questions involving control by the user (average 4.2), causing motivation necessary for learning (average 4.4) and accommodating the individual differences (mean 4.1). Regarding teacher support, the results show the efficiency of the MAR app in teacher support in educational activities (mean 4.9). In general, the standard deviation for this case was considered normal, not having too many dispersions in any attribute, except for the item related to the cognitive load, which obtained a standard deviation of 1.1.

RQ2: How do pre-service teachers perceive the use of MAR educational resources in Science Teaching? To answer the research question on the dimension involving the aspects of science Teaching, ten attributes of software quality were evaluated by the teaching professors, which were: Support to Concepts construction, Support for the Application of Concepts, Support for

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Table 1. Evaluation of the Pedagogical aspects.

ID	Questions	Avg	SD
Q1	Affectivity - It refers to the exposition of physical and psychological aspects and behaviors, capable of indicating the user's involvement when using the software, such as: emotion, states of humor, motivation, anxiety, feelings of anger, disinterest, joy, etc.	4.1	0.9
Q2	Flexibility - It refers to the ability of accessing the software, the access for people with disabilities and to educational teaching such as: self-learning, objectivism, constructivism, etc.	4.5	0.5
Q3	Cognitive Load - It refers to the mental effort required during the execution of the tasks in the software, such as exploitation of the contents, use of the structure, demanded responses, etc.	3.6	1.1
Q4	Conceptual Reliability - It refers to the software's ability to arouse reactions and behaviors that express confidence in the contents and results that it provides.	4.2	0.8
Q5	Collaboration Support - It refers to the support provided by the software for conducting activities in a collaborative way, supporting the sharing of knowledge and the development of social skills.	4.3	0.7
Q6	Objectivity - It refers to the way the software works and the procedures incorporated in it, i.e., how well defined and standardized they are.	4.4	0.7
Q7	Teacher Support - It refers to the level of support the software provides to the teacher, which will enable him to act as an information provider and/or facilitator of learning.	4.9	0.3
Q8	Control by the Student - It refers to the possibility offered by the software to the users, to define how to explore the modules and contents, that is, deciding which sections to study, which paths to follow, which material to use and the order involved in those decisions.	4.2	0.8
Q9	Motivation - It refers to the ability of the software itself to motivate users to explore themes and concepts through elements such as multimedia resources, good quality interaction, etc.	4.4	0.6
Q10	Accommodation of Individual Differences - Refers to the ability of the software to consider and facilitate the accommodation of individual student differences, i.e., reinforces heterogeneity in terms of previous attitudes, knowledge and experience, learning styles, etc.	4.1	0.7

Evolutionary Learning, Empirical Support, Association between Theory and the Real World, Support for Representation of Theory and Concepts, Precision of Calculations and Results, Scientific Rigor, Clarity of Procedures, and Support for Problem Solving. Each of these attributes is defined in Table 2, presenting the average of the answers obtained with the participants and their SD.

Regarding the results about science teaching, we can observe that the overall mean of the dimension assessment was 4.33. The attributes recognized by student teachers in the MAR app indicate that the technology supports the construction (mean 4.6) and application of science concepts (mean 4.4), contributes to student evolutionary learning (mean 4.3) and is presented as an empirical support resource (mean 4.1). According to the results, we can also infer that the MAR app provides an association between theory and the real world (mean 4.6), support for representation of theory and concepts (mean 4.4), precision of calculations and results (mean 4.3), scientific rigor of the information presented (mean 4.0), as well as clarity of procedures (mean 4.3) and support for problem solving (mean 4.3). In general, it is important to note that the standard deviation for this case was considered a little high in relation to the previous dimension, in which several requirements, such as Support for the Application of Concepts

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Table 2. Evaluation of the Science Teaching aspects.

ID	Questions	Avg	SD
Q11	Support to the Construction of Concepts - Refers to the construction of abstract concepts into more concrete concepts. It emphasizes the formation of concepts and promotes conceptual change.	4.6	0.5
Q12	Support for the Application of Concepts - Refers to the simplified application of reality, making abstract concepts into their most important elements.	4.4	1.0
Q13	Support for Evolutionary Learning - Refers to the growing learning that assists in understanding concepts from simpler stages to more complex phenomena.	4.3	0.7
Q14	Empirical Support - Refers to activities that make explicit the nature of scientific research and its theories.	4.1	1.0
Q15	Association between Theory and the Real World - Refers to understanding about the real natural world, interacting with underlying scientific models that could not be inferred through direct observation.	4.6	0.7
Q16	Support for Representation of Theory and Concepts - Refers to visual information such as formulas, results, 3D models and feedback to improve understanding of concepts.	4.4	0.7
Q17	Accuracy of Calculations and Results - Refers to the collection, generation and testing of large amounts of data to prove a hypothesis.	4.3	1.0
Q18	Scientific Rigor - Refers to the identification and relation between cause and effect between "complex systems", proven with criteria of scientific nature.	4.0	1.0
Q19	Clarity of Procedures - Refers to the reduction of cognitive "noise" so that students can use simple commands to focus on the concepts involved.	4.3	0.9
Q20	Problem Solving Support - Refers to support for problem-solving skills and to promote critical and analytical reasoning.	4.3	0.8

and Empirical Support, obtained a standard deviation of 1.0, indicating a high in dispersion around the assessments of student teachers.

RQ3: What is the opinion of pre-service teachers about the usability aspects of MAR educational resources in Science Teaching? In relation to the evaluation of the dimension involving Usability aspects, ten attributes of quality of educational software were evaluated by the student teachers, being: Software Adequacy, Learning Ease, Operationality, Memorization Support, Error Protection, Clarity of Information, Accessibility, Design Quality, User Satisfaction, and General Functionality. Table 3 presents the average of the answers obtained with the participants and their SD.

The results related to the evaluation of attributes of the dimension of Usability Aspects reached the global average of 4.24. The obtained results characterize the positively MAR app for this requirement, since the student teachers considered the app to be adequate (mean 4.5), it offers learning ease (average 4.6) and memorization support (average 4.1). However, the subjects understand that the MAR app offers a low operability (average of 3.9) and protection of user errors (average 3.6), although they consider that the app presents clarity in the information (average 4.2) and accessibility (mean 4.0). In general, evaluators believe that the app offers design quality (average 4.5), satisfies user interaction (average 4.6), and is useful in terms of overall functionality (average 4.5). In this dimension case, the values obtained in the standard deviation are similar to the

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Table 3. Evaluation of the Usability aspects.

ID	Questions	Avg	SD
Q21	Software Adequacy - Refers to the software's ability to enable the user to understand whether the software is appropriate for their tasks or not.	4.5	0.8
Q22	Ease of Learning - Refers to the facility offered by the software so that the user learns to explore and use the different modules and activities included.	4.6	0.8
Q23	Operability - Refers to the ability of the software to make its handling easy for users.	3.9	0.9
Q24	Memorization Support - It refers to the characteristics (standardization of screens, navigation, design, etc.) that facilitate the user memorization of the paths and interaction procedures for proper use of the software.	4.1	1.0
Q25	User Error Protection - Refers to the features that the software has in order to protect the user from making possible errors.	3.6	1.0
Q26	Clarity of Information - Relates to whether or not the information contained in the knowledge space incorporated in the software is presented in an understandable way.	4.2	0.9
Q27	Accessibility - Refers to the ability of the software to be used by people with different profiles and characteristics, in a specific context linked to the objectives of the system.	4.0	1.2
Q28	Design Quality - Understands aspects such as appearance and layout of the elements in the software screens, including text, icons, graphics, colors, etc.	4.5	0.7
Q29	User Satisfaction - Represents a subjective condition, according to which the user considers the interaction with the application pleasant and attractive, feeling satisfied with the software.	4.6	0.5
Q30	General Functionality - Represents a comprehensive dimension, related to the usefulness of the software and meeting the goals intended by the users.	4.5	0.6

first dimension, and there are no high differences to be highlighted, except for the Operationality and Protection to User Errors attribute, which indicates a divergence between the student teachers' evaluations.

4 Conclusion

For MAR educational resources to potentially become educationally beneficial, several aspects need to be taken into account at the time of their design and development, such as aspects related to pedagogical usability. In this way, this article sought to highlight how the pedagogical usability of MAR educational resources is seen by teachers in training in Science Teaching.

Based on the experiment carried out with teachers in the area of sciences, it was possible to evaluate the pedagogical usability of the MAR educational resources of the avatAR UFRGS app. In order to organize the discussion about the objective of this article, three research questions were defined, which enabled us to obtain the degree of the pedagogical usability perceived by student teachers regarding MAR educational resources in the dimensions of Pedagogical Aspects (global mean 4.27), Teaching Aspects of Sciences (global mean 4.33), and Aspects of Usability (4.24). Through what was presented in the discussion of the results, it is possible to affirm that the MAR educational resources evaluated by the teachers in training attended the most common pedagogical usability characteristics in digital learning material, defined by Nokelainen [10] as learner control,

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possibility for cooperative or collaborative learning activities, explicit learning goals, authenticity of learning material and learner support (scaffolding).

In this way, the results in a general scope could be considered positive, given that the participants identified through answering the questionnaire that the app has an adequate pedagogical usability, well structured and with potential benefits to the teaching practice. Aspects of improvement and usability difficulties have been identified in fewer quantities, but essential to be considered in the future improvements to be implemented in the app. Therefore, as future aspects of this research are the improvement of the items listed in the app, as well as the execution of research related to the impact that this type of approach has in the area of sciences for teaching and learning.

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Designing a serious game as a tool for landscape and urban planning immersive learning

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Abstract. Urban and landscape planning are critical to ensure there is a right balance between three crucial dimensions: human development, societal welfare, and nature protection and conservation. These instruments play an important role during the Environmental Sciences studies and, when facing them, it is crucial for students to learn the importance of compromising between the above mentioned three dimensions to guarantee general progress. This paper presents the design process of a serious game (a tabletop game) that should provide an immersive learning experience to Environmental Sciences students, and raise their awareness about the complexity of the topic and the need to balance between human development, societal welfare, and nature protection and conservation. We will introduce in detail the inception process, the identification of the learning objectives and how these have driven the design of the game. We also present the initial evaluation performed during a piloting phase. Finally, we will draw initial conclusions and define further lines of research.

Keywords: Urban planning, Landscape planning, Games, Serious games.

1 Introduction

One of the greatest challenges the humanity is facing is how to ensure development and welfare [1] while, at the same time, preserving the natural values of the planet [2]. As any recurring *cliché*, this challenge may seem trivial and overtaken but it represents an important conundrum. All human activities affect nature, most of the times with negative effects on biodiversity and natural resources. In fact, environmental awareness has traditionally arisen when environmental problems appeared linked to certain levels of development. It is also recognized that nature conservation is not going to be a priority until certain levels of development and welfare is ensured to all people in a society. In fact, nowadays the concept of environment incorporates both human development and welfare together with the preservation of natural assets (e.g. biodiversity) [1, 2, 3].

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All sort of societal instruments has been developed (in Western societies) to assist policies and decision making while mediating in the conflicts between nature conservation and human development: from administrative processes to planning and managing strategies. Landscape and urban planning are instruments in the category of prevention. They try to mediate in the underlying conflict before any human activity is deployed by planning human development, i.e., which and where activities are to be developed. The main objective is to use a territory in the most effective manner in order to optimize economical profits, human welfare and nature conservation.

Landscape planning is a complex process, in which multiple societal agents with confronting interests participate, coordinated by technicians and decision makers from public administrations. Public administrators should ideally coordinate the whole process by maintaining a neutral position, ensuring that the general interests are put forward. Landscape planning is a fundamental subject in Environmental Science studies [3], aiming to provide students with the necessary skills and tools to intervene in real-life situations. Our experience tells that most students have a strong bias towards nature conservation and sound conservation issues but have troubles to a) identify conflicts between development and nature conservation at more local scales, and b) to understand the importance of human development and welfare for itself but also for nature conservation. Hence, when case studies or examples are given to students, they mostly resolve them from that perspective, e.g., forbidding impacting activities (e.g. mining or gas extraction), or proposing unfeasible measures because of their economic impact. Providing students with an immersive experience should allow them to recognize the impact of the previous biases on landscape planning, which will result in students better equipped to face the challenges they will encounter as professionals.

Based on the foregoing motivation, we decided to develop a tool for immersive learning. The overall goal of the tool was to better introduce landscape and urban planning and related issues to students of Environmental Science, but also to raise awareness of its complexity to other people, e.g., high school students or decision makers. The main goal of this paper is to present the inception and development process of this learning tool. More specifically, this paper aims to: **Highlight how an immersive learning tool can be used to tackle existing learning issues**; **provide details on the design process**, in particular on satisfying the specific learning needs with specific features of the proposed learning tool; **discuss results obtained from a piloting phase** in which the learning tool has been evaluated; and **provide main conclusions and define future lines of work**.

2 Research questions and research approach

2.1 Research questions

Our main research question is defined as follows: "*Can an immersive learning tool let Environmental Sciences students experience the complex process of landscape planning?*". This broad and open research question can be decomposed in more detailed research sub-questions, as follows: **1) RQ1:** *What type of learning tool can achieve this and will, at the same time, guarantee a good learning experience?;* **2) RQ2:** *If such a*

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tool needs to be developed, how can we do this to ensure that the learning objectives are achieved?; and **3) RQ3:** *How can the learning tool be evaluated, before its general deployment in the educational context?*

2.2 Research approach

Our research approach involved the following steps (and is in line with the Design Science Research methodology [4] aiming for creation of artifacts): **1) definition of the learning objectives**, which should act as the base for the objectives of the learning tool; **2) selection of the format of the learning tool** based on the learning objectives, available resources and timeframe; **3) definition of features** to ensure that the learning tool achieve the learning objectives; **4) design and initial prototyping**; **5) initial evaluation of the prototype** in a series of sessions to identify issues and opportunities of improvement; **6) improvements based on feedback** from the initial evaluation; and **7) further evaluation.** The last two steps of the process are to be conducted iteratively, in order to quickly and continuously improve the tool.

3 Definition of learning objectives and selection of tool format

Because interest and learning are stronger when based on experience [5,6], the main objective was formulated as follows: **let the students experience the situation of an environmentalist in the process of landscape planning and decision making in a local environment**. By doing so, we expect them to recognize the importance and complexity of the subject and to develop interest in the topic (e.g., at the beginning of a course). More specifically, we identified the following detailed learning objectives: 1) **Make the students aware of the importance and necessity of compromises** between human development, human welfare and nature conservation at levels they usually do not think of (local scales); 2) **ensure that the students experience the complexity of the decision-making process** in landscape planning when trying to balance human development, human welfare and nature conservation, especially in the context of limited economic resources; 3) **introduce situations about specific topics** (e.g., transport systems) that can be further discussed during the classes.

We opted for a game because when using games, the learning experience seems to be better [7]. A game can supports our learning objectives as they provide students with an immersive, easy, and fun experience of the complexities of the subject. Among games, tabletop games are easy to learn and carry, and most human beings are used to play them [8]. Additionally, a board can easily represent geographical elements. Based on these arguments, our decision was to choose for a board game.

4 Related work

We conducted an initial search over IEEE and Google Scholar databases by using the following search strings: `"learning games" AND ("urban planning" OR "natural environment") AND ("board games" OR "tabletop games")`.

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There have been few attempts to introduce games as innovative learning tools in related fields (like natural environment, natural sciences, architecture, green building or environmental awareness) [8, 9, 10, 11, 12, 13, 14, 15] but there seem to be no existing game related to landscape planning. For instance, Marlow [9] identified existing digital games with potential to landscape architecture and environmental design education. Marlow presents and assesses the different existing games, but he does not present his own solution to the problem. In a different paper [10], Marlow presents how several computer-based games were designed as pilot projects in order to support landscape architecture teaching (which is different from landscape management), reporting good results. Juan and Chao [8] present a multi-player strategy board game to support the teaching of a green building strategy. Although the topic tackled is different from the one of our study, they give very interesting conclusions like the fact that the players have stronger learning motivation than the ones only attending the lectures and they have better learning outcomes. Similar to our approach, we found board games in the fields of urban sustainable development [11], energy simulation [12], and environmental and sustainability awareness [13, 14]. In all cases, board games are used as part of the learning process of environmental-related matters and seem to generate more interest from the students and give better results for those using these learning tools.

Overall, the previous papers suggest that using games, both computer-based and tabletop games, in related fields enhance the motivation of the students and improve the learning experience, helping to reach the learning objectives.

5 Design of the game

The definition of our board game features is based on the detailed learning objectives (section 3). Considering those and the peculiarities of landscape planning, we identified five main features that had to be present in the learning game: 1) Students need to **experience the decision-making process** and its conflicts; 2) **Decisions should be made in and affect a territory with its multiple aspects** (human activities deployed, impacts on natural assets, and human welfare and development, etc.); 3) **Decisions should be driven by individual interests** of various and potentially conflicting pressure groups; 4) Some **collective or public interest should apply** to force the students to balance between the individual interests of contrasting agents; 5) Some sort of **economic system should be used** to force all decisions being made in an environment with limited economic resources.

We opted to develop a multiplayer (3 to 5) tabletop game named “TERRITORY”, in which players play the role of decision makers subject to different interests when planning a territory. During the game, and by means of **action cards**, the players should decide how and when the territory should be developed, how the environment should be protected, and how industry and work-places should evolve. The fact of having several players represents the existence of several actors having different interests (conflicting or not). To simulate that decisions are often driven by individual interests, we introduced **individual goals** that the different players should pursue. These goals represent the main tasks of specific administrations or pressure groups lobbying decision

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makers and they represent each player personal agenda. As real life decisions are not entirely made driven by personal agendas, we also incorporated aspects of public interest by means of **global goals** and **habitability tracks**. **Global goals** represent the common good or elements that benefit the whole (or a wide part of the) society and allow players to collaborate to achieve them. The need to collaborate in a global goal might not necessarily represent an altruist point of view. In that sense, it is a semi-collaborative game in which personal and global agendas should be wisely combined in order to succeed. On the other hand, **habitability tracks** measure the performance of the players in employing several elements defining the welfare of the territory: employment, services, and natural environment. They reflect the societal outcome of the individual players' actions and act as external constraints that force the players to reach a minimum amount of collaboration. Indeed, if habitability tracks decrease under a certain threshold, the outcome is a societal collapse, meaning that the game ends and all the players lose. This "lose-lose" scenario has the pedagogic goal of showing the consequences of an inefficient landscape management, in which the society fails and collapses. On the contrary, if players have done a good job compromising their personal agendas and lining them up with global goals, the habitability tracks increase. When habitability tracks reach a certain level, the game ends and points are distributed to find the winner. This is the one that managed to get the best balance between its individual goals, the global goals, and the habitability tracks.

Available economic resources are limited and depend on the current development status of the society. The players need to find a balance between allowing economic activities to increase their incomes and develop or protect the territory according to their individual/global goals. This aspect will make the players to propose realistic measures of development/protection, and they will be forced to balance between development and protection.

6 Evaluation and first results

6.1 Pilot Evaluations

We choose individuals without prior experience in landscape or urban planning as potential participants for the piloting phase of the game, intending to avoid any pre-conception towards the game based on pre-existing knowledge and to mimic, as much as possible, the situation of new students attending a course. We also did not require "gamers" profiles (individuals with strong gaming background) for participation, although we did not explicitly veto them, in order to make sure that we represent a normal (student) population, in which one will have, in general, a mix of people with different interest and background on games.

After a small introduction and playing the game, each participant in the piloting phase was asked to fill a questionnaire with 38 questions grouped in 6 sections: 1) game's topic and message, where we assess if the general subject is understood; 2) learning potential, where we try to evaluate if the participants see potential in the game as a learning tool; 3) learning experience, where we try to identify if we are reaching

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the tool's objectives (e.g. Did the participants felt like decision makers? Did they experience the inherent conflicts of landscape managers?); 4) game experience, where we aim to evaluate the tool as a game (e.g. Is it easy? Fun?); 5) participant profile; 6) open feedback. Sections 2 to 4 used statements where the participants must manifest its level of agreement using a Likert scale [15] with values ranging from 1 (not at all) to 5 (extremely). All statements were affirmative and positive formulated, except for questions 3-5 in section 2 that were negative. Section 1, 5 and 6 were optional open questions.

So far, we have run two series of evaluations. Session 1 involved 12 participants, and took place in Brussels (Belgium), during July 2018 using the first version of the game. Session 2 involved 16 participants, taking place in Granada (Spain) during August 2018, and in Brussels (Belgium, during September 2018, using an improved version of the game based on feedback from Session 1.

6.2 Results

Participants of the evaluation sessions, who were instructed in the rules but received no information on the game's purpose or subject, defined the subject/theme of the game using words that clearly point towards environmental planning and management in which cooperation is crucial (Table 1). Fine-tuning of the game between the two sessions resulted in an increased recognition of collaboration and environmental aspects, while keeping the aspect of planning and management. Noteworthily, the number of words used in Session 2 to define the game decreased from 33 to 26, even though the number of participants was higher, suggesting that the changes resulted in improvements to understand the subject and issues of the immersive learning tool.

Table 1. Top-three keywords gathered to identify the game by participants in sessions 1 and 2.

Session 1		Session 2	
Keyword	**Number of occurrences**	**Keyword**	**Number of occurrences**
Planning/strategy	7	Collaboration/cooperation	10
Collaboration/cooperation	6	Environment	10
Environment	4	Management	7

All participants saw potential of the game as a learning tool and learned something by playing the game (Fig. 1: Section 2 and 3), and they were not missing knowledge to play, enjoy or learn (Q3-5). Results of sessions 1 and 2 were in general consistent, with a slight decrease on the amount of learning (Q1 and Q2) but also in the missing knowledge (Q3-5). This might point to the fact that we simplified some of the rules, making the game simpler to play but decreasing also the number of concepts that could be learned (Section 3). For the game experience, results were good (Fig. 1: Section 4), suggesting that the game is not monotonous or boring, provides a sense of satisfaction, is fun, challenging, but not too difficult…. More interestingly, the values for these characteristics increased in session 2. We can conclude that the simplification of the rules,

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although it slightly reduced the learning experience, increased the game experience, making it also more enjoyable.

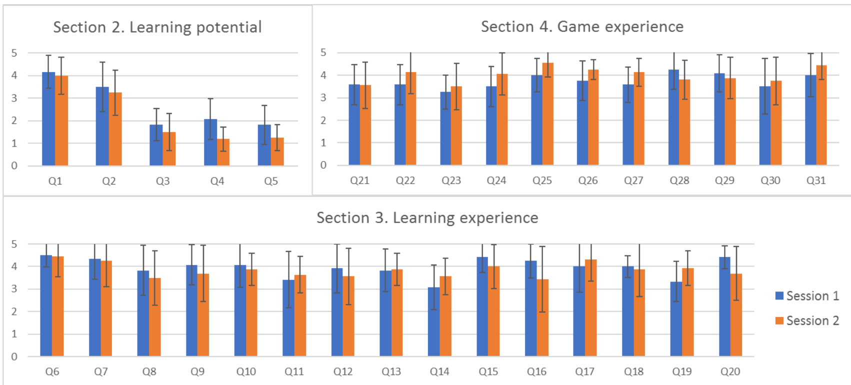

Fig. 1. Summary results with average (bars) and standard deviation (error bars) of Likert scale values in the questionnaires that were used in two sessions of initial evaluation.

7 Conclusions, limitations and future work

In this paper, we present the process of designing a tool to support the learning process in the context of urban and landscape planning. Starting from the main research question: "*Can a learning tool let Environmental Sciences students experience the complex process of landscape and urban planning?*", we investigated three specific sub-questions and were able to provide the following answers: **RQ1:** Based on the identified learning objectives, the available resources and constrains, and the literature analysis, we have chosen a tabletop board game; **RQ2:** We have provided a systematic approach to the design of the learning tool by moving from the main learning goal to the learning objectives and next to the characteristics and features of the game; and **RQ3:** We have applied an iterative approach based on the creation of prototypes and performing evaluations with participants with a profile close to the profile of the target audience. This allowed for fast feedback and improvements of the game.

Our game seems to fulfill our main learning goal: it presents and lets the players experience the complexities of decision-making for the management of a landscape and its urban development. We have experienced that some compromises were needed between game experience and learning objectives. In order to obtain a good game experience (by keeping the game fun and engaging), we had to lower the ambition for the learning objectives. In that sense, the process of refining rules and testing them with real players was very useful to come to realistic objectives. The presented evaluations have, of course, limitations, as the number of participants was restricted. Furthermore, the participants were not students in Environmental Sciences, which makes it difficult to generalize and extrapolate. Also, there is certain subjectivity in the evaluation, as we were asking for the participants' opinion. As further steps, we will introduce the game in official landscape/urban planning courses. It is very likely that this will result in a new round of fine-tuning. As part of the upcoming evaluations, we plan to include some

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quantitative measures that could allow an objective assessment of the impact of the game in the learning process.

Acknowledgements

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Lehigh River Watershed VR: The Lehigh Gap Immersive Virtual Field Trip

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Abstract. To promote learner engagement about our watershed, we designed and developed an immersive virtual field trip (iVFT) prototype to explore features about the Lehigh Gap in Pennsylvania, USA. The iVFT is designed to enable residents of the Lehigh River watershed to understand the environmental changes that occurred during the past two centuries. Prototype feedback included that the iVFT experience promoted a feeling of immersion, an authentic experience, high degree of realism, ease of use for navigating within the immersive virtual environment, a comfortable feeling, and little to no dizziness. Users also noted a feeling of high engagement and flow.

Keywords: Lehigh Gap, Virtual Field Trip, Immersive Virtual Reality, iVFT.

1 Introduction

Immersive virtual reality (IVR) has gained more focus and interest as an emerging technology among consumers as a recent result of an increased utilization of VR for video gaming, and affordable prices for immersive headsets such as Oculus Go at $199 USD. Approximately 4.9 million VR headsets units were sold in 2018, which made VR a $1 billion sector in the United States [1].

Following this recent trend of increasing consumer adoption of virtual reality technologies, IVR learning experiences are emerging into educational settings. For example, a recent study found IVR field trips successful to facilitate climate change learning [2]. To promote learner engagement about the Lehigh River watershed, our team designed and developed an immersive virtual field trip (iVFT) prototype to explore features about the Lehigh Gap in Pennsylvania, USA. Its primary audiences are: (a) urban high-school students and college undergraduates who are often impeded to join actual field trips due to health issues, athletics schedule, and/or disabilities; (b) and visitors of the Lehigh Gap Nature Center for pre-field trip visits.

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1.1 Site selection

The Lehigh Gap, internationally known for housing part of the Appalachian Trail, is located adjacent to the Palmerton Zinc Smelting Plant. This area is the largest Superfund site east of the Mississippi river in the USA. Superfund sites are locations that are contaminated with hazardous substances and pollutants that are prioritized by the U.S. Environmental Protection Agency (EPA) for remediation [3]. A green mountainous ridge became a barren “moonscape” as a result of zinc smelting activities that began in the 1890’s. The Palmerton Plant emitted approximately 3,450 pounds of sulfur per hour from 1918 to 1970, along with heavy metals (e.g., arsenic, cadmium, carbon, lead, mercury) into the atmosphere [3]. These pollutants spread over the native vegetation via acid rain. Five years after the smelting plants ceased operations, a comprehensive and laborious revegetation work was initiated by the EPA and a local community group. The Lehigh Gap has been revitalized today through a mixture of warm season grasses that have trapped the heavy metals in the soil.

Our immersive virtual field trip is designed to enable residents of the Lehigh river watershed understand the environmental changes that occurred during the past two centuries in the Lehigh Gap area as a result of the zinc smelting plant operation. In addition, iVFT learning experiences enables users to learn about the construction and operations of historical transportation systems in the area (railroads and canals along the Lehigh River). Our VR design model includes digital reconstruction of historic assets to allow the current generation of students to experience historical events and geographical landmarks that are difficult to access or are no longer readily available.

2 The development

Photos were taken along a Lehigh Gap trail with a 360° camera on a tripod in June 2018. Unity 3D was used to develop the iVFT. Users can immerse themselves in the Lehigh Gap by moving along the trail in a sequence of 360° texturized inverted spheres. They can manipulate 3D models of an exotic piece of coal found at the site (Figure 1), and view authentic trail information signs (Figure 2) containing rich geographical and historical aspects of the area. A trail map with a compass allows users to navigate through the trail pathways.

The initial prototype was tested by a secondary student, undergraduate and graduate students, and faculty at our university. Prototype feedback included that the IVR experience promoted a feeling of immersion, an authentic experience, high degree of realism, ease of use for navigating within the IVR, a comfortable feeling, and little to no dizziness. Users also noted a feeling of high engagement and flow.

2.1 Future development

Based on the feedback from the prototype users, the iVFT is being further developed to include: (a) additional historical images; (b) 360° high resolution video and audio to envelope the spheres; (c) high resolution photos at interactable points of interest where

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zooming can enhance users' observations - for example, provide users with the capability to analyze geological strata; (d) improve the navigational map of the trail; (e) replicate the field trips in different seasons; (f) and extend the length of the current trail to include additional ones. These modifications will improve not only the Lehigh Gap iVFT, but also refine the user experience by achieving higher fidelity levels of environmental representation, incorporating scientific processes, promoting a feeling of presence; and granting the user more control and choice according to their interests or learning needs.

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Fig. 1. Using the controller 'Grip', it is possible to freely manipulate 3D objects. Once grabbed, its description appears.

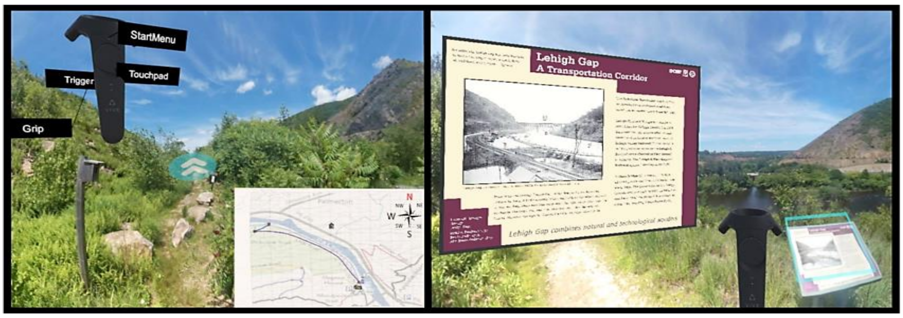

Fig. 2. Vive controller commands: (a) 'StartMenu' opens the trail map; (b) 'Trigger' select buttons and highlighted elements.

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A Virtual Reality Game To Identify Locations in the Lehigh River Watershed

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Abstract. Immersive virtual reality (VR) is a learning technology that is emerging in secondary schools. We have designed and developed a prototype immersive VR learning game for urban students to learn about local features in the Lehigh River watershed in Pennsylvania, USA. We used a series of design principles to engage students who are unmotivated to learn in traditional classroom settings, students with disabilities and English learners. The VR game incorporates realism, immersion, and interactivity to promote learning. In the learning game, students must identify nine different locations in their watershed using geographic features. The initial prototype implementation resulted in high engagement, immersion, and a sense of flow.

Keywords: Virtual Reality, Learning Game, Watershed, Immersion.

1 Description

Traditional teaching and learning environments for secondary learners include didactic, lab, and field experiences. These experiences often cannot meet the learning needs of all students, especially students with disabilities or are English learners. Classroom learning environments have many distractions that include off-task talking, cell phone use, and gaming on laptop computers. In secondary urban classrooms, many learners are not engaged or motivated to learn. They avoid challenges, do not complete tasks, and are satisfied to “just get by” and are at-risk for dropping out of school [1]. To address this, we have designed and developed an immersive Virtual Reality (VR) game for secondary students to learn about locations in their watershed.

Immersive VR is a learning technology that is emerging in schools and colleges [2]. Immersive VR is an interactive computer-generated experience that takes place within a simulated environment. Immersive VR technology uses VR headsets to generate realistic images and sounds and hand-held controllers that together simulate a user's physical presence in a virtual environment. A person using VR is able to move and look around in an artificial world and interact with virtual features or items. The effect is commonly created by VR headsets that display a small screen in front of the eyes. Immersive VR offers learners an active rather than passive experience. It provides learners an immersive experience without distractions through immediate learner engagement,

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and can be designed and developed to provide a novel learning experience to help students understand complex concepts and develop important skills. In a VR environment, authentic imagery, content, data, animations, video, and narration can be incorporated to provide learners with an improved learning experience. Prior studies have identified positive benefits of VR as an educational tool for English learners [3], emotional/behavior disorders [4], and visual disabilities [5].

We designed our watershed VR environment using Unity. The VR space includes a map-based interface using 3D map with labels, realistic models of objects, topography, and terrain. We developed an OpenVR controllers input C# script to enable the learner to "fly" and move through the VR environment. We use a series of design principles to assist diverse learners within the VR environment. These include navigational and map aids, audio options for listening to text to help build mental representations of key vocabulary terms, highlighting key vocabulary text that is being read, avoiding green and red colors, and UI elements such as buttons, pictures, and text.

When the user first enters the VR system, they are placed in a tutorial area and select a virtual tutor that will help them to learn about the watershed location identification game (Figure 1). The user is introduced to the game's contextual challenge: They are volunteering to help out at the Lehigh Gap Nature Center to get equipment and arrive to a locked door. The key has been lost at one of nine locations in the Lehigh River watershed. The user must go to visit all locations and correctly identify each one to acquire the key.

The user then enters the location game. It initially places the user in the center of their city where there are nearby locations that are readily apparent. The virtual tutor instructs students how to use the handheld controllers to move in the VR environment and interpret the navigational and map indicators. When the user selects a target location, a pop-up question appears that prompt the user to identify the location (Figure 2). If the user selects an incorrect answer, contextual hints appear and the user tries again. When the correct answer is selected, an icon specific to that location appears on the badge board. The game is over when the student collects all nine icons on the badge board. The key is always found when the last location is correctly identified. The user's last mission is to return to the LGNC and open the door.

During Summer 2018, the initial prototype was used with a secondary learner from our target population of an urban school in which all students are economically disadvantaged. The outcomes were high student engagement, immersion, and a sense of flow. Revisions have been made and the VR game and will be used in Spring 2019 with students in a secondary Environmental Science class. We will investigate students' flow experience, their sense of immersion and presence, their attitudes toward using VR, and their perceptions of using VR in school learning environments.

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Fig. 1. The tutorial area of the VR watershed location game.

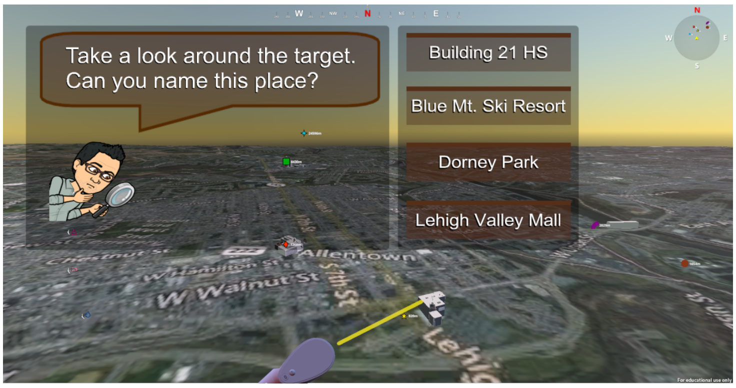

Fig. 2. VR watershed location game displaying response choices when a location target is selected.

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Unpacking Oakland Cemetery: Immersing Students in Atlanta History

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Abstract. Working with Oakland Cemetery, Georgia State and Emory Universities, and Beam Imagination are creating an experimental, public-facing digital archive that combines maps, a burial database, 3D visualizations, and curation.

Keywords: Digital Heritage, Visual Heritage, Historic Preservation, Lidar, Photogrammetry, Location-Based Learning, Generative Scholarship.

1 Place as Platform for Teaching and Learning

Historic Oakland Cemetery is one of Atlanta's oldest burial spaces and public parks. Working with the Historic Oakland Foundation, Georgia State University, Emory University, and Beam Imagination are creating an experimental, collaborative, and public-facing digital archiving project that combines maps, a burial database, 3D visualizations, and data curation. The project is an example of what Ed Ayers has called *generative scholarship*, as it is "built to generate, *as it is used*, new questions, evidence, conclusions, and audiences" and "offers scholarly interpretation in multiple forms as it is being built"[1]. The project will serve as a platform for connecting community storytelling, experiential learning and research projects at K-12 and higher education institutions, game development, walking tours, and archaeological findings.

Fig. 1. GSU student using a Red Camera to experiment with photogrammetry.

Fig. 2. GSU and Emory faculty and students working with Beam to create drone map.

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2 Connecting Cemetery Map to Burial Database

Our team has created a drone aerial map of the cemetery using the DJI Inspire 2 and x7 camera and Drone Deploy from Beam's team with GPS calibrations from Emory and GSU. We then combined this visualization of the land with the section, block, and lot maps from the cemetery. Using the open source platform, Omeka, we then joined the database of over 40,000 burials to our maps, creating a map of the burials accurate to the lot level. Using students and volunteers, we will move the burial records to the accurate grave locations. This data rich map will provide the platform for online visualizations and experiences at the site.

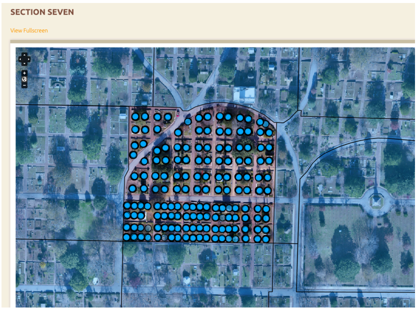

Fig. 3. Burial record on Omeka map

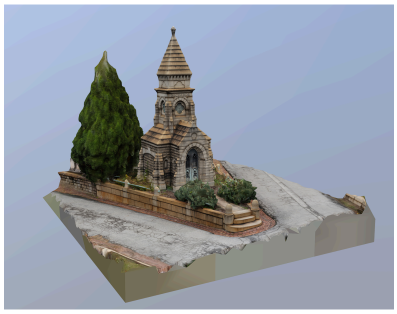
Fig. 4. Mausoleum photogrammetry

3 Data, 3D Visualization, and Location-Based Learning

Our map and data will eventually connect with our 3D visualization of the cemetery. We have two main approaches. Beam is leading efforts to create a full 3D version of the cemetery using Lidar with a Mantis Rover with Ladybug 5 360 camera by FLIR as well as a backpack mount with the Lidar Mill for cloud based processing. At the same time students are capturing individual headstones, statues, and mausoleums using photogrammetry. Along with generative scholarship, underlying our project is the concept of location based learning, which Woodhouse and Knapp argue is "inherently multidisciplinary," "inherently experiential," and "connects place with self and community"[2]. Our purpose is to connect students and the community to important places in our city. While Beam and a few paid fellowship students with experience have created the majority of our models, we are developing and testing instructional documents that will allow any student or community member with a camera to add to our collection of 3D visualizations. Similarly, students from many disciplines and community members will be able to both participate in building projects through research, storytelling, and data curation as well as learn about this significant historical place through the projects that are built on the larger platform.

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A Framework for Augmented Reality Based Shared Experiences

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Keywords: Augmented Reality, Shared Experience, Networking, Multi-user

Abstract. Meetings occupy 40% of the average working day. According to the Wall Street Journal, CEOs spend 18 hours, Civil Servants spend 22 Hours, and the average office worker spends 16 hours per week in meetings. Meetings are where information is shared, discussions take place and the most important decisions are made. The outcome of meetings should be clearly understood actions, but this is rarely the case as comprehensive meeting minutes and action points are not often captured. Meetings become ineffective and time is wasted and travelling becomes the biggest obstacle and cost (both monetarily and environmentally). Video conferencing technology has been developed to provide a low-cost alternative to expensive, time-consuming meetings. However, the video conferencing user experience lacks naturalness, and this inhibits effective communication between the participants. The Augmented Reality (AR) shared experience application proposed in this work will be the next form of video conferencing.

This work demonstrates the use of AR for creating shared experiences; the main contribution at this time is to demonstrate the ability to use networking alongside AR, and to visually and audibly interact with other users. A shared experience allows users to experience natural human interaction in an AR space. The first AR application was introduced for a smartphone in 2005, a multiplayer AR tennis game. Since then, AR has become more mainstream. In July 2016, Niantic and The Pokémon Company released an AR application called Pokémon Go. This was the first time an AR application became truly mainstream. The application made $795 million worldwide during 2018 alone; and has earned a total of $2.2 billion since its launch. AR is one of the three major elements in the immersive industry alongside virtual and mixed reality. Besides games, AR can be used to help make tasks simpler for many industries and reduce or remove obstacles.

The aim of this work is to create meeting rooms allowing users to have their own virtual rooms to hold conferences. this application will remove the

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obstacles required for the meeting, i.e. venue, available participants and the travel time and costs. This application removes these obstacles and allows the user to have a meeting from their location. Spatial, a new collaboration platform that will allow users to collaborate, search, and share content as if they were in the same room using the Hololens. Spatial is Skype in 3D, provides the same tools as the telecommunication application, converts 2D images into 3D models to represent the users and provides 3D equipment. Spatial has a similar concept 2 however, the application being developed in this work is available on various devices i.e. cardboard headsets (Aryzon, Holokit), smartphones and Hololens. Having multiple hardware options widens the audience as not many people can afford a Hololens. Kato and Billinghurst's paper on marker tracking and HMD calibration for a video-based augmented reality conferencing system have some similar elements, as both applications freely position a user in space. Users can collaboratively view and interact with virtual objects using a shared virtual whiteboard. However, our application is audio based which uses little bandwidth in comparison to Kato and Billinghurst's work where the video based streaming uses 10 to 20 times more bandwidth than audio.

In this work to date, we have demonstrated that it is feasible to develop an AR conferencing application on multiple remote mobile devices with shared experience features. The main aspect and purpose of the work are to demonstrate the ability to visually and audibly interact with other users in a common AR environment over the Internet. Each participant can see an AR visualisation of the other meeting participant's avatars in their own office environment. Besides audio and text communication, the application will record audio and convert it to text, i.e. providing real-time subtitles which will be visualised for each user. The subtitles will persist for a time to aid understanding and increase communication efficiency between meeting participants. This application represents a significant first step towards the goal of this work. Thus far, the application can connect users, communicate with one another over the Internet and display their avatar in a synchronised shared experience. The end result will contain similar elements to what Spatial provide but will also feature automatic speech recognition (ASR) and natural language processing (NLP) to convert speech into text. At the end of the conference meeting the application will save and send a HTML format of the conversation to each user's email.

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Deep Learning Using Serious Games: An Application for Andragogy in Human Resource Development

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Abstract. The progressive substitution of soft skilled jobs for technological advancement creates a necessity for adult learning and honing of soft skills. The objective of this research is therefore to effect and measure Deep Learning using Serious Games which are games created for purposes other than entertainment and in this case, a tool for teaching soft skills to adults in corporate environments. We have developed a framework called the Game ELC+ Framework to test the strength of adult teaching (andragogy) as well as facilitate Deep Learning of a soft skill – judgment and decision making in recruitment and selection – through a Serious Game. This novel quadripartite framework fuses Yu Kai Chow's Octalysis Framework which focuses on gaming elements, Bloom's Taxonomy which focuses on learning levels of the learner, Cognitive Theory of Multimedia Learning which focuses on learning channels, and Ruskov's four evidences of Deep Learning. As a result, this research aims to augment Human Resource Development efforts and contribute to adult Deep Learning.

Keywords: Game ELC+, Serious Games, Deep Learning, Andragogy.

1 Introduction

With rapid technological advancements, it would suggest that soft skills will be a critical component of employability for one to prove invaluable to a company [1]. This gives rise to the need to teach (soft skills) in a method that ensures Deep Learning by the adult learner, in order to optimize the quality of actions taken based on knowledge learnt [2].

Following Ruskov's theory [3], the assessment for evidence of deep learning will be framed around **Ev1:** Change in complexity of reasoning; **Ev2:** Considering new concepts; **Ev3:** Relating new to previous knowledge; and **Ev4:** Adopting the vocabulary of what is learned.

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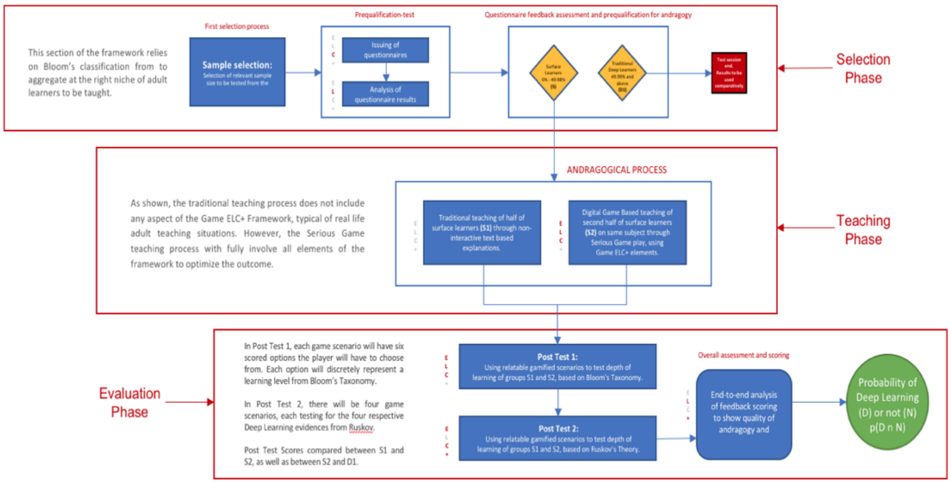

"ELC+" label at the side of each activity box represents the framework attributes, and the letter(s) highlighted in red represent the attributes most prominent in that activity.

Fig. 1. Game ELC+ Framework: Game play assessment and feedback structure

2 Expected Results and Hypothesis

H1: Deep Learning can be created, measured, and assessed using Serious Games. H2: Deep Learning in adults can be more easily achieved through Serious Games than traditional teaching.

Combining the four existing frameworks to create the Game ELC+ framework considers the critical aspects involved in the processes of both andragogy and learning (dissemination of information and absorption), being the end-to-end process involved in Deep Learning. The expected results should prove to have created a scientific means by which Deep Learning can be defined and measured, by proving a measurably higher level of knowledge and understanding in adults who learnt through playing the Serious Game created using the Game ELC+ framework, compared with a control group who learnt the same skill through traditional learning methods.

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A Virtual World to Promote Experiential Learning through Role-play in Distance Education

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Abstract. Distance education still has challenges that put it in a disadvantage regarding the traditional face-to-face mode of instruction, including the lack of professional practices. This exploratory research conducted with 24 students presents the initial findings regarding the use of a Virtual World to promote Experiential Learning through role-playing. Feedback was gathered regarding the difficulties of using a new platform, but satisfaction with the experience.

Keywords: Virtual Worlds, Experiential Learning, Distance Education.

1 Introduction and Method

In order to help with common limitations faced by distance education students, as the main textual web virtual learning environment and the lack of professional practices, we present the design of a Virtual World (VW) using OpenSimulator, which is a free user-friendly open source platform.

The VW was created towards the Financial Mathematics discipline, following a role-playing approach. It has a narrative that revolves around the context of a fictitious accounting firm. The student receives the role of a first-day trainee and is challenged with quizzes in order to be admitted by the firm, passing through five sectors. The Kolb's Experiential Learning [1] was the pedagogical model chosen to guide the VW development, with stages designed as follows.

- **Concrete experience:** students are inserted in a practical situation related to their future professional life (post-training), which contextualizes the knowledge.
- **Reflective observation:** as they experience it, students make observations about the simulated work routine and interpret the situations.
- **Abstract conceptualization:** students are faced with challenges, being asked to apply the theoretical knowledge acquired to continue the activity.
- **Active experimentation:** at the end, students receive a different role within the simulation, being asked to respond to a slightly more complex exercise.

At each sector, the avatar who represents the "chief" explains a little about the working routine and asks the student to sit in a chair to begin a quiz composed of three multiple-choice questions, developed using heads up display (Figure 1-Left). In the end, the messages pronounced by the "chief" indicate the next room where the student should go, and so on, in a concatenation of events.

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The simulation culminates with the student reaching the goal of obtaining the internship, arriving in a room where several "employees" (NPCs) are already actively "working", with a workstation reserved for the student (Figure 1-Right).

Fig. 1. Heads up display quiz (Left) and student seated in the workstation (Right).

The sample consisted of 24 students with a mean age of 34 years (M=34, SD=9.2), being 22 (~61%) female, from the Technical Course in Administration, whom after the activity responded an online form with questions regarding their perceptions.

2 Results and Conclusion

Five main aspects emerged in students general perceptions, addressing the pros and cons of implementing a technology different from what they are accustomed to.

Satisfaction. They defined the VW as constructive and productive, very different from platforms they already tested, and that it seemed that they were being personally interviewed in the company.

Learning benefits. They said it was very interesting for learning, mentioning the possibility of reviewing the content, and that it thus is good for practicing knowledge.

Novelty factor. They mentioned the lack of ability with the VW navigation, but that after understanding the proposal it was accessible.

Design improvements. They reported some confusion with the textual narrative, suggesting a dialogue bubble to facilitate it. They also mentioned getting lost in the VW sometimes.

Technical difficulties. They reported problems with the installation of the viewer, that is should be "less heavy". In addition, delays inherent of slow Internet bandwidth were mentioned, as "the handling of the virtual doll (the avatar) left to be desired".

To conclude, overall students showed enthusiasm, feeling that the activity seemed like the real work scenario, and that it was useful to practice the knowledge. Although exploratory, the research is a field study, not a laboratory controlled one, with results that reflects the actual effect and experience of the VW intervention with real students from distance education.

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Rheumatosphere AR: Public Engagement and Education with Interactive Print Posters

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Abstract. Rheumatoid arthritis (RA) affects around 1% of the UK population, places a heavy burden on society and has severe consequences for the individuals affected. Early diagnosis and treatment significantly increase the chance of long-term sustained remission. Raising awareness of RA amongst the general public is important to help decrease the time of diagnosis of the disease.
In this poster and demo we explore the use of Augmented Reality (AR) in the creation of interactive print posters for public engagement. Previous studies have shown that AR can be effective in a teaching and learning context, where the coexistence of real and virtual objects aids learners in understanding abstract ideas and complicated spatial relationships. It has also been suggested that it raises motivation in users through interactivity and novelty.
We explore the use of AR in public engagement, and outline the design, development and evaluation of an engagement experience utilising AR. For this, a set of informative printed posters was produced and these enhanced by an accompanying interactive AR application. Evaluation involved participants at a science outreach event at the Glasgow Science Centre. The poster includes a demo of the public engagement application: Rheumatosphere AR.

Keywords: Augmented Reality, Public Engagement, Interactive Print, Augmented Posters, Rheumatoid Arthritis

1 Interactive Print and Public Engagement

The combination of Augmented Reality (AR) with printed material appears to have significant potential in an public engagement setting. Print materials such as posters and leaflets are widely used in these settings, and familiarity of such materials combined with a more novel AR experience can potentially promote intrinsic motivation for exploration of a subject [1]. Further, such materials can also allow free exploration with learners able to take their time and make active choices over the amount of information they consume, helping manage the overall cognitive load [2]. Here we refe to such materials as *interactive print* [2].

The Rheumatosphere research groups at the University of Glasgow regularly organizes public engagement events to increase awareness of Rheumatoid Arthritis (RA) and promote early medical referrals. Outreach events are held across Scotland, including at

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the nearby Glasgow Science Centre, and finding ways to make the materials more attractive and engaging is important to help improve engagement and outcomes. From an initial concept of creating an AR booklet, an interactive print poster format was decided on. This benefits from the larger scale, visual layout and the low requirement for strict narrative ordering further favours this approach.

A series of posters were developed, with a range of textual, 3D modelled, and animated AR content. These help explain what RA is, and to highlight how RA affected joints compare to healthy joints.

Rheumatosphere AR was shown at a ‘Science Lates’ public event at the Glasgow Science Centre in the summer of 2018. A set of posters were displayed and tablet computers with the companion app pre-loaded were made available for members of the public to use to explore the posters (see Fig. 1). Feedback was highly positive, supporting the initial hypothesis that interactive print can help promote public engagement with science.

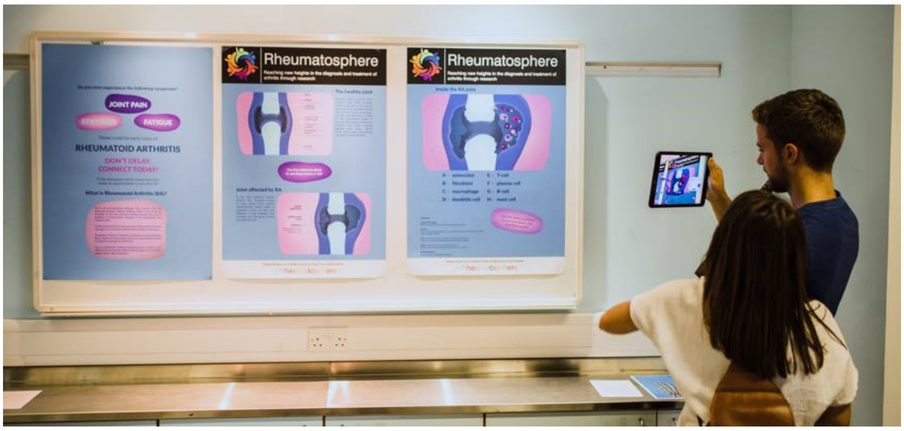

Fig. 1. Visitors at the Glasgow Science Centre using the application to view augmented reality content over the posters. Image: Glasgow Science Centre.

Key advantages of the approach are improvements in engagement and the ability to place information into the companion app allowing for a reduction in the information contained in the posters themselves. Disadvantages are increased development time and costs and a possible decreasing return as AR becomes familiar or even routine.

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Mixed Reality use in Higher Education: Results from an International Survey

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Abstract.
Respondents identified some challenges in implementing MR in their work with a majority reporting student reluctance, faculty reluctance, and lack of infrastructure and hardware as significant challenges. There was a significant reduction in perceived value added by the research respondents. Poor user experience, difficult to use hardware and software, and lack of educational content were among the lowest ranked challenges.

Keywords: Mixed Reality, Survey, Community of Practice.

1 Mixed Reality Task Group Mission

Mixed Reality (MR) is comprised of Augmented Reality (AR), Virtual Reality (VR) and arguably, 360-degree video. AR and VR are in use in numerous commercial applications from Pokémon Go to the NY Times. These tools have serious implications for higher education in areas that include virtual labs, student engagement, and student success and retention. The State University of New York, FACT2 tasked the Mixed Reality Task Group with exploring the use of Mixed Realities in the higher education setting and analyze the opportunities they offer to enhance the teaching, learning, and professional development experiences of students and faculty using the following paths of inquiry [1], such as: What are the opportunities for these emergent tools to be integrated into higher education outcomes? What training, tools and hardware are needed to initiate and support integration into teaching and learning? Describe the learning curve to optimize course and degree outcomes. Is there enough research and experience to frame the potential benefits of these tools in fully online, hybrid and conventional modalities?

Additionally, the Task Group sought to recruit collaborators from SUNY and beyond (faculty, instructional designers, content and product manufacturers) who have subject matter expertise and experience with a goal to augment and expand teaching and learning opportunities that can be sustained as a Community of Practice (CoP). Research

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effective strategies for creating and sustaining a CoP. Create a special interest group to explore the tools and methods being developed to support course and degree outcomes and lay the groundwork for a CoP.

The Task Group met a total of 20 times throughout the 2017-2018 academic year and consisted of 18 initial members. The Task Group developed a survey to investigate the current uses of MR in higher education and research. The survey was circulated internationally with an emphasis within SUNY. A total of 123 respondents completed the survey. Of these, 35% (43) are currently using some form of MR tools in the classroom. Of the remaining 80, only six stated they planned to use MR in the future, 20 said they had no intentions of using these technologies, and 46 felt that they may consider it in the future. Most of the respondents were in the role of faculty (61%), followed by researcher (22%), and instructional design/support (17%). Fifty-eight percent of respondents were from a SUNY campus. The survey found a rather long list of challenges for both teachers and students and for researchers using MR. These challenges along with the hardware, software, classroom designs and course design are listed in more detail on the poster.

Fifty-eight percent of respondents are employed by a SUNY school covering the following campuses: University at Albany, Binghamton University, University at Buffalo, SUNY Delhi, SUNY Downstate Medical Center, Empire State College, Fashion Institute of Technology, Finger Lakes Community College, SUNY Geneseo, Maritime College, SUNY Old Westbury, SUNY Oneonta, SUNY Plattsburgh, SUNY Potsdam, Purchase College, Stony Brook University, SUNY Polytechnic, and SUNY Ulster. Non-SUNY representation (42%) includes Canada, UK, Germany, Ireland, Massachusetts, Colorado, Italy, New Zealand, Scotland, California, and Australia.

2 Conclusions of Mixed Reality Task Group Activities

Aside from the survey results, the outcomes of the FACT2 Mixed Reality Task Group activities can be summarized as follows. 1) An open Community of Practice (CoP VR) was formed to continuously explore, collaborate and share their findings as resource to the SUNY system. 2) A Communication Strategy was developed to actively provide information (using a FACT2 website), with quarterly summative reporting to the FACT2 Council. 3) A repository of content that includes: past reports, case studies, resources and an active list of AR/VR resources that would be regularly updated, evaluated, reviewed, and changed as the technology evolved. 4) Partnerships with colleges and groups like COTE, CPD and others to share information and to be a persistent resource for all stakeholders. 5) Present and discuss issues at events to disseminate the results.

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Engage, Immerse, and Innovate: Best Practices in Immersive Teaching

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Abstract. Research in terms of immersive learning has made great advancements in recent years. Still, the integration of augmented and virtual reality technologies in the classroom depends on teachers. By comparing two seminars designed for pre-service teacher education, this paper presents evaluated strategies which promote the fostering of competencies in terms of immersive teaching and learning. We propose the best practices engagement by design (practice-oriented teaching), immersion (hands-on experiences in virtual and augmented environments), and innovation (starting the design process from the learning content/research question and then experiment with the new technology).

Keywords: Immersive Teaching, Teacher Education, Educational Virtual Environments, Teaching, Higher Education

1 Immersive Teaching: Using Immersive Technology in the Classroom

When thinking about the integration of immersive technologies in the classroom, teachers have to be considered as one of the crucial factors for its success. Even though teachers are rarely the ones to develop educational virtual environments (EVE), it can be assumed that they have an important role in the process of immersive learning: It is their task to select (considering didactical and methodical design) and supply (integration in the classroom) the immersive educational material that can then be used actively by the learner [1].

Regarding this role of the teacher, the process of immersive teaching can be understood as a set of skills enabling a teacher to evaluate and select existing immersive learning environments with regards to their prospective educational benefits for a given target group. The target group may be heterogeneous in terms of age, previous knowledge, motivation, cognitive skills, etc.

As there are several obstacles for the integration of augmented (AR) and virtual reality (VR) in the classroom, teacher preparation programs on immersive technology adaption are important for fostering such immersive teaching skills [2]. A central question for research on immersive teaching is, therefore: "How can we prepare pre-service teachers for the use of AR and VR in their teaching?" This paper focuses on best-practice-guidelines derived from the comparison of two independently developed immersive teaching seminars for pre-service teachers.

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2 Lessons Learned from Preparing Pre-Service Teachers for Immersive Teaching

We compared two seminars from the universities Würzburg (AR/VR, 27 students, 19 finished) and Passau (VR, 9 students, 5 finished), Germany. The seminars targeted pre-service teachers and followed a learning by design approach [3]. The students started by gathering experiences with immersive media; they then thought of a suitable research question/content and started developing an immersive EVE prototype, complemented by an evaluation phase with undergraduate students/middle school students. By comparing the results from group-interviews, participant observations, and online evaluations, we summarized three best-practice-guidelines for fostering immersive teaching skills:

– *Engagement by Design*: Students reported a high emotional involvement in designing their own educational experiences [-]. It motivates students to learn more ("practice-oriented") and creates continuing interest in using, developing, and experiencing immersive educational virtual environments ("want to do more"). While also reporting a lot of workload in both seminars, students emphasized how important designing their own environments was.
– *Immersion by Hands-On Experiences*: Using existing EVEs helps to learn about the possibilities, limitations, and obstacles of immersive learning. These experiences determine the acceptance of immersive technology as part of the classroom, and increase motivation ("I had so many things in mind").
– *Innovation by De-Fragmentation*: Starting the design process from a learning content/research question allows students to experiment with the technology while keeping pedagogical/content questions in mind. Connecting pedagogical, technological, and content knowledge in interdisciplinary workgroups may enhance self-efficacy ("I have the feeling I am capable now").

There are a lot more things to consider when creating immersive EVEs; we tried to summarize the main objectives that our approaches had in common. While we are aware of the limitations of the small sample size and the used methods, these guidelines may help researchers and practitioners in designing studies and courses targeting immersive teaching and learning processes.

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Serious Games for Mathematics Support in Higher Education

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Abstract. Serious games may complement existing content in higher education and promote student engagement with taught materials. A systemic review of serious games for mathematics support in higher education between 2008 and 2018 was undertaken. There was limited research in this specific area but key themes emerged. These were the application of ARCS theory for initial design, technical considerations in creating serious games for mathematics, consideration of student computing abilities and provision of clear instruction and training prior to use. The review will inform the development of a local gaming resource to support existing mathematics support materials.

Keywords: Mathematics, Numeracy, Serious Games, Support

1 Introduction

Wide ranges of resources are available to support undergraduate students with the mathematics requirements of science, technology, engineering and mathematics courses. Institutions may have a dedicated mathematics support centre as part of their academic support, embed the mathematics support into the course content or use an extensive array of text, quiz and video resources such as those available from mathcentre [1]. University of Westminster, School of Life Sciences, mathematics support currently comprises of a series of brief instructional videos, worksheets, automated quizzes on the virtual learning environment and a locally produced booklet supporting the content. Small group face-to-face drop in tutorials are available throughout the year and are popular with those attending. A bespoke interactive resource was also created in 2011 but has had limited usefulness due to its perceived complexity by students [2]. In order to determine the extent of serious games incorporation into higher education mathematics support, a systematic review of publications from 2008 to 2018 was undertaken.

2 Method

Using University of Westminster Library Search, ERIC, Google Scholar and Science Direct, a search was performed on the terms *mathematics* and *serious games* in the title and/or abstract. From the fifty-four articles sourced, nine were duplicates and thirty-seven excluded as the focus was on primary and secondary school education or there was no specific mathematics information. The content of the remaining eight articles summarised for the review.

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3 Results

The small number of articles demonstrated that currently there is limited use of serious games for mathematics support in higher education. Some key themes emerged however, for application to the design and production of such resources. Pedagogic theories such as ARCS [3] are applicable from the early stages of serious game design [4] [5]. Toolkits and guidance are available for the production of mathematics serious games suitable for higher education purposes. One suitable for advanced mathematics incorporates the use of Python's C API, Python's SymPy and MatPlotLib libraries and C# DLL [6]. Single or multiplayer games should be considered to suit learner preferences, for some students group interactions for problem solving may be beneficial in the same way as preference for forming study groups. The computer skills and experience of intended users must be carefully assessed and suitable initial guidance and instruction on the use of games be provided [7]. Presently there is no consideration of serious games for summative assessment for mathematics but they represent a means of formative assessment. No articles included pilot studies for the incorporation of serious games into existing higher education mathematics support resources.

4 Conclusion

To maximize the usefulness of serious games for mathematics support the design can be undertaken in partnership with students of variable mathematics entry qualifications and self-assessed computing skills. The resource should be compatible with the local virtual learning environment and enable users to view feedback on their progress and see correct answers on completion of each game. Games should be available at different levels of difficulty with each level acting as a standalone resource to avoid negative experiences for users. Written and video guides to the purpose and use of the serious games are required in addition to initial face-to-face tuition. In addition, a local programming toolkit will enable undergraduate and postgraduate computer science students to develop and expand the resources. Combining existing mathematics support resources with serious games may align well to the learning preferences of some students and enhance their development of these skills.

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Connecting Indigenous Knowledge and Western Science through co-design & XR on the Flathead Indian Reservation

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1 Introduction

Since 2016, faculty in the Digital Design Technologies Program at Salish Kootenai College have conducted three years of co-design with area 7th – 12th graders, tribal college students, and expert tribal community members committed to solving local challenges through science, design, and computer programming workshops, problem solving, digital storytelling, art, game design, field trips, virtual reality experiences, and social media marketing. This group, known as "Flathead Tech4Good" has created numerous board games, videos, social media, story narratives, flyers, posters, and design ideas for solving local community challenges.

In 2016 – 2017, Flathead Tech4Good began their first year-long Community Challenge theme of "Food Sovereignty". By the end of that first year, the group, led by students attending Glacier Lake School and Polson Public Schools had co-created a board game with the Tech4Good partners called "Feast or Famine". In 2017 - 2018, the Community Challenge theme was "Water is Life!" and participants co-designed both a card game and a board game based on combatting aquatic invasive species. In 2018 – 2019, to be inclusive of the partners from the first two years (food and water) the co-design Challenge Theme has been "Community Health" and the Tech4Good partnership has expanded to include an animal/human health board game, a student science fair, augmented reality school community gardens, and almost a dozen classrooms doing a "Tech Challenge" that has them design Rube Goldberg contraptions-as-interpretations of local datasets about food, water, people, or animals.

This ongoing Action Research project to discover "what works" for community members of the Flathead Reservation – particularly young people – to access and meaningfully engage in co-design efforts around pressing challenges faced by the community has led to applying science, technology, engineering, and math expertise within a variety of cultural problem-based contexts. This poster presentation will showcase the products of the past three (3) years of Tech4Good Community Challenges, depicting the cultural contexts and critical inquiry within which these projects have been situated – demonstrating the connections between indigenous culture and western science and technology – and illustrate plans for next year's 2019 – 2020 Flathead Tech4Good Community Challenge Theme: Climate Change, including the nine (9) sectors of community-based data T4G's seeking to engage students and the community in partnership with the Confederated Salish and Kootenai Tribe's Climate Change Advisory Committee – next year's expert partners.

2 Research Questions

Research Question 1: What kinds of engagement leads to most meaningful co-design learning opportunities for STEM students to apply their emerging expertise?

Research Question 2: What approaches are best for the Salish, Pend Oreille, and Kootenai people to integrate their cultural knowledge with western science to solve complex, pervasive challenges such as food sovereignty, community health, and climate change?

A particular focus of this community effort has been on finding ways to intentionally connect traditional indigenous knowledge and western science. The project has created a Community-based Co-Design model to complement the Flathead Reservation community's cultural traditions following the seasons and living as part of the lands of western Montana. This poster will show that model and display some of the artifacts of our past 3 years efforts – seeking input on improved measures of engagement, learning outcomes, and

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Gathering community members, middle, high school, and tribal college students to meet with co-owners Rebecca and Brandon Goff of local game company Native Teaching Aids, Salish Kootenai College faculty, and challenge theme experts “across the seasons” to (a) storyboard and brainstorm the challenge in the Autumn; (b) Troubleshoot and Dive Deep in Winter; and (c) Playtest and Celebrate Accomplishments in the Spring.

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At the Heart of the Virtual City – Creating Global, Diverse, Accessible, and Environmentally Sustainable Communities of Practice Using Virtual Worlds

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Abstract. This poster presentation showcases how attending multiple virtual world conferences and events enable engagement with a global community of practice not otherwise accessible. The examples include the author's ongoing contributions to a virtual world resource center, and other virtual world initiatives at the author's university. The quality and persistence of virtual world events is evidence that accessible, affordable, and environmentally sustainable professional networking is possible, and this brief paper synthesizes the literature suggesting why adopting virtual worlds is more important than ever.

Keywords: Virtual Worlds, Communities of Practice, Second Life, OpenSim.

1 The Affordances of Virtual Worlds

Interest in virtual worlds peaked a decade ago, but lack of institutional support quickly left educators discouraged and simulations abandoned [1, 2]. Redesigning learning spaces and integrating mixed reality, however, are important trends amid a myriad of challenges facing higher education [3]. Confusion around terminology is another issue, and widespread adoption of virtual worlds will not happen without remediating a persistent knowledge gap in what makes them different [4]. While many educators have moved on [1, 2], the community of practice that remained developed relevant expertise and continue to articulate the value of virtual worlds in teaching [1]. Large numbers of those with the most experience want to move beyond Second Life [1], and open source platforms like OpenSim offer the same options with more freedom [1, 5,6,7], lower cost [8], and the ability to connect separately hosted worlds into an emerging metaverse [9].

At the heart of the word "immersive" is experiential and learning by *doing*. Interested educators would benefit from interacting with peers who have first-hand experience using virtual worlds in teaching [1, 7, 10]. Among other things, however, a successful community of practice needs options for different levels of participation, public and private community spaces, and it must be able to evolve to meet the needs of diverse people [11]. Virtual worlds meet these needs without requiring anything more than a computer with internet and a willingness to learn.

2 Increase Access and Diversity

Virtual worlds support access to global communities for those who are "ability diverse" [12]. Since 2007, Virtual Ability in Second Life has hosted free events and

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professional conferences enabling people of all abilities to get into virtual worlds, socialize, and learn [13]. Virtual worlds can provide access to learning and socializing far beyond the isolated silos of our institutions, or physical and location limits. Virtual worlds also provide a sense of place and collaborative co-presence that facilitates development of a variety of communities of learning [7, 10], they are an effective way for educators to build and share their knowledge [10], they increase access to immersive learning for rural and disadvantaged populations [14, 15], they can support the development of skills in empathy and reflection [16], and they provide opportunities to express more nuanced representations of self [17], all of which is needed for global civic engagement.

3 Environmentally Responsible

With urgent concerns about global climate change, and the United Nations calling for a 45% reduction of greenhouse gasses over the next decade [18], it's essential we reconsider our options to increase access to collaborative communities. Researchers have long known about the impact of travel on the environment and technologies to promote sustainable professional development [19]. Web conferencing, however, does not provide the same sense of being embodied in a space and empowered to interact with others. The fact that more conferences are not held in virtual worlds is disappointing given that a variety of organizations have been doing this for a decade [20-24].

4 Conclusion

Virtual world technologies pose challenges to widespread adoption, but primarily when considered through the lens of expecting industry or institutional support [1, 2]. Virtual world pioneers demonstrate that leveraging virtual communities of practices enables us to do this for ourselves. Anyone can create, join, and help sustain international and interdisciplinary communities of practice, *right now*, and doing so empowers the robust collaboration needed to solve the complex challenges of the future that face our global community.

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Immersive Environments for Absolute Beginners

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Abstract. This presentation outlines a simple approach which focuses on small 'elements of immersion', such as 3D models, 360 photography and augmented reality. We outline how to review existing work and 'scatter' small elements of immersion throughout this. This adds value to work already completed and allows students to sample it in a new, more immersive, way. The aim is to show educators and content creators how to start using immersive techniques without embarking on large, complex, projects.

Keywords: Immersive Environments, Virtual Reality, Augmented Reality.

1 Background

A new wave of affordable Virtual Reality (VR) technology allows us to engage learners like never before. We can capture our environment using 360-degree photography, immersive video and 3D scanning. Create experiences using VR headsets. And combine the real world with the virtual using augmented reality.

But if you haven't previously used these techniques then getting started can seem daunting. This presentation shares our initial experiences of developing immersive materials for distance learning MSc courses.

We introduce some of the technology, resources and approaches that have shaped our thinking over the last 12 months with a view to encouraging others new to immersive environments to take their first steps.

2 Aim

In simple terms, immersive environments can be defined as a simulation that gives the sensation of physical presence. Loomis et al. explains; "Immersive virtual environments are virtual environment systems that amplify the effect of simulation by surrounding the user with numerous layers of sensory and perceptual information created by digital devices" [1].

Such words conjure up a vision of learners using specialised hardware to explore a vast virtual world. This is truly impressive, but for many educators, the opportunity to develop such material is out of reach. Creating large immersive environments are

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complicated projects. A wide range of skills are required to achieve this [2]. And these projects consume time, people and money, with typical costs ranging from £20,000 - £150,000 [3]. So, as a beginner, how can we take our first steps into this new world?

This presentation outlines a simple approach which focuses on small 'elements of immersion', such as 3D models, 360 photography and augmented reality. We outline how to review existing work and 'scatter' small elements of immersion throughout this. This adds value to work already completed and allows students to sample it in a new, more immersive, way. The aim is to show educators and content creators how to start using immersive techniques without embarking on large, complex, projects.

3 Method

The method we devised outlines how immersive environments can be explained in simple terms of 'objects' and 'places'. If we can identify real-world objects and places in our work, then we can start to understand how we can represent these online using immersive techniques. We define some key principles to guide the process.

For example, thinking about 'objects', you may start by identifying real-world objects used in the classroom. This could be a prop, a resource or some equipment. Consider how immersive techniques like 3D models and augmented reality might allow these to be shared online. When thinking about 'places', look for places which are difficult to reach in the real world. They may be too far away, too difficult to reach or too dangerous to visit. Techniques like 360 photography and video provide a means to resolve this.

This presentation outlines some practical steps to help develop immersive material using affordable technology. It offers an evaluation of 360 photography taken on the Ricoh Theta V camera and 3D scans produced using the Occipital Structure Sensor. It highlights freely available alternatives for developing immersive material with little cost, such as free photogrammetry software by 3D Flow to create 3D models and the TeliportMe app to take 360 photos. Examples of Augmented Reality developed using the free AR.js web-kit are shared, along with an overview of its strengths and weaknesses.

Finally, we highlight the importance of building experiences that can be accessed on tools learners already use – computers, tablets and mobile phones. This is important for our 'beginners' approach. We want our work to be accessible to the widest possible audience without expecting users to have specialised equipment. The 'small elements' of immersion we describe - 3D models, 360 photography and augmented reality – are simple enough to run on everyday devices. This certainly lowers the barriers to user adoption and participation.

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4 Summary

This presentation is aimed at educators and content creators looking to take their first steps in developing immersive material. We outline a simple approach which uses small 'elements of immersion' to add value to existing work. We highlight some practical steps and focus on building experiences for tools learners already use.

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Design considerations of an original serious game for training working memory in Down syndrome individuals

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Keywords: *serious games, Down syndrome, cognition, pedagogies, m-learning, mixed reality.*

1 Introduction

It is a fact that people with Down syndrome (e.g. DS) have deficits related to verbal working memory [1]. Previous research proves that working can be improved through rehearsal training using computerized environments [2]. However, technology enhanced interventions on people with DS have not focused to verbal work memory alone. Studies have either combined evaluation with other cognitive functions or not at all [3, 4]. In this paper we describe a technology tool designed for specific verbal memory training of people with DS, called "Memorize- Image it!" and its design aspects as they have been evaluated by DS intervention facilitators.

2 Materials and methods

The "Memorize-Imagine it!" application is a simple memory game adapted for the needs of children with DS. The game was created following some simple design guidelines in order for it to be both educationally appropriate and technically simple. It consists of several levels on which the user hears and reads a series of words and then has to choose in the correct order the objects that are described with these words. The game starts from two words and has an upper limit of 7 words.

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3 Results.

The “Memorize- Image it!” application was put for testing in front of 6 facilitators who have worked in DS technology-based interventions of more than 100 DS users. They were asked to evaluate the application by a qualitative 4-item questionnaire, structured as a 5-point Likert scale (e.g. 1= strongly agree) focusing on the characteristics of the application as well as its potential for transfer to VR. The results of these quantitative questions are presented in **Figs. 1&2**

Fig. 1. Results of evaluators’ perceptions about the usefulness of the application regarding users with DS.

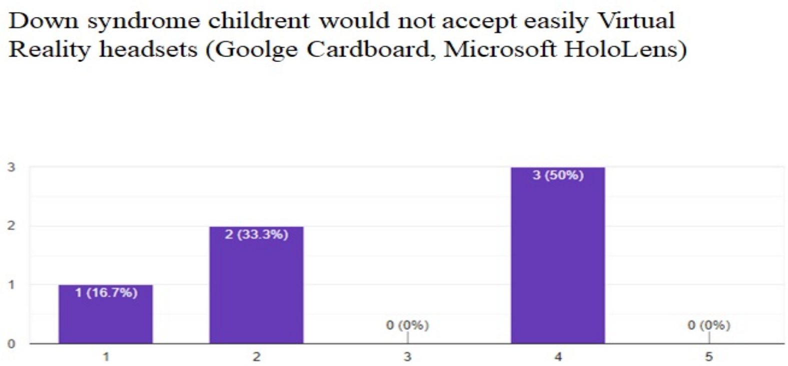

Fig. 2. Facilitator perceptions for acceptance of MR equipment for use with children with Down Syndrome.

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4 Discussion

The results of the facilitator's evaluation revealed some interesting insights. The first of these was that the facilitators did not perceive the application to have been designed with enough focus for DS users, since the user experience was not deemed transparent enough. Additionally, the qualitative responses revealed interesting design insights. The strongest point in the design was the simple but audio-visually rich design. The use of simple but impressionable color schemes and the use of audio cues for the word lists were considered significant advantages. On the other hand, the difficulty of the game, the fact that its word lists reached the 7 objects was deemed an unnecessary difficulty. Furthermore, the initial choice of having a definitive lose state and not just revert to lower difficulty at different times has been identified as key weaknesses. A common theme for improving educational efficacy was exactly this addition as well as adding the capability of repeating the audio descriptions of the word lists. Regarding the transfer to VR the most noteworthy result is that it isn't recommended by the facilitators.

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Immersing Learners: Using Immersive Technologies in the classroom to create immersive learning activities and increase student engagement.

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Abstract. The proposed research aims to investigate the use of Immersive Technologies in the classroom through supporting teachers via a sustained Professional Learning (PL) program that seeks to introduce them to new technologies that can be implemented into the classroom to create innovative learning opportunities. These learning opportunities will utilise Virtual Reality and Augmented Reality technologies to create immersive learning experiences across all year levels and subject areas with little cost to schools and parents. The project will use a Design-Based Research methodology to conduct a multi-phase research project that will see primary school teachers engaging in a PL workshop which will introduce them to the concept of Immersive Technologies and how they can be used in education. They will work collaboratively to design classroom learning activities utilising these technologies during the workshop and after the workshop, teachers will further develop and implement these immersive learning activities in their classrooms, with on-going support provided by the researcher. The teachers will reflect on the implementation of these technologies in their classroom, the activities conducted and share their perceptions of the educational benefit of Immersive Technologies. The proposed research seeks to educate and support teachers in the use and implementation of emerging Immersive Technologies, through a transformative PL program and understand how these technologies can benefit students learning and engagement while developing key 21st-century skills.

Keywords: Immersive Technology; Virtual Reality; Augmented Reality; Education; Professional Learning; TPACK; Educational Technology.

Introduction

The last 30 years has seen great advances in modern day technologies; personal computers, the Internet, mobile phones and other devices (1). Recently, Immersive Technologies like Virtual Reality and Augmented Reality has provided even greater opportunity and access to information. These technologies have changed how society works, plays and communicates. (1) Education has seen a steady uptake of these new technologies since the 1990s (2) and this has changed the way teachers teach and learn. Therefore, it has become very important for educators to learn about technologies and how they can support learning. Teacher participation in Professional Learning is a critical part of their on-going growth as an educator (3). Many Professional Learning

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opportunities are presented as one-off workshops or conferences whereby the teachers attend to learn about a valuable teaching strategy, or about changes in their curriculum or policies. Teachers usually return to their school with little to no support to help them implement their new knowledge into their teaching practice (4). The use and implementation of Technology particularly, poses a challenge for teachers to integrate into their teaching due to many limiting factors such as, meaningful technology integration due to a lack of Technological, Pedagogical, and Content Knowledge. (2).

Developing a supportive Professional Learning Framework to skill teachers in Immersive Technologies

Research Design

This research project will use a multiphase approach to support primary school teachers in implementing Immersive Technologies in their teaching.

Phase 1

The first phase will use a Design-Based Research methodology. A Co-Design Professional Learning workshop will introduce teachers to the concepts of Immersive Technologies which includes Virtual Reality, Augmented Reality and digital 3D objects and simulations. Teachers will see and experience how they can be used in their classroom to increase student engagement. They will learn new teaching strategies and develop learning activities utilising these technologies which will immerse their students in learning. In this phase, multiple data items will be collected, including a pre-workshop online survey and artefacts produced during the workshop for qualitative data analysis.

Phase 2

The second phase will collect qualitative data on the teachers' reflection on the use and implementation of these technologies in their classroom and their perceptions of the educational benefit of Immersive Technologies. This will be done through an online survey to capture as many of the participants as possible. Teachers will be invited to participate in a focus group interview, designed to better understand their experiences in creating immersive learning experiences and reflect on the impact this has had on student engagement.

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Blueprinting an edu-centric design and development workflow for a prototype mixed reality neuroanatomy resource.

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Keywords: *Medical Education, Technology Enhanced Learning, Mixer Reality, Neuroanatomy, HoloLens*

1 Introduction.

Mixed reality (MR) is an immersive modality similar to augmented reality (AR), but with one key difference; instead of the real world marker being a pre-programmed static item or image, the content overlay is done after completing a 3D mapping of the current environment. This way features can be used in intuitive ways such as tables-positioned 3D models or 2D images and "hanging" notes on walls. There is evidence that such technologies significantly increase the educational impact of an episode of learning and subsequently can have a significant impact on educational outcomes [1]. Realized examples include the incorporation of such modalities for VPs [2]. It is this immersive capacity of these modalities that allows the educational material to be internalized, avoiding conceptual errors [3]. This work presents an approach for the creation of immersive digital content for medical education based on participatory design processes in order to permeate it with content and context of the topical information.

2 Materials and methods.

4 use cases were explored for use of the immersive resource. The one selected for implementation was a lecture oriented exploratory review of the ascending and descending pathways of the central nervous system. This was chosen as the most straightforward methodological modality that is immediately relatable to the everyday practice of anatomy education. The, codenamed “HoloAnatomy”, MR application in HoloLens

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was conceived as a teaching aid for the lecturer. With that, we aimed to have a holographic "Mannequin" that would take the role of the anatomical cadaver and would present specific educational immersive material on the specific topic of ascending and descending pathways of the central nervous system. The scenario was story boarded based on the narrative of the lecture. After an initial introduction to the topic by the lecturer, the flow of the lecture would shift to the MR application, which would be projected for all users to follow.

3 Results.

The first part of the presentation included a short visual depiction of the human body. After that, a transparent depiction of a human body was presented with the only structure visible being that of the Spinal Cord (SC). The user had the capability, through the app, to select specific sections of the SC, the Pons, the Medulla or the Midbrain. There the lecturer could select one of four ascending or descending neural pathways to be depicted in each section either separately or altogether with different colorcoding. Finally, the lecturer, through a split view of the two hemispheres of the brain could demonstrate where each pathway reaches the cerebral cortex. A demonstration panel was also present for showing selected structures at all times.

The core of the edu-centric approach for the development of "HoloAnatomy" deviated from the standard software development process of requirements elicitation, design and development. Instead, it consisted of an iterative cross-disciplinary process for immersing the developers in the medical topics and the medical experts in the design processes of the digital resource. The process involved several sessions in which the medical experts actually educated the developer team in the medical topics in order for them to anticipate implementation hurdles. Also, the technical team reciprocated by familiarizing the medical educators with the technical limitations and opportunities of the medium and platform so that they make informed design choices in their iterative requests for features. This smooth development process had the added benefit of transferring useful, digital skills to the lecturer and participating medical experts so that they can be maximally efficient when they use the resource in the classroom.

The application was developed in Unity3d for the Microsoft HoloLens. After the iterative educationally centric design process, the "HoloAnatomy" application was created with just some shifts in the presentation. The core flow that was storyboarded was maintained with two caveats. The initial provision for a panel on which each section of the spinal cord would be presented has been determined by the lecturer to be disorienting. The transition between the full anatomical body and the panel was confusing both the lecturer and possibly the students. Thus, it was deemed necessary to be removed and the selected sections of the CNS to be presented mid-air in front of the whole human depiction. Beyond that, the lecturer requested that we implement two modes of presentation in the application. One "lecturer" mode and one "exploratory" mode. The first would be liner, with arrows to move forward and backward in the application's narrative so that the lecturer could focus in presenting the material during his presentation the second would be available for questions and discussion, where the lecturer could easily jump from place to place and explain things immediately as needed.

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4 Discussion and future work.

A pilot evaluation of 200 students (125 control 75 MR assisted) by the authors explored anatomy teaching using MS Hololens versus screencasts for lesson support was conducted and the results, as have been presented in a joint symposium in AMEE2018 [4] demonstrated that no significant differences have been observed between the two teaching modes. These results suggest that this resource development pipeline did not adversely affect the educational process. In addition, the use of the resource as a straight lecture aid did not tap into the strengths of seamless interaction and immersion of the MR resource. It is expected that through more learner-centric incorporation of such resources their true potential will be realized.

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Usable Virtualization of Guided Inquiry*

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Abstract. Improvements in immersive interactive technologies have made the creation of effective educational software running in a (three dimensional) Virtual Learning Space (VLS) feasible. Applications built for these environments may leverage the inherently visual and dynamic interactivity of the technology to accelerate learning outcomes; however, a set of design principles for effective VLS application development is needed to do this optimally. One of the most important design principles is assessment followed by "Immediate Feedback" with targeted instruction–a principle which is central to many instructional design approaches, such as Inquiry-based learning, and for which an adaptive control style implementation shows promise. In this study, a guideline for effective implementation of evidence based principles of learning and memory within VLS environments, using intelligent tutoring system (ITS), is developed using the ProMethEUs methodology for domain heuristic generation.

1 Introduction

Immersive environments coupled with intelligent content delivery–commonly referred to as Intelligent Tutoring Systems (ITS)–together make for an emerging and yet to be explored area of learning design.

The practical aspects of how learning activities could best be designed within this domain, remains unanswered. A set of design heuristics is presented here to meet this need. They are the result of combining existing usability heuristics for general software design, for educational software design, and for software designed for virtual spaces. These, along with evidence based principles of human learning and memory, taken from current cognitive science literature, have been transmuted into a comprehensive guideline for VLS application development. In particular, VLS coupled with strong emphasis on feedback–as a form of guided instruction with facilitation. In future work, the current artifact will be validated and refined according to the same methodology used to generate it: ProMethEUs[2].

Problem Statement

The confluence of existing environments constitute a domain, and each new domain has its own properties which require something beyond what general or preexisting usability principles can readily manage.

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The design of content that can accelerate learning, set within the VLS environment and augmented by ITS, is an emerging domain which stands in need of a framework for guiding designers and content domain experts–regardless of their backgrounds in the learning sciences. This study seeks to meet that need.

2 Literature Review

The methodology chosen for generating the domain heuristic starts with the collection phase [2], in which existing assets (i.e., heuristics or software applications for the given domain or sub domains) are cataloged, ranked, and described.

Domain Heuristics

The term *domain heuristic* describes a set of design and evaluation rules for an application domain. Often such domains are easily described by combinations of other sub domains having preexisting design heuristics. A valid approach their construction should be identified, however.

ProMethEUs [2] is a procedural methodology for evaluation of usability heuristics that is an extension of a methodology proposed within an earlier study [3]. Both take into account all requisite steps identified in [1]: collection, transformation, validation, and effectiveness. ProMethEUs more thoroughly articulates the steps to follow, the artifacts to be constructed, and the metrics needed to generate a valid artifact.

3 Method

Design and Validation Approaches

The ProMethEUs methodology is the more robust of the two identified above, while not requiring significant additional burden of process. It is selected as the methodology of choice for this study. Currently in the explanatory stage of the methodology, the results reported here are the first iteration of the domain heuristic–after the normalization and prioritization, but prior to the validation and refinement phases.

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Hearing the Voices of ILRN What We Learn from Listening

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Abstract. This article explores the nature of work that the membership of ILRN is undertaking. Through an analysis of survey results and podcast recordings, this article lays out the key areas where the respondents have undertaken work, what they wish in terms of their next steps and what they view as the biggest questions yet to be answered in the field. A review of these results indicate that there are vast areas of potential for the field as a whole, but we have to navigate some of the growing pains inherent in a relatively young field of study.

Keywords: Listening, Immersive Learning, Survey, Podcast.

1 Introduction

1.1 The Importance of Listening

"Wisdom is the reward you get for a lifetime of listening when you would have rather talked."

Doug Larson

As with many academic I know, I am more than happy to stand in front of a group of people and talk at them for what may seem an interminable amount of time – at least to the people doing the listening. Additionally, my students would likely say that I am prone to tangents and "soapbox standing" on occasion, however, they would likely be a bit more diplomatic about their wording. If I am honest with myself, my default position in front of a group is to be the one talking, not the one listening. The common platitude that every first year teacher can repeat back without delay is that they should be "The Guide on the Side, not the Sage on the Stage." And while I agree in general with that axiom (as ill-defined as it may be), I must admit that I do not always follow its edicts. Of course, as with almost all things, balance is the key. It is perfectly fine to be the lecturer, as long as lecturer is not all you are.

However, as Doug Larson (as quoted by Meah, 2018) so artfully stated, wisdom comes from listening, not talking. As such, the purpose of this article is to describe the results of my efforts to listen more – specifically, to listen to the voices making up the Immersive Learning Research Network (ILRN). What wisdom would those voices provide? What lessons might be gleaned from better understanding the work that is already

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being done into immersive learning, and how might those lessons most effectively and efficiently be disseminated to the widest audience? This article is intended to take a first step towards answering these questions.

1.2 The Nature of the Conversations

There are two distinct types of opportunities for listening that this article will describe. The first of these is an online survey and the second is a series of conversations between scholars that has been released as a weekly podcast since 2015.

Survey. Birthed out of a desire to better understand the current work that is being undertaken by the membership of ILRN, a survey was administered during the spring of 2018. This survey was sent electronically to every individual on the ILRN membership email list. It gathered information on the background of the participants, the nature of the research work they undertake, and the future directions they wish to move towards as they progress in their careers. The specific questions that were asked on this survey are as follows:

- Where are you physically located?
- What is your field of study?
- How long have you been working with immersive technology?
- What variables and/or phenomena do you explore in your work?
- What methodologies do you use in your research?
- What are your data (unit of study)?
- What kinds of hardware do you use in your work?
- What kinds of software do you use in your work?
- Have you received any sort of external funding for your work?
- What are some future directions for your work?
- What do you consider the biggest unanswered questions in your area of study?

Podcast. The second source of information that this article will describe is the conversations undertaken as part of the ILRN-supported podcast, The Versatilist. This podcast consists of a series of weekly conversations with scholars in various immersive learning fields. The nature of these recorded sessions is conversational in tone, and the individual who is being interviewed guides the substance of each recording. This podcast series has been live since the summer of 2015.

Interviewees are identified through the ILRN membership lists along with a series of Google Scholar alerts associated with the terms "Augmented Reality + Education," "Virtual Reality + Education," and "Immersive Learning." These alerts result in the regular delivery of an email digest of the most recent articles published in these fields. The author(s) of those articles that appear interesting are contacted and invited to participate in the podcast recording. Each recording is usually between 30 and 40 minutes long, and consists of a short introduction to the guest, a longer discussion of their work, and a concluding segment intended to give them an opportunity to discuss the areas of concern within their field that they are trying to "fix" with their work.

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2 Methodology

2.1 Analyzing Survey Results

The survey results consisted almost entirely of qualitative responses to open-ended questions. As such, a thematic qualitative analysis was conducted to determine themes that emerge from repeated readings of the responses. The results of this analysis were then quantified to demonstrate where the major consensus was held within the answers to a particular question (if there was such a consensus).

2.2 Analyzing Podcast Content

A database of the podcast recordings has been maintained over time, containing the guest name(s), the title of the work that they were discussion, and their physical location. This database was also coded thematically in terms of the topics that have been focused upon so far on the podcast. Additionally, a geographic breakdown was developed to determine where the interviewees are located.

3 Results

3.1 Survey Results

A total of 56 responses were returned for the ILRN survey. Although this is a very small response rate given the size of the ILRN membership email list, it would still be considered a starting point for the conversation. It is difficult to know how representative this sample is of the larger ILRN population, but it can safely be assumed that it consists of academics that are highly motivated to take part in the conversation.

Location, Field of Study, and Experience. The first three questions on the survey asked for general demographic information about the respondents. The sample was weighted heavily towards European (50%) and North American (30%) respondents, making up more than 80% of survey participants. Unsurprisingly, similar percentages of the respondents indicated that they came primarily from the academic fields of Education, Computer Science, and the Humanities (79%), and had fewer than 15 years worth of experience researching immersive learning technologies (82%).

Variables. There was no clear consensus in terms of the variables that were studied. The responses for this particular question varied greatly and included the expected topics such as motivation, engagement and learning while also including more granular topics such as foreign language anxiety, evolution, and heritage.

Methodologies. As with the responses concerning variables, there was no clear consensus in terms of the methodologies used to study them. The responses for this particular question varied greatly and included the expected qualitative, quantitative, and

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mixed-methods approaches. In several cases more specific examples were provided, such as virtual ethnography, Action Research, Covert Turing Tests and Cultural Historical Activity Theory, but the general response indicated relatively traditional qualitative and quantitative approaches, with neither being a clear favorite of respondents.

Hardware. Unlike previous areas, there was a clear consensus in the area of what hardware was used. As would be expected, the majority of respondents identified their preferred computer system – although no clear preference was identified for Windows or Mac machines. Following that category was the use of some sort of Head Mounted Display (HMD), which was identified within 48% of responses. The most popular HMDs that were specifically identified were Oculus Rift and HTC Vive. The third most common category of technology was mobile devices of some sort (phone, tablet, laptops), which were identified within 34% of responses.

Software. In this particular area there was also a general agreement that Unity 3D (43%) was the software of choice. OpenSimulator (16%) and Second Life (9%) were distant second and third choices.

Future Directions. When asked directly about what future directions the respondents would like to take for their work, some intriguing opportunities presented themselves. There was no clear consensus around a single issue, but the responses did solidify around four areas: Collaboration/Networking, General AR/VR technical research, Specific Content Areas (such as Language Learning) and the Nature of Learning within immersive settings. Some variation of these four categories was identified on 80% of survey responses. As can be seen in Figure 1, none of these four categories clearly outstripped any other.

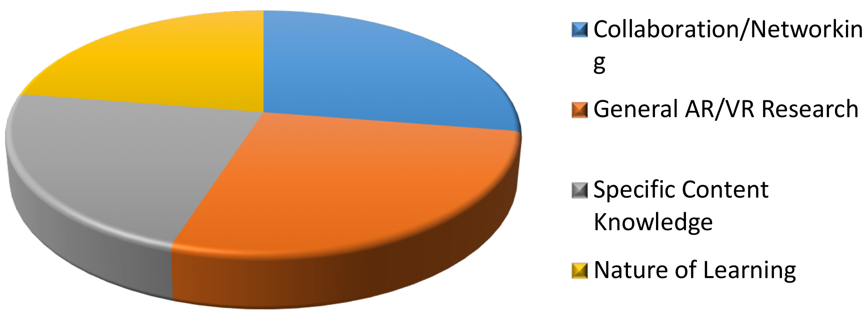

Fig. 1. Distribution of four most commonly identified directions for future research

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To a lesser extent, participants identified evaluation practices or specific technology issues (9% each) or game-based learning (7%) as their next professional step.

Unanswered Questions. The responses to this particular question also mirrored the response to the future research in that there was no clear consensus on one area. Interestingly, however, these categories differed from what respondents thought of as their next step in their research agenda. Specifically, the responses for this question, which accounted for 57% of responses, focused on the following four areas:

- Specific Technology Issues (that is, “How do I get tech X to do what I want it to do?”)
- Pedagogical Design Issues (that is, “What instructional designs will benefit from these technologies?”)
- Benefits and Impacts (that is, “Is this technology even worth it?”)
- Research and Evaluation (that is, “What are the most effective approaches to studying these issues?”)

As can be seen in Figure 2, there was relative balance across these four areas when they were identified as the biggest remaining question.

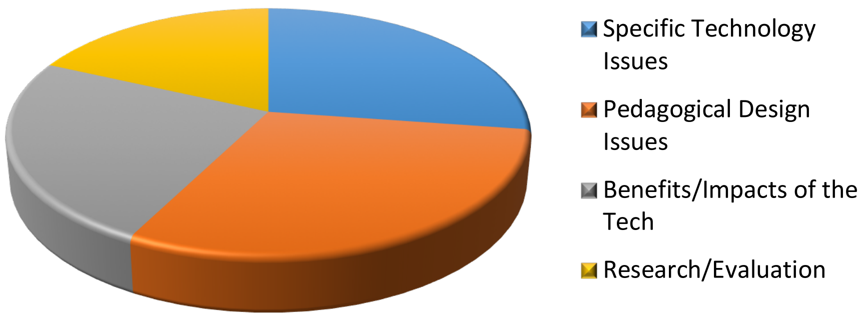

Fig. 2. Distribution of four most commonly identified “biggest unanswered” question

To a lesser extent, respondents identified Learning Theory issues (7%), Specific Content Learning (5%), Scalability & Portability (5%), Funding (3%), Gender Issues inherent in the technology (3%), and Embodiment (3%) as unanswered questions waiting to be explored.

3.2 Podcast Results

As mentioned previously, there have been 120 episodes of the Versatilist podcast to date. Fifteen of those released episodes were removed from the analysis due to the fact that they represented recordings of ILRN Conference-based material (such as

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conversations with ILRN Board Members about upcoming conferences or recordings of presentations given at prior ILRN conferences). The remaining episodes were analyzed thematically based on their content, and the geographic representation for interviewees was determined.

Location. As with the survey respondents, the majority of interviewees for the podcast were from either North America (53%) or Europe (27%), while Australasian participants comprised the third largest group (11%) followed by Asia (7%).

Content Analysis. The content analysis indicated that there was no predominant area that the podcast interviews focused upon. As can be seen in Figure 3, the four most common topics were Art/Museum/Culture, General AR/VR Research, Usage in K-12 Settings, and Hardware/Software Development. These four areas combined to account for 65% of the podcast recordings.

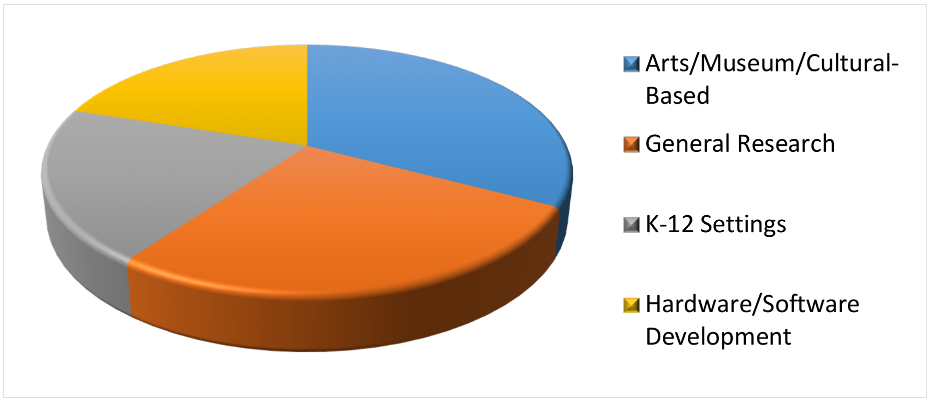

Fig. 3. Distribution of four most common content themes from podcast recordings

Additional themes that were the subject of podcast recordings are the use of these technologies in Engineering, for disabled individuals, for literacy instruction, within medicine, at the college level, and to facilitate physical activity.

4 Analysis

It is important to understand that drawing conclusions about the field as a whole from what amounts to a relatively small sample size is fraught with difficulty and should not be undertaken lightly. Having said that, however, there are insights that can be gleaned from these data, and if we listen to it carefully we may be able to gain some of the wisdom we all desire.

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4.1 How do we Listen Effectively and Efficiently?

The first insight to explore is what we can learn from such diversity in the case of variables and methods. The fact that there is very little consensus within these areas should not surprise us given the fact that we are working in a relatively young field. One might quibble that some form of "immersive learning" has been around for decades and decades, but the reality is that most of us have been working in the field for fewer than 15 years (at least according to the survey results), and a field of study such as this is bound to be a bit disjointed and unstructured. In fact, and quite honestly, this lack of focus could be seen as a strength rather than a weakness. It is through exploring the numerous facets and directions that we will get a better picture of the landscape.

The issue we confront here, though, is the difficulty that this "disjointed-ness" creates in terms of learning from each other. The fact that so many of us are still researching variables such as motivation, engagement and "learning" would indicate that either those issues are not yet settled or that we are not aware of work already done to answer those concerns. I would argue that these issues have largely been covered – in fact, some of the earliest work in educational uses of Augmented Reality dealt with its effect on engagement and motivation (Dede, 2009; Dow, et al., 2007; Dunleavy, Dede, & Mitchell, 2009; Squire & Klopfer, 2007, to name a few). Thus there is a good deal of work to do on getting that word out effectively. It is perfectly fine in a young field of study to re-tread ground that has already been covered, but over the long-term that does not lead to much forward momentum.

If we were to accept this as true, then the next logical question is "How do we get better at learning from each other so that we don't continue to cover the same ground?" Perhaps unsurprisingly given the title of this particular article, my answer to that question would be founded in our ability to listen to each other. There are numerous means through which we can get the word out about our own work – we publish articles, chapters and books, we give presentations at conferences, we teach, and we use social media (among other possible avenues). But the reality of the situation is that this process is fundamentally a "loud" process. There are so many avenues for disseminating results that it becomes difficult to identify any particular subset of them that makes sense to follow to get the whole picture. In essence, we have lots of means to "talk" but very few ways to "listen" efficiently and effectively. The result of this is a natural tendency to follow those voices in our own specialized field, but by doing so we run the very real risk that we are creating echo chambers where we are missing important outside voices that could provide context to help us move forward.

4.2 Aligning Next Steps with Unanswered Questions

Another insight that I would highlight from this data is the disconnect between how we view ourselves as researchers and how we view the field as a whole. There is very little reason to disagree with the next steps that individuals have identified in their own practice. After all, we make our choices about our research agendas based on our own interests and circumstances. Likewise, there is little reason to question the perceptions of the group concerning the big unanswered questions in their fields. Those people closest

DOI: https://doi.org/10.3217/978-3-85125-657-4-37

to the problem are likely to be the best suited to identify the issues associated with the problem.

However, we should recognize the disconnect between what we see as the unanswered questions and the steps that we are taking professionally. The survey responses indicate a need to answer questions like "What instructional designs will benefit from these technologies?", "Is this technology even worth it?", and "What are the most effective approaches to studying these issues?". But our own focus moving forward is much more granularly on things like creating and building professional networks for collaboration and using these tools to teach content like foreign language and cultural awareness.

Obviously, an argument could be made that each of the steps that we take in our own research is a step towards answering the biggest questions out there. In fact, I wouldn't argue with any researcher who stated that explicitly. After all, the saying "a journey of a thousand miles starts with a single step" is true on its face. The difficulty here is that the opposite is not by necessity true. A single step does not always lead to a thousand-mile journey. It is only through understanding the overall objective that we can effectively plan out how each step leads us to answering the unanswered questions in the field.

4.3 Expanding the Community

Another result from both the survey and podcast analysis that stands out is the clear over-representation of European and North American voices in the conversation. The fact that approximately 80% of survey respondents and podcast interviewees are drawn from these geographic area would seem to be a clear indication that voices from outside these areas are missing. It is quite a stretch to believe that this is by design, so the intent here is not to ascribe ill-intent, however, it is imperative that we expand the community. There is exciting work that is taking place in Asia, South American and Africa in the field, and making a more concerted effort to bring those voices to the table will provide invaluable context for how to address the biggest questions at hand.

The means through which this is accomplished would appear to require active participation on the part of the leadership of the community as it is presently constructed. As a start to that process, thought leaders from these geographic areas should be approached and actively recruited to participate. These individuals would then be able to recruit other scholars from their regions to participate. In order to ensure the best chance for success in this endeavor, there is a need to think about structures that would incentivize participation. This could include key speaker slots at conferences and positions on the ILRN Board, but it may also include more mundane concerns such as a more inclusive meeting schedule for time zones in Asia and Africa.

5 Conclusions

This is clearly a very exciting time to be involved in immersive learning. The tools are developing and expanding rapidly. The field of research is relatively new and the community of people working on these issues is still small enough that an effective and

DOI: https://doi.org/10.3217/978-3-85125-657-4-37

vibrant network can be developed. There is a sense that these tools can act as the agent to facilitate large structural changes in how we educate each other. All of that in mind, it would be difficult to not be excited about the possibilities.

The purpose of this article is not to put the brakes on that excitement. In fact, I see it as quite the opposite. The reality of the situation is that we have opportunities to tap potential we do not even know about yet. The main impediment that I see to making rapid advances is that we are insolated in our domain silos and do not search out views from outside that silo. We need to find ways to effectively learn about what people outside of our particular specialization are working on. Organizations such as ILRN are an effort to break down those walls, but more work is clearly needed. A secondary concern is that we might spend too much time talking at each other, and not enough time listening. If there is a “call to arms” to be found in this paper it is that we should be working on building into our organizational structures the systematic means through which we can listen. After all, that is the fastest way to wisdom.

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New Spaces - Learning in the Global Languages & Cultures Room

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Abstract. This session aims to introduce delegates to the Askwith Kenner Global Languages and Cultures Room, which is designed to encourage the adoption of immersive technologies in foreign language and cultural study.

Keywords: Creative Learning Design, Language learning, Cultural studies.

1 Introduction

1.1 Reshaping Learning for All in Immersive Learning Environments through Creative Learning Design

This session forms part of the Reshaping Learning track and aims to introduce delegates to the Askwith Kenner Global Languages and Cultures Room[1]. This room is designed to encourage the adoption of immersive technologies in foreign language and cultural study. Opening in August 2019, the room provides workshops, teaching spaces and lab facilities for those seeking to engage with XR and adopt its use in the delivery of teaching and learning.

The Global Languages and Cultures Room is a multi-purpose classroom and lab designed to engage students in language learning and inter-cultural competence. It is equipped with VR technology and an immersive space for interactive presentation. The room funds projects in collaboration with partners across the university, including the ETC - Entertainment Technology Centre, creating new experiences and applications for use in curriculum delivery. The room also runs electives for students and staff on XR use, focusing on curriculum delivery and use in teaching and learning, with the aim to explore a pedagogy for immersive technologies.

In this session delegates will gain insight into the workings and current progress of the room, through an overview of recent projects. Delegates will discuss strategies for adoption of immersive technologies in the curriculum, current challenges and longer-term aims. We will discuss ways to engage students in the technology and opportunities

[1] https://www.cmu.edu/dietrich/modlang/kenner-global/

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for educators to gain greater confidence in the design of learning that addresses the particular affordances of XR. We will look at case studies and further examine the role of XR in the development of language learning and cultural study.

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360 3D Interactive Learning Experience for Communication and Feedback

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Abstract. We present a 360 3D interactive learning experience to improve communication and feedback within the corporate environment. The experience is consumed through Oculus Go. After a brief contextual introduction, the experience places the user in the employee point of view in front of a boss who explains a situation. The user has to take action choosing among three different text responses. Once a user has taken action, the boss answers in consequence.

Keywords: 360, interactive, 3D, communication, feedback

1 Description

Communication and feedback are two of the most demanded soft skills in today's corporate activity. We have designed an experience that demonstrates how soft skills can be effectively trained through the use of 360 3D Interactive Video.

We have designed an interactive plot in which the user plays the role of an employee that has been called to a meeting at his/her boss' office. The experience starts with the user inside an office. Then a presenter steps into the office and explains to the user the context of the situation and what is expected from him/her (Pic 1).

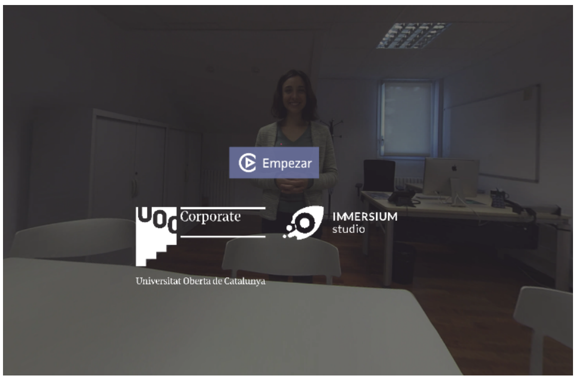

Fig. 1. Introduction

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Once the introduction has been completed, the user has to choose among three bosses (Pic. 2). Each boss represents a stereotypical role: aggressive, passive and assertive.

Fig. 2. Bosses menu.

Once the user has chosen a boss, the door opens and the selected boss steps into the office. Then the boss sits down at the other side of the table, explains the situation to the user and asks him for an answer. The user is then presented with three answer options, chooses one and the boss reacts to the chosen answer.

Once the boss has reacted with a speech to the user answer, he/she leaves the table and the presenter steps again into the room to debrief the experience and offer the user to either try another answer or try another boss.

This way, the user can explore which is the effect of different strategies answering the three different bosses' profiles.

Immersium Studio is a spin-off born from the Universitat Oberta de Catalunya which focuses its activity on the application of immersive technologies to education, culture, health and tourism.

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Demo: Mobile VR Site Experiences for Education in the Earth Sciences

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Abstract. A focus of our work is creating mobile educational VR site experiences for smartphones or low-cost standalone HMDs, suitable for a wide range of learning scenarios. Such experiences are of particular importance for Earth Science disciplines, such as Geography, Geosciences, Biology, and Ecology. In the demo session, we will showcase two of these experiences of real world places and demonstrate how they can be employed in different learning scenarios.

Keywords: Virtual field trips · SENSATIUM · Earth science education.

1 Introduction

The adoption of immersive technologies and associated experiences into classrooms is on its way [1]. However, this trend in immersive learning needs to be accompanied by both basic research [2,3] and studies in the wild [4]. ChoroPhronesis is conducting a wide range of VR and AR projects with the goal of (a) promoting the mainstream adoption of immersive learning environments and experiences into the day-to-day learning portfolio of instructors and students, and (b) of empirically assessing the benefits and effects of these experiences.

A focus of our work is creating mobile educational VR site experiences for smartphones or low-cost standalone HMDs such as the Oculus GO that allow for providing easy and low-cost access to the learning content to the masses and are suitable for a wide range of learning scenarios including individual learning, group classroom experiences, and multi-user experiences with remote participants. Such experiences are of particular importance for Earth Science disciplines, such as Geography, Geosciences, Biology, and Ecology. Providing virtual alternatives to actually visiting a place allows for reducing costs or risks, incorporating additional perspectives and simulations not available during the real visit, or re-living the experience as often as desired.

In the demo session, we will showcase two of these experiences of real world places (explained further in the following) and demonstrate how they can be employed in different learning scenarios. Participants will be able to try out and get hands-on experience with the two applications to get a better impression of the potential these kinds of VR experiences provide for immersive learning. We will also discuss some results from running empirical studies to evaluate these kinds of VR experiences.

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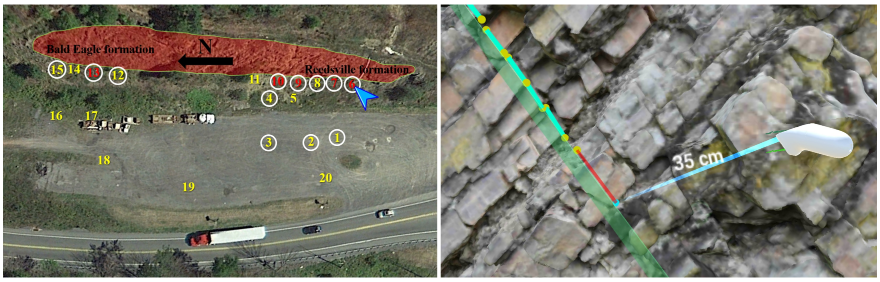

Fig. 1. Study area (Source: Google Maps) and interactive measuring.

2 Demo Application 1: A Geoscience Virtual Field Trip

Immersive virtual field trips (iVFTs) hold the promise to deliver access to a site almost independent of space and time. This particular mobile iVFT delivered through Oculus GOs leads students to the Reedsville and Bald Eagle geologic formations accessible through an outcrop about 12 miles from our university. We used a combination of 360° images and structure-from-motion photogrammetry to capture the field site digitally. Figure 1 (left) provides an overview of the Reedsville/Bald Eagle field site in the form of an aerial image. The numbers indicate locations where we took high-resolution 360° images. Locations indicated by yellow numbers allow users to experience the outcrop from an elevated perspective (27'/8.2m). Locations with a white circle include audio information. The blue arrow shows the location at which users have to measure the stratigraphy by accessing a 3D model of a part of the formation (see also Figure 1 (right)). Users can access essential details of the outcrop and additional information usually found in the field through interactive markers embedded in the 360° images and higher resolution photographs.

3 Demo Application 2: Joint Wildfire Ecology Experience

The Ishi Wilderness in California is one of the few contemporary examples of structurally restored old-growth ponderosa pine forest making it particularly interesting to wildfire ecologists and relevant for establishing fire and forest management strategies. The VR application we developed in collaboration with wildfire experts uses two different kinds of views (see Figure 2, two leftmost images): First, an overview map showing the locations of where 360° images, ground level and elevated ones, were taken. Second, upon selecting one of the locations, the user is instantaneously teleported into the 360° image view allowing for an embodied experience of the location while listening to audio comments by the experts. A visual guidance approach showing flashing circle markers and arrows helps with following which parts of the scene are being explained.

We enhanced the Ishi app with a multi-user VR component allowing several instances of the app to enter a joint session. To realize guided tours, the application can be set into 'Lead' mode or into 'Follow' mode. All scene/location changes made by the leading instance will be reflected by all instances currently in follow mode. We designed

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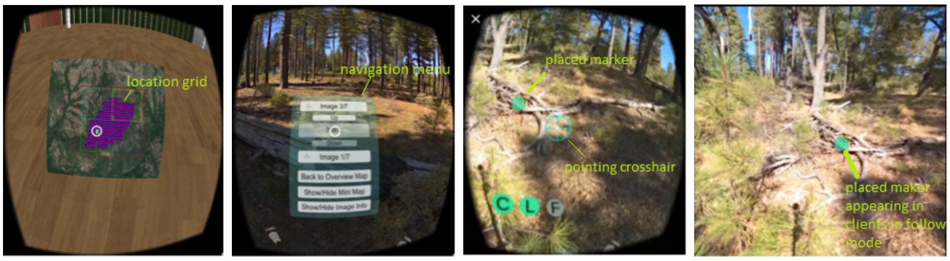

Fig. 2. Ishi app. Left: Overview and 360 view. Right: Lead and following client view.

a pointing approach (Figure 2, two images on the right) that allows for placing markers in the scene that will then become visible to the other users. This joint VR component allows for implementing scenarios such as teachers guiding their classes or remote students through the experience, or experts informing a group of decision makers.

4 Demonstration Details

We will provide several Oculus GOs for this session. After a demonstration and overview of the two applications, participants will be able to put on GOs and try out the applications themselves including the different roles in the joint version of the Ishi Wilderness application. We will continue with a discussion of the impressions and wrap up with a brief report and further discussion of insights we gained from running empirical studies with the iVFT application.

We hope that the demonstration and hands-on part will inspire new ideas and a productive discussion on novel ways to employ VR site experiences in Earth Sciences education programs and how to evaluate the effectiveness of these experiences.

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Cubist's Visual Reality/CVR Device Hands-on Demo and Experiment

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Abstract. This is the presentation of the Cubist's Visual Reality/CVR Device experiment and demo, which aims to impel the participants to change their perspective and become more conscious of how we see and navigate in space.

Keywords: perception, spatial cognition, viewing device, drawing, navigation

1 Presentation of the CVR Device Hands-on Demo.

The visual arts have always been a creative viewpoint through which we see and understand the world around us. As an architect and artist I have always been interested in comprehending what lies beyond of what we can see; what are all these forces that form our experience of space. Of course, this is a part of the architectural method; to understand how space works and how can this knowledge be used for a designed *telos*. For that to happen we need to be conscious about how and when we perceive our immediate environment.

It takes time to design something as big as a city or even as small as a house and sometimes it takes even more time to cognitively understand how we navigate in space and our built environment in extent. Although, in our days we have so many digital tools to help us in this task, we still rely on the abilities of our brain and bodies. At the end of the day, our existence begins and ends with them and anything beyond them would be an assisting tool. Therefore, while we explore the Virtual/Augmented/Cross realities as we should, we owe to be able to be conscious of our Physical reality.

When we place ourselves into an unfamiliar space or when the sense of depth that we so accustomed to is eliminated, it is inevitable that we (our brains) will aim to make sense of what we see. In this way, acting under unusual conditions impels immediate reconsideration of the given parameters. This has been one of the tools that the artists of Cubism [1] used in order to reinstate the sense of time in an artwork. In a 'typical' Cubist painting the perspective would be fragmented in such a way that the viewer would be able to many sides of a given still-life or portrait. This perspective would have nothing to do with the perspective of the Renaissance which resembles the way that we see space; as close as it could be by using one viewpoint while we use two – our eyes.

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In my current work I am researching how vision functions, initially through fragmented viewing, in an attempt to replicate what the world would look like through the Cubist perspective, which was very much influenced by the virtuality of the fourth dimension as time [2]. For that reason, I created the Cubist's Visual Reality device (CVR device) which has a wearable version [Fig.1] and as well as a camera attachable version.

Fig.1 (left) Maritina Keleri (2018) CVR Device, wearable, version 5.

Fig.2 (right) Maritina Keleri (2018) CVR Device, wearable, experiment at Tate Exchange 2018

2 Structure and expected outcomes.

The proposed hands-on demonstration aims to engage the audience in an experiment of spatial perception which will be achieved with two ways. The first will be to invite them to draw what they see while looking through the wearable CVR Device [Fig.1 & 2]. The goal will not be to demonstrate a skill in drawing but it will be to offer the viewer a tool of understanding spatial perception. The second way will be to wear the device and try to navigate into space, testing this way the adaptability of our brains when our visual field changes.

The objectives of the Demo are to review the experimental method of the CVR Device by documenting the it via video recording and data collection through a questionnaire, as well as review how much time each participant needs to adapt to the new *visual reality* and to what level they would get dizzy. The final objective will be to record the drawing process and discuss with the participant their experience of the drawing and help them understand the process they followed (e.g. what they drew first, where their eyes focused first etc). The goals and expected outcomes of this experiment are to encourage the audience to use this analogue medium and enhance perception as well as making them conscious of the way we see and navigate in space. Additionally, I am wishing to collect date that in a later stage will be applied in VR environment design, as vision is the sense that is primarily involved.

The CVR Device demo will last 120' and the audience will have the chance to try the 9 different versions of the wearable device either by drawing or by navigating in space. Their experience will be discussed and the key elements will be recorded via video and questionnaires. The targeted audience is Architects/urban designers/interior designers, VR/AR/CR designers, artists, performers, neuroscientists and everyone who would like to experiment with the devices or is willing to question their visual perspective.

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