Dennis Beck · Colin Allison
Leonel Morgado · Johanna Pirker
Foaad Khosmood · Jonathon Richter
Christian Gütl (Eds.)

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Immersive Learning Research Network

Third International Conference, iLRN 2017
Coimbra, Portugal, June 26–29, 2017
Proceedings

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iLRN 2017 Preface

The iLRN conference is planned by the Immersive Learning Research Network (iLRN), an international organization of developers, educators, and research professionals collaborating to develop the scientific, technical, and applied potential of immersive learning. This year's conference was the third annual meeting of reporting high-quality results in immersive learning research. Effective immersive learning experiences are created within multiple media using myriad techniques and employing a wealth of knowledge that spans many disciplines wherein immersive learning and training may be relevant. The vision of iLRN is to seek out, innovate, and share the evidence and potential for immersive learning. One way of doing this is by hosting a worldwide conference for immersive scholars from across the disciplines, beginning in 2015 in Prague, Czech Republic. These conferences are designed to support and create opportunities for ILRN members to meet in collaborative contexts and build their professional immersive learning research and development capacities, and share practical experiences in various scientific tracks and other presentation formats. But more than this, they were devised as an incubator during which iLRN members can collaboratively develop a comprehensive research and outreach agenda that encompasses the breadth and scope of the learning potentialities, affordances, and challenges of immersive learning environments.

The third annual iLRN conference was held this year, hosted at the University of Coimbra in Portugal, one of the oldest universities in the world, dating from 1290, just one century after the founding of the Portuguese nation. Situated in the heart of the historic city of Coimbra, the university is poised amidst a fusion of new and old, as newer technology corporations and non-profits vie for prominence with historic architecture and tourism attractions. It is a setting where we hope to better define "immersion" and what that means across our connected interdisciplinary focus. We hope to highlight what "immersive" learning means to a number of focused disciplinary areas. We hope to immerse ourselves in a number of designed experiences to compare and contrast what capabilities they bring – and what things they disallow or take away.

This year's special focus was "Honoring Tradition, Immersed in the Future." Set at the nexus between old and new, with ancient physical structures mixed among modern architectural marvels, this year's conference concentrated on the fusion between old and new in immersive learning. Creating immersive experiences is becoming easier every day, but doing it well so that people learn effectively is much harder. People engaged in the production of high-quality immersive learning experiences, thus, must be a specialist in one or more disciplines with the ability to appreciate and work effectively from the lens of other specialties. Some of these specialists will be from "old" professions, such as writers, teachers, thespians, attorneys, and sports professionals, while others will be from newer occupations such as computer coders, 3D graphic designers, and educational technologists. Creating effective learning experiences using immersive technologies requires the coordination of both “old” and “new” types of special expertise and effort. Old and new must work together.

As such, this conference is focused on providing opportunities for individuals from a wide variety of areas to share their information across the fields involved with the research, development, implementation, practical experiences, and business of immersive learning. The conference format was designed to gather submissions to the main track focusing on the conference theme, while the six special tracks, workshops, and two publication outlets were planned to draw more interest from diverse communities of scholars and practitioners based on discipline, methodology, or technology type. Five stimulating keynotes from academia and research-sponsored industry complement the technical program. We showcase and discuss all of this scholarly and embodied experience through our podcast, *The Versatilist,* with our host and 2017 ILRN Finance Director, Dr. Patrick O’Shea. The podcast is one great way for us to explore the scope and depth of this exciting emerging interdisciplinary field.

Like the inaugural conference, iLRN 2017 was an important forum for immersive learning research. The call for papers resulted in a total of 76 submissions from around the world. Every submission underwent rigorous review by at least two members of the Program Committee to keep high scientific and quality standards. The editorial board decided, based on the reviewers’ comments, to accept 17 full papers and four short papers for the proceedings, which is an acceptance rate of 27%. The full papers are arranged into two parts in the proceedings, the main track and the special tracks. The accepted papers’ authors are from: Austria, Brazil, China, Cyprus, Finland, Germany, Greece, The Netherlands, Norway, UK, Portugal, and USA (Arkansas, Indiana, Massachusetts, Minnesota, Ohio).

We would like to thank all who contributed to the success of this conference, in particular the members of the iLRN committee (and the additional reviewers) for carefully reviewing the contributions and selecting a high-quality program. Our academic chair, Christian Guetl, did a perfect job of organizing and coordinating the conference details. Michael Gardner performed admirably as general chair, as did Anasol Peña-Rios in her role as website and communications director. We also thank all of the international chairs and board of reviewers for their support. Colin Allison did an incredible job as program chair, handling the development of a wonderful program, and Johanna Pirker and Fooad Khosmood did the same in their roles as the special tracks co-chairs. Dennis Beck prepared and organized the Springer proceedings and ensured that every submission was of high quality, spending hours interacting with authors and other editors. Thanks also to Leonel Morgado, Ana Amélia Carvalho, and João Caetano for serving as local co-chairs and coordinating all of the very important details in Coimbra along with their doctoral students. Of course, we would like to especially thank Jonathon Richter, iLRN executive director, for taking care of the local arrangements and many other aspects in the organization of the conference.

The following people performed admirably in their roles as special track organizers:

- Alexander Nussbaumer, Rob Nadolski, and Samuel Mascarenhas – “Personalization in Immersive and Game-Based Learning Environments”
- Alexandra Gago da Câmara, Helena Murteira, and Maria Leonor Botelho – “Digital Heritage and the Immersive City”

- Johanna Pirker and Foaad Khosmood – “Immersive and Engaging Educational Experiences”
- Ilona Buchem, Ralf Klamma, István Koren, Fridolin Wild, and Alla Vovk – “Wearable Technology-Enhanced Learning”
- Markos Mentzelopoulos, Daphne Economou, and Phil Trwoga – “Serious Games Using Immersive and Assistive Technologies”
- Ana Isabel Veloso and Ruth Contreras Espinosa – “Immersive Experiences in Later Age”

We hope that you enjoy reading the content of these proceedings. Browse the papers, reflect on the interdisciplinary connections and applications, contact the authors to continue discussions, and continue to advance iLRN’s immersive learning agenda by becoming part of both “old” and “new” – able to apply a depth of skill to a progressively widening scope of immersive learning situations and experiences, equally at ease with technical issues as with disciplinary strategies and content.

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iLRN 2017 Main Conference Preface

ILRN 2017 was the third annual international conference of the Immersive Learning Network. It followed on from the inaugural conference held in Prague in July 2015 and the second conference held in Santa Barbara in June 2016.

The past 12 months saw a further increase in the availability and capabilities of devices that support augmented and virtual reality systems. The mission of iLRN is to stimulate the use of, and share knowledge about, these exciting technologies as they are applied effectively in education and learning scenarios. This requires fundamental and applied research from both single and inter-disciplinary approaches. iLRN includes but does not limit its focus to virtual and augmented worlds, learning and motivational games, educational simulations, mixed/augmented reality, related learning and teaching tools, techniques, technologies, and standards. iLRN aims to develop a comprehensive research and outreach agenda that encompasses the breadth and scope of all the learning potentialities, affordances, and challenges of immersive learning environments. To achieve this, iLRN 2017 invited scientists, practitioners, organizations, and innovators across the disciplines to explore, describe, and apply the optimal use of immersive worlds and environments for educational purposes. The conference aims to explain and demonstrate how these immersive learning environments best work using a variety of rigorous, systematic, and meaningful research methods and outreach strategies. In all, 46 papers were received for the main conference and after a rigorous reviewing process ten were selected as full papers and three as short papers for this Springer publication (28% acceptance rate). The authors of these papers come from all over the world, including Austria, Australia, Brazil, Cyprus, UK, Germany, The Netherlands, Portugal, and the USA.

These main conference papers cover a wide range of topics in some depth. Hutzler et al. use a location-aware scavenger hunt game as the basis for *enjoyable* exploratory learning; Saloko et al. seek to demonstrate the value of immersive technologies for collaborative innovation spaces; autism and life skills are targeted by Schmidt et al., who bring virtual world technologies to bear on these challenges; Coelho and Costa take the old idea of a sticker album collection and reimagine it using augmented reality in a museum space; Sheafer and Gardner report on lessons learned from a set of trials on MIRTLE: a Mixed Reality Teaching and Learning Environment, conducted at Saint Paul College, Minnesota; Greenwald et al. explore the unusual situation where users are located in the same physical small space (a room) but can only communicate via their immersive virtual reality headsets and gesture detectors; Silva et al. evaluate a CSCW protocol using the popular OpenSim VR platform for providing aircraft maintenance training; from a cultural heritage perspective, Fabola et al. find that museums can provide compelling and informative experiences that enable visitors to travel back in time with minimal interaction and relatively low cost systems; Schneider et al. analyze the effectiveness of the nonverbal communication of learners and provide them with feedback, in cases where human feedback is not available using a prototype:

Presentation Trainer; Herpich et al. advance the case for virtual laboratories in virtual worlds by describing a pilot using AVATAR for supporting experiential learning about principles of electricity; Nisiotis et al. take the concept of a Transactive Memory System and assess its utility in an immersive cyber campus for supporting collaborative and socially constructed learning.

This is a fascinating collection of papers reflecting the unbounded possibilities of immersive learning research. We hope that you will find these stimulating and encourage you to also contribute to the activities of the Immersive Learning Research Network.

Colin Allison
Main Conference Programme Chair

iLRN 2017 Special Tracks Preface

Every year, the concept of immersion becomes more and more important for various fields including digital education. Digital education brings together various disciplines and the concept of immersion adds a layer of complexity. The immersive learning research field is therefore highly interdisciplinary involving research groups from a wide range of fields and interests. The special tracks of iLRN are designed as a forum to strengthen and highlight the interdisciplinary nature of the subject. Continuing from our successful experiences at iLRN 2015 and iLRN 2016, special tracks give us the opportunity to bring together experts from a wide range of backgrounds and enable interdisciplinary research collaboration and knowledge exchange.

For iLRN 2017, the following tracks promoting emerging and innovative topics related to immersive education were offered:

- The special track “Personalization in Immersive and Game-Based Learning Environments” was chaired by Alexander Nussbaumer, Rob Nadolski, and Samuel Mascarenhas. The aim of this track was to gain insights into personalization strategies in immersive and game-based learning environments.
- In the track “Digital Heritage and the Immersive City,” the track chairs Alexandra Gago da Câmara, Helena Murteira, and Maria Leonor Botelho invited participants to explore and discuss immersive representations of digital heritage studies.
- In the track “Cognitive Serious Gaming,” the track chairs Markos Mentzelopoulos, Daphne Economou, Vassiliki Bouki, Aristidis Protopsaltis, and Ioannis Doumanis explored how cognitive principles can be applied to improve the training effectiveness in serious games.
- In the track “Immersive and Engaging Educational Experiences,” the track chairs Johanna Pirker and Foaad Khosmood discussed how immersive and engaging educational experiences can be designed, developed, and analyzed.
- In the track “Wearable Technology-Enhanced Learning,” the track chairs Ilona Buchem, Ralf Klamma, István Koren, Fridolin Wild, and Alla Vovk invited authors to present work on wearable technologies as part of immersive user experiences.
- The track “Serious Games Using Immersive and Assistive Technologies” was chaired by Markos Mentzelopoulos, Daphne Economou, and Phil Trwoga. This track aimed to explore how immersive and assistive technologies can be applied to improve the effectiveness in serious games in achieving formal or informal training.
- The aim of the track “Immersive Experiences in Later Age” chaired by Ana Isabel Veloso and Ruth Contreras Espinosa was to discuss the challenges and strategies in order to extend technology-enhanced learning to older adults.

In all, 30 submissions were received for the special tracks and ten were chosen as full papers to be published in the Springer proceedings, for an overall acceptance rate of 30%.

We would like to express our deep gratitude to all special track chairs and reviewers of the special track papers for their engagement and commitment to make the tracks an essential and integral part of the iLRN conference. These tracks brought together a variety of different research fields related to immersive learning to this conference. We cordially thank each and every person who contributed toward making these special tracks such an important part and unique experience of iLRN.

Johanna Pirker
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Contents

Virtual Worlds and Virtual Reality

Towards Online Immersive Collaborative Innovation Spaces

Oluwatimilehin Salako(✉), Michael Gardner, and Vic Callaghan

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Abstract. We live in an increasingly competitive world where success is closely linked to a person's or organisation's ability to innovate which, in turn, means that innovation has become increasingly important in education and business. One response to this has been the introduction of special environments, tailored to supporting innovation, namely Innovation-Labs (i-Labs). Research has shown that creativity thrives in environments that are playful and customizable, rather than in the somewhat sterile environments of most workplaces. In this paper, we describe our efforts to create a model for an online immersive environment that can be customized and dynamically adapted to the needs of individuals and specific innovation sessions. In creating this model we have been inspired by earlier pioneering work in innovation labs, virtual reality, HCI and the World Wide Web. This work-in-progress paper presents the output of our theoretical studies, and an initial specification for an immersive reality innovation space called iSuite. This environment is based on an underlying model that is made up of a number of innovative features which include a customisable template-based generic interfacing scheme which supports human-machine and machine-machine interactions and supporting systems to assist i-Lab users during brainstorming.

Keywords: Innovation-Labs · HCI · Templating · Reconfigurable spaces · Personalization

1 Introduction

This paper presents our research which aims at creating more advanced solutions for online immersive collaborative innovation spaces. We have developed a computational model for implementing dynamic reconfigurable spaces and plan to investigate whether this model when instantiated as an online immersive multi-user virtual environment can benefit people working in these spaces. We have chosen innovation-labs as an exemplar application for this research. Our research challenge arises from how this computational model can support successful space reconfiguration and how innovation activities within such a space can be enhanced. We introduce the iSuite model as an exemplar for this approach, which is later described in this paper.

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1.1 Innovation Labs

A recent report of the World Economic Forum [1] highlights creativity as one of the top ten skills required for students in the job market in the year 2020. Creativity has moved up from tenth place in 2015 to third place by 2020 generating an increased requirement to support this need in education. Another related report by Schwab [2] has also highlighted Cyber-physical systems as the fourth industrial revolution, following the third industrial revolution which was based on electronics, information technology and automated production. An earlier project by the UK Royal Mail and other partner universities [3] found that creative thinking functioned best in playful spaces, which followed a particular set of rules that engendered uninhibited collaborative activity. These finding motivated the design of a special online environment, tailored to supporting innovation, namely an Innovation-Lab (i-Lab). An innovation-lab (I-Lab) has been defined as an "*inspirational facility designed to transport its users from their everyday environment into an extraordinary space encouraging creative thinking and problem solving*" [4]. A related report by Powell [5] has also pointed out that place governs people's beliefs, behaviour and their ability to be innovative and creative in their thinking. Thus, i-Labs need to be well designed to be able to support creativity and innovation. This also brings about the need to personalise such spaces and the activities it supports for i-Lab users. Multi-User Virtual Environments (MUVEs) show great promise for visualization, immersion and enhancing users' experiences but the current evidence suggests that they struggle to compete with their physical counterparts. Therefore, in this research, we hypothesize that it is possible to create a computational model for dynamic reconfigurable innovation spaces and that implementing the model in an online immersive virtual 3D environment will bring benefits above and beyond real physical innovation spaces. In the following sections we review related literature in relation to our research and further explain our proposed model.

1.2 The Importance of Personalising Space

Earlier research has pointed out the importance of being able to personalise built-environments and the activities they support. According to Bentley [6], a built environment should provide its users with flexible settings and opportunities to maximize the choices available in their environment. Such an environment, with these affordances, are said to be "responsive". A key design parameter for such a space is its ability to support personalisation, in which users can put their 'stamp' on such spaces. Research by Chin et al. [7] also explored how non-technical users can creatively construct functionality based on networked appliances within the home by using a programming-by-example approach. The research carried out by Sailer et al. [8] proposes the use of data-driven design as an emerging design approach for spaces. Our research also aims to explore these emerging space design methodologies. Some research [9, 10] have explored automatic customisation of rooms, creation of spaces from architectural plans and integrating virtual worlds with information systems and learning management systems. In this work, we are more concerned with the elemental creation of the space and its associated HCI issues. We propose a templating approach in which interactions occur between users and template interfaces and between computational components, leading to more personalised MUVEs which are specifically tailored to support required innovation activities.

It is hardly surprising to find that employers tend to favour university graduates that have creative-thinking and innovation skills. Courses and programmes that enhance such skills need to be introduced more in traditional science and engineering curriculums. In this paper we are exploring a new approach to introducing innovation to the higher education curriculum through i-labs. This approach was first proposed by Callaghan et al. [11] at the 2016 immersive learning conference in Santa Barbara. This paper expands on this vision and provides more detail on a computational architecture for enabling customisable spaces.

2 Related Work

This section reviews related work in innovation labs as an environment for creative thinking, innovation lab design and some innovation methodologies that have been developed to encourage producing creative and innovative solutions to user problems.

2.1 Innovation Labs as Creative Thinking Environments

Research by Gill and Oldfield [3] proposed that an i-Lab should consist of three interlinking components; the environment, the technology and facilitation mechanisms. In this context, I-Lab activities include a mix of the following:

- Discussion and getting other people's perspectives
- Icebreaker and reviver activities
- Headlines, cut and paste collages and PowerPoint presentations
- Wall activities (doodling, collaborative writing etc.)
- Brainstorming and Voting
- Role play
- Scenario building

At the core of the process is the brainstorming activity. This was described by Wu and Callaghan [12] as "*a technique for unleashing a flood of thoughts by members sparking ideas off each other, or from carefully injected external stimulus*". After sufficient ideas are generated, a group then go on to categorise, rationalise and vote on the suggestions. The actual implementation of these ideas occurs beyond the session carried out in the i-Lab.

2.2 Innovation Lab Design

The research by Lewis and Moultrie [13] examine the design of some innovation labs selected from a range of sectors including corporate innovation, university staff development and governmental policy 'futurology'. The labs examined are the Royal Mail Innovation Laboratory, UK Department of Trade and industry Future Focus laboratory and the University of East Anglia Staff Development Hub. The researchers mention from their findings considering these cases that the physical form of an innovation lab is significantly beyond its aesthetic value. It is integral to the functionality of innovation labs. For instance, they point out that it is important to avoid creating structures such as big curved walls that minimise the future flexibility of the space. This further justifies the need for creating flexible spatial layouts which our iSuite model addresses. Also, they emphasise in their research that the extent to which an innovation lab is successful is the degree to which it is a physical reinforcement of the strategic intent of an organization to be innovative or creative. The work by Moultrie et al. [14] developed a conceptual framework in which they also emphasize the concept of strategic intent. They mention that a key element of both creating and using an innovation lab is understanding the needs and type of people who will use the space. However, they also stress that the role of facilitators is important in enabling innovation labs to work effectively. Considering various strategic intents that may exist and the important role of facilitators in innovation labs, it is therefore necessary to develop supporting mechanisms to create innovation labs to suit various intents which our iSuite model also aims at addressing.

2.3 Innovation Methodologies

Some methodologies have been developed to encourage the generation of creative and innovative solutions to user problems. Science Fiction Prototyping (SFP) as described by Callaghan et al. [11] involves "*writing short fictional stories that imaginatively extrapolate current practices forward in time, leaping over incremental developments, exploring the world of disruptive product, business and social innovation*". This technique is able to create high-fidelity analogues of the real world adopting a rich story-based structure enabling it to serve as a type of prototype to test ideas. A similar and complementary approach to SFP is Diegetic Innovation Templating, which involves extracting creative innovation ideas from fictions that are created for entertainment rather than for technology, business or social innovation. Another Innovation methodology is Scenario-based User Needs Analysis (SUNA). This is described as a method for envisioning, clarifying and refining ideas for developing software products and services usually involving two or more parties. It entails opening up, encouraging creative thinking and systematically narrowing down to extract salient details ensuring collaborative agreement and documenting outputs that would then be used for software development [15]. An end-to-end product development approach called the Creative Innovation Development (CID) model (from concept to customer), which incorporates these ideation methodologies is described by Wu and Callaghan [12]. It combines process flow and cyclic iteration to create an agile evolutionary product innovation cycle. A product's features and design is established as a result of continued tuned evolutional iterations. At the heart of all these approaches described above is the process of brainstorming and ideation.

3 iLab Features

We have used a real physical i-Lab that is located at the University of Essex Southend campus, to capture information about the features of these spaces and how activities are performed within them. Figures 1 and 2 below show views from the Southend i-Lab. We then present a model of the natural processes that take place within the i-Lab as shown in Fig. 3.

Fig. 1. A view from the University of Essex Southend iLab (brainstorming room)

Fig. 2. Another view from the University of Essex Southend iLab (shared reception area)

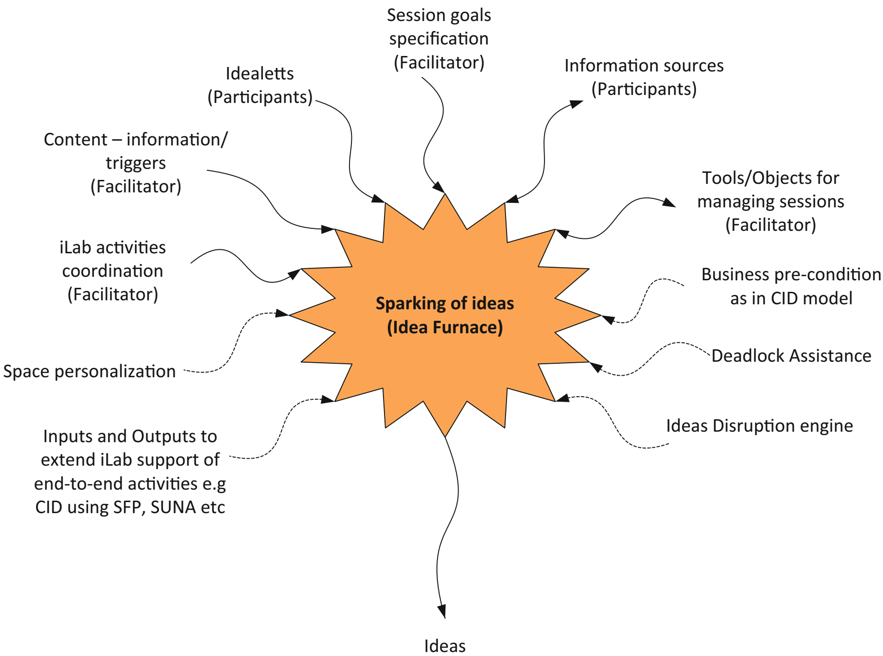

Fig. 3. Natural process model of i-Lab

The i-Lab processes involve a facilitator and participants as key actors. As illustrated in Fig. 3 above, the role of a facilitator includes specifying session goals, coordinating i-Lab activities, providing resources that would be used during innovation sessions for participants, providing necessary information needed to drive innovation activities and leading participants from one activity to the other as they complete the different sessions. Each participant contributes innovation ideas that we refer to as 'idealetts' that are generated from their personal wealth of knowledge and other information sources. In our research, we introduce some additional features to this model which includes the following (as shown in Fig. 3 above with dotted lines). These are:

1. I-Lab space personalisation/customisation
2. Inputs and outputs to support i-Lab support of end-to-end activities such as the CID model [12] using SFP, SUNA etc.
3. Support of business pre-conditions as highlighted in the CID model
4. Deadlock assistance to support i-Lab users participants when they run-out of ideas during brainstorming
5. A disruption engine to change ideas generated by participants meaningfully e.g. disruption of micro-fiction as used in SFP [11]

These additional features are included in our proposed iSuite Model. We plan to implement these features in a number of development stages, and in the first phase of our research we will explore i-Lab space personalisation/customisation issues. These issues are elaborated in the following sections.

4 The iSuite Model

In this section, we describe some space personalisation/customisation issues and features of the iSuite Model. We explain the template based configuration approach and the underlying computational model, showing both human and machine processes. We then describe our current implementation of this computational model.

4.1 Phase I: i-Lab Space Personalisation/Customisation

We consider some issues relating to i-Lab space personalization such as features of the space itself, the tasks performed within the space, its support for group activities, tools and information accessible to users and interaction and communication issues. We view the conceptual innovation space in the real world and MUVE as the same. We go further to compare real world and MUVE affordances for innovation tasks based on these features:

1. **The Space attributes –** this includes the spatial layout, room ambience etc. Reconfigurations could be limiting in the real world but the virtual world could support more reconfigurations for innovation activities
2. **Tasks** – innovation tasks are manually monitored in the real world while monitoring could range from manual to automated approaches in MUVEs

3. **Support for people/group activity** – this is limited to the space available in the real world but there could be more people/group support for innovation activities in MUVEs
4. **Accessible tools/information** – this could be limited in real spaces whereas MUVEs could provide more support
5. **Interaction/communication issues** – the real world allows high fidelity communication while MUVEs can support the use of user interfaces and user devices for interaction during group activities.

Earlier research [16, 17] has investigated issues concerned with classroom design and the design of spaces for active learning [18]. From this previous research, it has been shown that changes made to the spatial layout of objects in a room and changes to room ambience can affect the performance of the active learning and group work that takes place within it. We build on this research and hope to incorporate these concepts in order to better personalise and reconfigure i-Lab spaces. We next proceed with the development of the iSuite model starting with implementing the following features:

- Spatial layout – this includes changing the position and size of objects in the space, such as walls, displays, etc.
- Room ambience – this includes changing wall textures to fit the theme for individual sessions, and includes changing the colours of the sidewalls etc.

4.2 Template-Based Configuration Approach

In order to achieve our aims for i-Lab space personalisation, we introduce the use of specified templates into which i-Lab users (specifically facilitators) can input data to create the i-Lab space. In this templating approach, the facilitator can vary the size of walls and wall displays that reflect the theme of the session, the position of the walls and displays in space and also the textures of the walls to create different spatial layouts and room ambience. This template is then used by a space adaption engine to create the i-Lab space. The template thereby serves as an interface between the human configuring the space (facilitator) and the computational framework that creates the space (machine processes). Figure 4 below shows an example of such a template with some of its fields as described (being a tentative approach, we name this Innovation Protocol Version 1 – InPV1 for instance, as different variations/versions of this template may exist). This approach would be further improved and extended. We aim to use template views with different levels of detail and different modes of interfaces (e.g. visual interfaces).

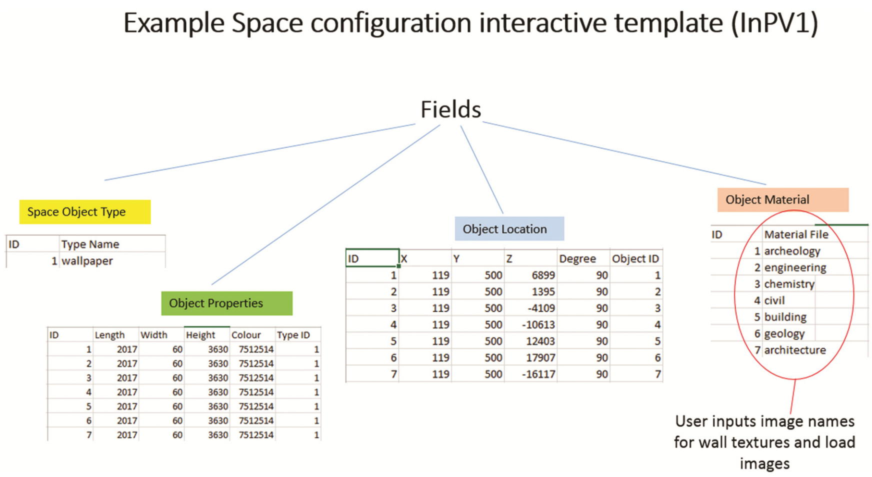

Fig. 4. Example space configuration interactive template

4.3 Computational Model Showing Human and Machine Processes

Figure 5 below shows the computational model in which the user interacts with the space adaption engine via the use of specified templates (an example template is shown in Fig. 4 above). The space adaption engine then processes the template specifications to create the virtual 3D space thereby creating a customised/personalised space for the user.

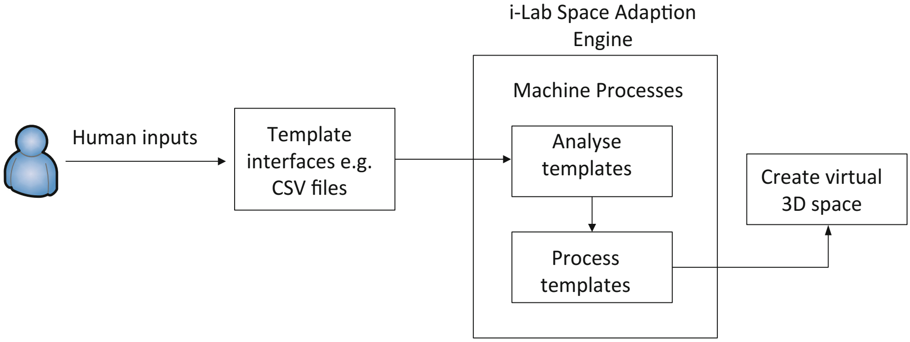

Fig. 5. Computational model showing human and machine processes

4.4 Implementation of the Computational Model

Figure 6 below shows an implementation of the computational model. The template in the form of.csv files are fed into a database server (MySQL server) which accepts specifications of dimensions and locations for objects to be created in the virtual world. The engine (implemented using Unity3D game engine) then creates instances of these objects in the virtual 3D space, getting information from an online application server

(SmartfoxServer-SFS). Initially, a test script is used to check if the template object dimensions and locations in the 3D space are acceptable e.g. to check if objects are not overlapping in space. When the space has been created, various clients can then log on to the application server to view and use the 3D space resources. Further stages of the iSuite model implementation would provide a platform to explore different ways of user representations and social interactions in the 3D space. This may involve using avatars for example but, since anonymity is an essential element of brainstorming, their purpose would be primarily to indicate presence in the space and evidence to show user activity.

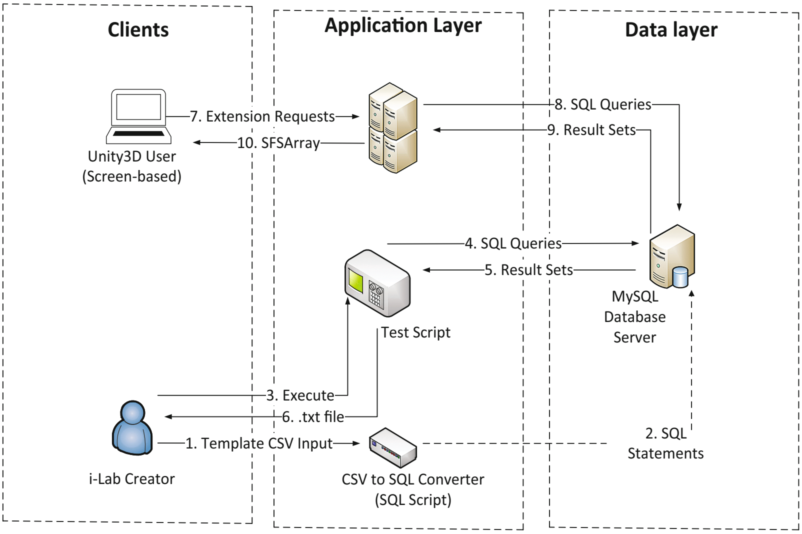

Fig. 6. Implementation of the computational model

Fig. 7. Custom i-Lab space created by the space adaption engine

Figure 7 below shows an early example of a custom space created using the above architecture which will be refined considerably as the project progresses.

5 Summary and Future Directions

This work-in-progress paper was motivated by the idea that MUVE's can be reconfigurable and personalised to support desired user activities. An i-Lab was chosen to evaluate these ideas because, from the literature, there is much evidence that space has a direct effect on the quality of the processes being undertaken. Our vision is to develop dynamic and extensible systems to accommodate and support various user configurations with plug-in architectures. For instance, supporting immersive virtual reality devices as plug-ins. We have taken inspiration from the success of the World Wide Web, which is flexible and supports different communication protocols and plug-ins. The main contribution of this paper is the iSuite model. This includes a space adaption architecture and supporting template approach with human-machine and machine-machine interactions for creating personalised extensible spaces and activities to support creativity and innovation. Clearly, this is work in progress, with the intention of this paper being to present and justify the theoretical foundations of the proposed pedagogical activity and computational model, including an early implementation of the work.

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Extended Field Trials of a Mixed-Reality Teaching Environment: Practical Issues Beyond the Technology

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Abstract. This paper reviews the results of a set of field trials on MiRTLE - the Mixed Reality Teaching and Learning Environment conducted at Saint Paul College. We report on some of the lessons learnt using the platform and its relationship to the underlying pedagogies.

Keywords: MIRTLE · Virtual reality · Mixed reality · Essex university · Saint Paul College · Multi-user virtual environment (MUVE)

1 Introduction

Early in our research efforts into virtual environments at the University of Essex we felt that extending the virtual environment into the physical world of a classroom and bringing the classroom into the virtual environment could achieve higher levels of tele-presence within such environments thereby heightening student engagement which we felt would increase student academic achievement. Our thought was to mix video streaming and virtual reality to create a mixed reality environment. We began a research and development program that produced a Multi-User Virtual Environment (MUVE) platform that we called the Mixed Reality Teaching and Learning Environment, or MiRTLE, Gardner and O'Driscoll [3] and an extended platform version which we call MiRTLE+.

While our empirical research supports the concepts on which MiRTLE and MiRTLE+ are based we felt that it was very important that the technology be tested in the actual classroom in order to develop a broader assessment of the efficacy of this technology in education. We developed a cooperative research program with Saint Paul College in Minnesota, USA who agreed to construct and operate a large-scale implementation of MiRTLE, use it in a standardized first course in computer science and to record their observations concerning its utility. In parallel to the field trial at Saint Paul we developed and conducted a series of laboratory experiments on MiRTLE and MiRTLE+ at our iClassroom facility at the University of Essex.

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The data from our field trials and laboratory work are encouraging leading us to believe that when systems are put into place that incorporate the wider pedagogical and behavioral aspects effected by the technological platform student achievement within these mixed reality immersive environments is comparable or better than that of face-to-face instruction.

2 Background

Our first project that combined real and virtual worlds was MiRTLE, Gardner et al. [4]. The objective of the MiRTLE (Mixed Reality Teaching and Learning Environment) project was to provide an online virtual classroom to augment live lectures. This was inspired by the observation that even if remote students were able to watch a live lecture remotely (for example using video conferencing or other similar technology), they often would choose to watch the recorded session instead. The main reason for this is that there was very little perceived value in their participation in the live event, as often there was only limited means (if any) for them to interact with the people in the live classroom. This meant that the recorded version of the event usually offered an equivalent experience with the advantage that they could also choose to watch in their own time.

MiRTLE provided a mixed reality environment for a combination of local and remote students (both dispersed and local students are able to see and talk with each other, in addition to the teacher). The MUVE environment was intended to augment existing teaching practice with the ability to foster a sense of community amongst remote students, and between remote and co-located locations. In this sense, the mixed reality environment links the physical and virtual worlds. Using MiRTLE, the lecturer in the physical classroom is able to deliver the class in the normal manner but the physical classroom also includes a large display screen that shows avatars of the remote students who are logged into the virtual counterpart of the classroom. Thus the lecturer will be able to see and interact with a mix of students who are present in both the real and virtual world. A schematic of a MiRTLE classroom built at Saint Paul College is shown in Fig. 1. Audio communication between the lecturer and the remote students is made possible via a voice bridge. A camera is placed in the classroom room to deliver a live audio and video stream of the lecture into the virtual world. From the remote students perspective, they can log into the MiRTLE virtual world and enter the classroom where the lecture is taking place. Here they will see a live video of the lecture as well as any slides that are being presented, or any application that the lecturer is using. Spatialised audio is also used to enhance their experience so that it is closer to the real world. They have the opportunity to ask questions just as they would in the physical world via audio communication. Additionally, a messaging window is provided that allows written questions or discussion to take place. The MiRTLE virtual world also offers a common room where students can meet socially and access other resources for their course. Figure 2 illustrates the virtual world for the online students in a MiRTLE class.

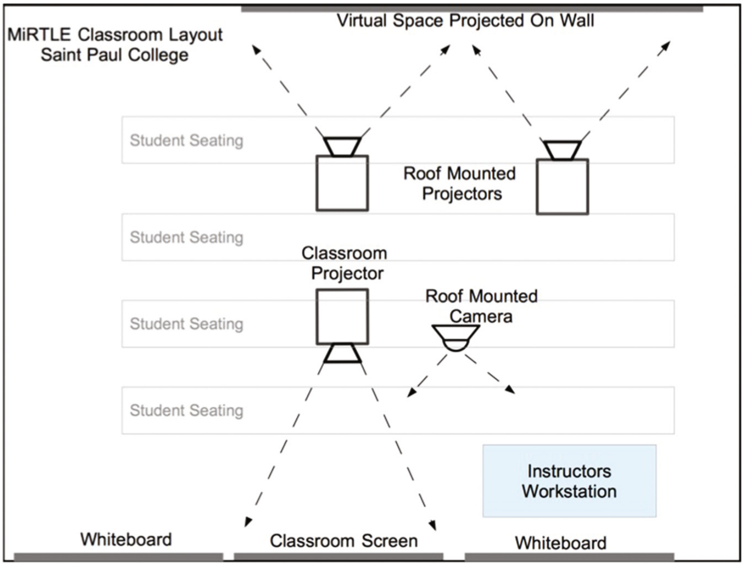

Fig. 1. Saint Paul MiRTLE classroom - General arrangement

Fig. 2. MiRTLE classroom

3 Experimentation and Field Trials

During the 2008–2009 academic year the Computer Science department at Saint Paul College, Saint Paul, MN, USA, remodeled a general-purpose classroom into a MiRTLE classroom. The general arrangement of this classroom was shown previously in Fig. 1. In this facility life size avatars are projected on the rear wall and lectures are captured and distributed using an inexpensive ceiling mounted security camera.

Following the construction of the MiRTLE facility a set of field trials were run from 2008 until 2014 comparing MiRTLE assisted instruction and traditional in-person attendance. Student achievement and retention were thought to be the best indicators of student success and were measured as follows:

1. *Student achievement:* measured by the absolute improvement in the percent of correct answers on a standardized examination administered during the first class meeting and subsequently used as the final examination in the course:

$$Student\ Achievement = Final\ Exam\ Score - Initial\ Class\ Meeting\ Score$$

2. *Student retention:* measured as the percentage of students attending the course relative to the initial enrollment in the course.

A standardized first course in computer science was selected as a test case. During these trials the learning objectives, textbook, content, instructor and assessment instruments were held constant.

Three field trials were conducted in which the student could elect to participate through MiRTLE or attend meetings in person. The trials were conducted as follows:

1. *Field Trial 1:* students chose whether to attend lecture based courses in-person or via the MiRTLE facility. This trial started in Fall of 2008 and ended in Spring 2010. Students in the sample: 240.
2. *Field Trial 2:*[1] students chose whether to attend lectures in a blended delivery course in-person or via the MiRTLE facility. This trial started in Fall of 2010 and ended early in Spring of 2011. Students in the sample: 120.
3. *Field Trial 3:* students chose whether to participate in active learning meetings in person or via the MiRTLE facility. This trial started in Fall of 2010 and ended in Spring of 2014. Students in the sample: 240.

Table 1. Field trial results - Saint Paul College

Student retention and achievement			
Type of class meetings	Trial period	Absolute improvement in the percent score on a standardized examination over the academic term	Percentage of students retained over the academic term
Traditional lecture meetings	2008 to 2010	45.3	60.4
Traditional lecture meetings - MiRTLE attendance	2008 to 2010	44.4	62.8
Blended delivery with traditional lecture meetings	2010 to 2011	33.0	51.8
Blended delivery with active learning meetings	2012 to 2014	50.3	75.8
Blended delivery - MiRTLE attendance with active learning meetings	2012 to 2014	52.0	72.1

[1] This field trial was terminated early due to student complaint, low retention and reduced student achievement. MiRTLE attendance data has been excluded due to unreliable record keeping which occurred during periods of course adjustment following student complaint.

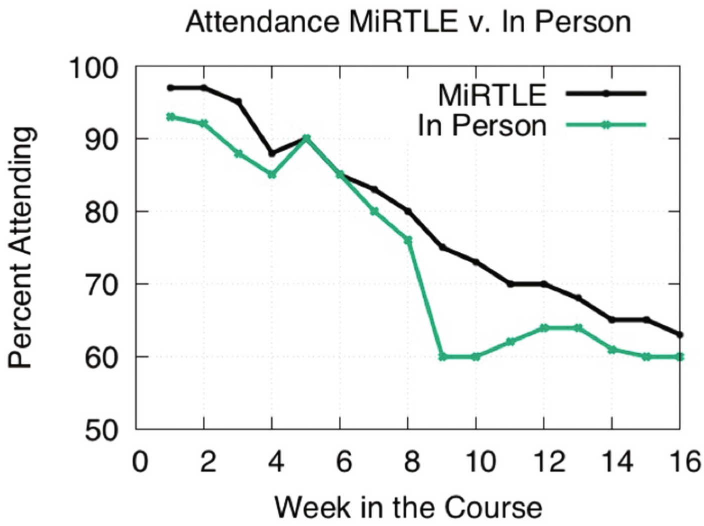

Fig. 3. 2008–2010 MiRTLE implemented with a traditional classroom

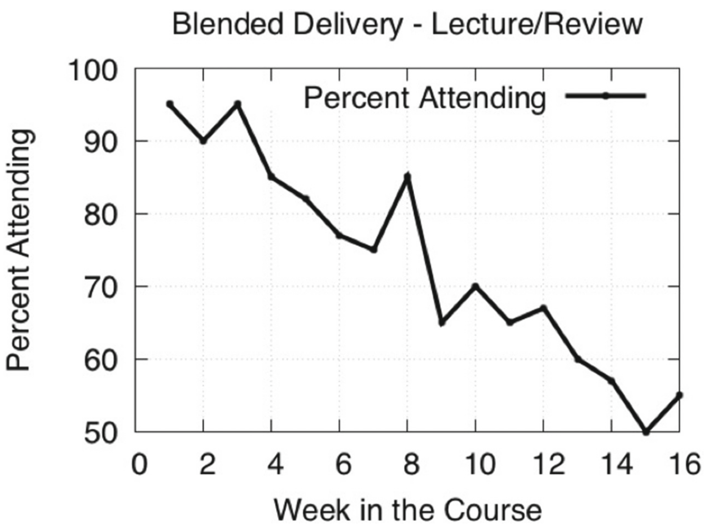

Fig. 4. 2010–2011 blended coursework delivery model

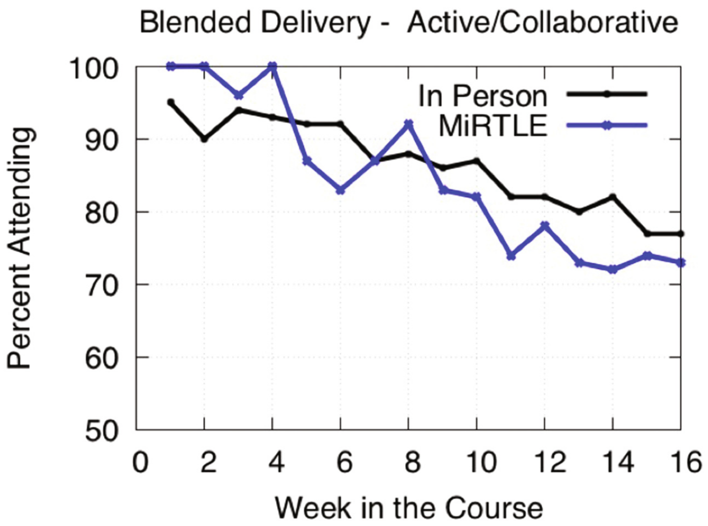

Fig. 5. 2012–2014 MiRTLE with active laboratories

The results of the field trials are summarized in Table 1. Retention levels during each of the trial periods is shown in Figs. 3, 4, and 5.

4 Discussion

The MiRTLE facility at Saint Paul College was built in order to address concerns that the computer science faculty had over the efficacy of asynchronous distance education. MiRTLE was selected as the primary platform for distance learning for the following reasons:

1. MiRTLE is not intrusive. Faculty and students can use it without any changes or modifications to their normal pedagogical routine.
2. MiRTLE brings the classroom to the distance learner and the distance learner to the classroom in a very engaging manner, Gardner et al. [4]. It has many features that support both co-creation and collaboration in a virtual world environment, Potkonjak et al. [10]
3. MiRTLE is a mixed realty platform which extends the virtual world that supports it. When this virtual world is not being used for lecture activities it can be easily utilized as a virtual world platform on which students and faculty can communicate and collaborate, Gardner and ODriscoll [3].
4. Since it was based on the Open Wonderland platform MiRTLE, easily supports the typical teaching tools used in a first course in computer science. Terminals, editors, compilers, presentation software and web access are readily available within a MiRTLE implementation, Gardner, Scott and Horan [5].

5. With a properly configured client computer MiRTLE is easily accessible and simple to use.
6. A MiRTLE facility is multipurpose in that the classroom technology platform is not restricted to MiRTLE enabled virtual worlds. It can support alternative platforms such as Second Life or OpenSim with very little effort.

The MiRTLE facility was placed into classroom operation in the Fall of 2008. It was remarkably easy for various faculty to use and required no training other than how to turn it on. Faculty conducted their lecture sessions in the normal manner and found the interaction with avatars to be very natural.

4.1 Field Trial 1 - Comparing MiRTLE to Traditional Lecture

During the first field trial conducted from the Fall of 2008 through Spring of 2010, 8 sections of 30 students were given the option of attending a traditional first course in computer science either by MiRTLE or in-person attendance. Initially about 15 percent of the class chose to attend via MiRTLE. As the the term progressed the number of students attending via MiRTLE increased to about 40 percent of the class.

As shown in Table 1 student scores on a standardized examination improved by 45.3 percent points for those attending lectures and by 44.4 percent points for those attending via MiRTLE. Retention during this period was 60.4 percent for those who attended in-person and 62.8 percent for those who attended via MiRTLE. Examining the weekly attendance plot in Fig. 3 it seems MiRTLE attendance was uniformly better, particularly during the usual dropoff period following midterm examination.

We feel the results show that MiRTLE when used in this manner provides distance students with similar learning outcomes to those in the physical classroom. This is considered a successful trial since MiRTLE met all of its design expectations, students performed as well on the MiRTLE platform as in the lectures and it appeared that as students and staff became more comfortable with the MiRTLE platform they migrated to it.

4.2 Field Trial 2 - Implementing Blended Delivery Using MiRTLE

Due to the initial success of MiRTLE the computer science faculty elected to run a second field trial beginning in September of 2010 utilizing the MiRTLE platform and a learning management system to offer the course in a blended delivery format. This approach reduced face-to-face instruction by 50 percent resulting in weekly rather than twice a week classroom meetings. The idea was to move the static curriculum content to the asynchronous learning management system and utilize weekly meetings to answer questions and conduct lecture reviews of the material for the week. Students were also encouraged to attend the weekly meetings remotely using the MiRTLE facility and to meet and collaborate on problems together when lectures were not being conducted.

The second field trial was terminated in May of 2011 due to lower student retention and measurable decreases in learning achievement. The frequency and nature of student complaints and interventions by the college administration also played a role in electing to end the trial. The data gathered from this trial involved 4 sections given over two academic terms or 4 cohorts of 30 students. Data from the four sections was aggregated. Based on the aggregated data the first meeting scores on the standardized examination were again around 30 percent however the absolute improvement in student scores on the standardized examination were only 33 percent points compared with 45.3 percent points in the lecture led sections. Overall student retention dropped from 62 percent to 52 percent of the initial enrollment. There was also a troubling drop in retention during the beginning weeks of the course. Students made little or no use of MiRTLE and did not utilize the virtual world meeting rooms available to students in these sections as in the earlier trials with MiRTLE.

Following the rather dramatic failure of the second field trial a lengthy retrospective review was conducted by a group of faculty and students. The group developed a set of recommendations to address what were thought to be the most critical issues. Based on this review is was decided to re-examine the pedagogy in light of the technological approach being used. This led to the development of an alternate model of course design and a modification of the instructional pedagogy. This model envisions a course design of sequential learning modules that utilize a mixture of behaviorist and constructivist based pedagogies. Figure 6 illustrates this general design.

This pedagogical approach utilizes active/collaborative learning laboratories for in-class instruction and divides on-line learning into behaviorist and con-

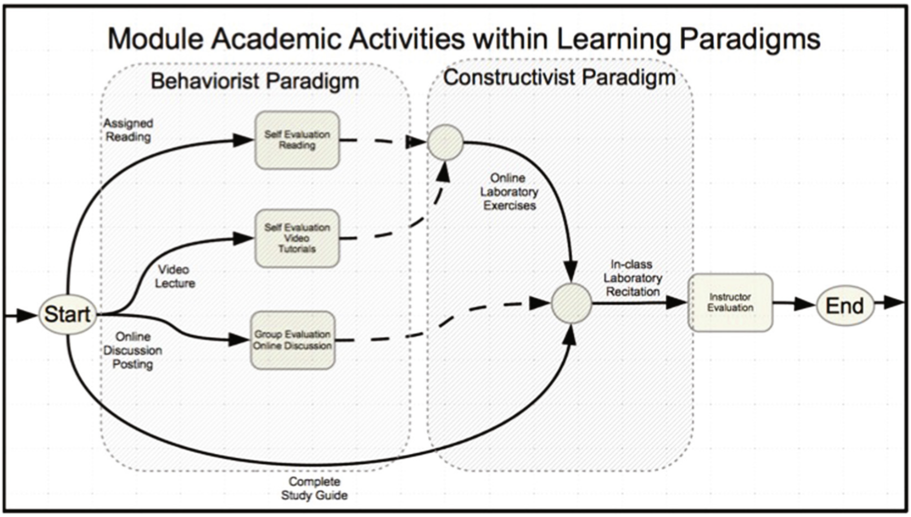

Fig. 6. Modified pedagogy explicitly recognizing MiRTLE technology

structivist learning activities. The asynchronous on-line behaviorist instruction utilizes familiar behaviorist tools such as programmed instruction, structured study guides and a token economy. The appropriate use of such methodologies was outlined in the work of McDonald et al. [8] and Doll et al. [2]. This portion of instruction is completed asynchronously and entirely within the learning management system. Learning tools such as instructional videos and self-evaluations are used extensively. Adding structure to the asynchronous on-line materials was considered a critical component of this design as the study group found that if as few as 10 percent of students came to the blended meetings unprepared the meetings were essentially useless and a large portion of the class became dissatisfied. The asynchronous portions of the pedagogical model based on constructivist theories were influenced by the work of Ben-Ari [1] and the actual pedagogical designs were largely based on the work of Jonassen, [6,7]. Once the work on the pedagogy was complete the course materials were redeveloped and field trials resumed in the Fall 0f 2012.

4.3 Field Trial 3 - Active Collaborative Instruction with MiRTLE

During the third field trial conducted from the Fall of 2012 through Spring of 2014, 8 sections of 30 students were given the option of attending a traditional first course in computer science conducted using the modified pedagogy shown in Fig. 6 either by MiRTLE or in-person. Initially about 20 percent of the class chose to attend via MiRTLE. As the the term progressed the number of students attending via MiRTLE increased to about 40 percent of the class.

As shown in Table 1 student achievement in the standardized examination was a 50.3% point improvement for those attending in person and by 52.0% points for those attending remotely using MiRTLE. Retention during this period was 75.2 percent for those who attended in-person and 72.1 percent for those who attended via MiRTLE. Examining the weekly attendance plot in Fig. 5 it seems in-person attendance was slightly better over most of the term.

The results of this third field trial showed essentially equal performance between those students using MiRTLE and those who attended the sections in person. Once again MiRTLE attendance was shown to be essentially as effective as in-person attendance. Remarkably both achievement and retention measures were significantly higher using the modified pedagogy which implemented structured asynchronous activities and active/collaborative laboratory sessions rather than periodic lectures. If we assume the increase in retention and achievement was largely attributable to the modified pedagogy we observe that despite this shift MiRTLE students had similar outcomes. We feel this further validates the efficacy of MiRTLE as an alternative distance learning platform.

5 Conclusions and Directions for Future Research

The Saint Paul case study clearly shows that the technology is only one part of the picture, and the other aspects (particularly behavioral aspects) are equally important when designing new learning activities. This work has also shown that the mixed-reality approach can work well, particularly when incorporated into a sound pedagogical/behavioural approach. This is also reinforced by the evidence from the Saint Paul case study.

It could be said that this early work only demonstrates a glimpse of the potential benefits from the use of a mixed-reality technological approach. MiRTLE was deliberately very simplistic in terms of the pedagogy being supported (but effective because it was so simple). MiRTLE was successful not because it was technically advanced but because it was so natural for the instructors to use, requiring no new training or lesson planning. Effective use of any of these platforms in an educational setting is very dependent on the structure of the pedagogy. Here pedagogy is king and technology is servant. This might explain the reason for the relatively slow uptake of virtual and mixed-reality where often due to the complexity of the platforms a lot of effort is spent on the technology and little effort on how to apply it. Here the relationship the technological system has to the environment it will be operated in is a key success factor. In addition the work being done at the University of Essex to extend the MiRTLE platform particularly with the use of new devices and more collaborative learning activities, shows great promise, and seems to lead to more engaging, and effective learning (when compared to more traditional approaches) see Pena-Rios et al. [9].

A simple unifying observation can be made for the tests conducted at Saint Paul to date. When implementing any system of technologically supported learning, care should be taken to consider the overall course delivery mechanisms, systematically recognizing as key system components the nature of the platform, the structure of the pedagogy and the capacity of both students and instructors to adjust their respective approaches to learning and instruction in the new environment. The constructivist pedagogy is preferred over other approaches but there may be a role for behaviorist techniques to be used to support enhanced learning within the constructivist framework.

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Impact of Non-verbal Communication on Collaboration in 3D Virtual Worlds: Case Study Research in Learning of Aircraft Maintenance Practices

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Abstract. Virtual worlds are widely regarded as a successful approach for professional team training, due to promoting collaboration through user avatars. Current theoretical models of Computer-Supported Cooperative Work (CSCW) do not account for the specificity of virtual worlds' affordances for collaboration, particularly regarding non-verbal communication affordances, which led Cruz et al. to propose in iLRN in 2015 a specific protocol to collect data to support the empirical-grounded refinement of the theoretical treatment of virtual worlds in CSCW. Here, we present the results of applying this protocol to a case study in the training of aircraft maintenance practices. A training simulator platform was built with the Open Simulator platform for this purpose. Through activity observation, collected data provided a set of chains of evidence as proof elements, increasing the amount of empirical data available for future theory development.

Keywords: Virtual environments · Virtual worlds · Collaboration · Presence · Non-verbal communication · Aircraft maintenance

1 Introduction

Three-dimensional Virtual Worlds (3DVW) offer users the opportunity to feel immersed in a digital environment that simulates the physical environment [1] and create immersive environments conducive to collaboration among users. Collaboration can be analysed with the theoretical framework of Computer Supported Cooperative Work (CSCW) [2] but its taxonomies fail to address the key characteristics of 3DVW [3]. Cruz et al. sustained that the impact of non-verbal communication on collaboration in 3DVW is not well known, even considering that some characteristics, such as embodiment in an avatar and immersion within a (virtual) physical space, support this type of communication [4]. It has thus been called forward the necessity to have more empirical data about this problem to increase the degree of confidence in data and possibly develop CSCW theory frameworks [3]. Thus, our approach presented herein

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was the development of a case study focused on training in aeronautical maintenance practices, to collect new data about the impact of non-verbal communication in a cooperative learning context. The case study was carried out at CENFORTEC, a training centre for aircraft maintenance technicians (AMT), located at the Cascais (Portugal) municipal airfield. With this work, we provide new data, collected using the protocol proposed by Cruz et al. in iLRN 2015 [3] and subsequently detailed in 2016 [4], but with a new case study that can contribute to improve the knowledge about the theoretical model of CSCW. The data was extracted from an aeronautical practices scenario. We related the evidences obtained with the propositions defined by Cruz et al. [4]. The analysis of the data identifies several chains of evidences, replicating some of them found in the scenario analysed by Cruz et al., and showed new chains of evidences.

2 Background

3DVW are collaborative virtual environments allowing users to feel immersed inside them, through a graphic representation called avatar, which can communicate with other users' avatars using audio, video, and gestures, among other possibilities [6]. CSCW is an interdisciplinary scientific area that studies how information technologies can aid group work [12]. It is an area that has driven the application and systematic evaluation of avatar interaction and features because they have desirable effects on the experience of social presence on the sense of task execution [10].

The sense of presence, in particular is important to understand collaboration in 3DVW [5]: it has been shown that these worlds enable users to interact in a way that contributes to the sense of presence [7]. Collaboration itself relates to the sense of presence [9] and it is also recognized that immersion, non-verbal information [8], communication [10] and interaction [5, 11] are important to the sense of presence. Non-verbal communication can be used to improve awareness, the sense of belonging to a group, and collaborative tasks in general [5, 10].

In general, there is a broad consensus on the importance of the communication functions of non-verbal communication, but there is still little knowledge about its specific mechanisms [8]. In particular, there is a lack of data about the relevance of low-level subtle and transient effects inherent to non-verbal communication, like the use of specific gestures and coordination of verbal and non-verbal activities [10]. This is a limitation of the ability of current CSCW theoretical frameworks to handle 3DVW [13] that this work aims to address by collecting evidences towards building up data that may eventually enable reshaping those frameworks.

3 Methodology Overview

This work adopted the case study research methodology following Yin's perspective which sees it as "an empirical investigation that investigates a contemporary phenomenon within its real-life context, especially when the boundaries with the context are not clearly defined, or the investigator has little control over these points" [14].

This methodology comprises (1) *Research Design*, (2) *Preparation for Evidence Collection*, (3) *Evidence Collection*, (4) *Evidence Analysis* and (5) *Sharing of Results*. Cruz et al. defined the first two steps for our specific problem as part of their case study protocol [4]. The *Research Design* contains: *Research questions* that provide an important key, establishing the most relevant research strategy to be used; *Propositions*, which direct attention to what should be examined within the study objective; *units of analysis*, which relate the data with the fundamental problem, linking them to propositions; and finally, the definition of a *criterion* for the interpretation of the results obtained [14, 15]. We applied this protocol to a scenario developed in OpenSimulator, using its research questions (as well as its propositions and units of analysis):

RQ1: How does the use of an avatar influences collaboration 3DVW?
RQ2: How does the virtual spatial environment influences collaboration 3DVW?

Our case study consists of a simulation in a 3DVW (built using OpenSimulator) of a learning activity on the process of aircraft towing. The participants, within the scope of a training-learning activity, collaborate in the required tasks. Data about interactions between the participants and the environment were collected by direct observation.

4 3DVW Aircraft Towing Simulator

Aircraft maintenance is a complex, rigorous, delicate and exhaustive process that requires a very precise training program [16]. Therefore, is essential to undergo proper maintenance training to ensure that aviation maintenance technicians have the qualification, proficiency, and certification required to perform their tasks [17]. It is in this context that simulation in 3DVW arises as an alternative way to obtain part of this training by providing new opportunities that can be used by trainers and trainees [18].

We developed an e-learning module for this purpose and provided it on a Moodle e-learning software platform at the CENFORTEC (Cascais, Portugal) training centre for aircraft maintenance technicians. This e-learning module allowed a group of trainees to acquire knowledge on how to conduct a maintenance activity, aircraft towing, in a simulation scenario. The module is organized into topics: (1) Introduction, describing the objective of aircraft towing training; (2) Security issues that users must respect; (3) Constitution of the tow crew and responsibilities of the participants; (4) Description of the aircraft towing process; (5) Equipment used in the towing process; (6) Signals defined by International Civil Aviation Organization (ICAO) for non-verbal communication; (7) Introduction to the simulation environment. It also included a tutorial for installation and setup of the 3DVW viewer to access the scenario.

The simulator was built specifically to support this theoretical module, using Open Simulator for the server, and made accessible through the Internet. Users accessed the virtual environment through the Firestorm client viewer.

The simulator scenario intent was to be visually simple but sufficiently credible for the trainees, who are familiar with the aeronautical environment. It was constructed from scratch, modelling all necessary objects with the tools made available by Firestorm. The 3D graphical modelling of the scenario recreated an airfield (Fig. 1):

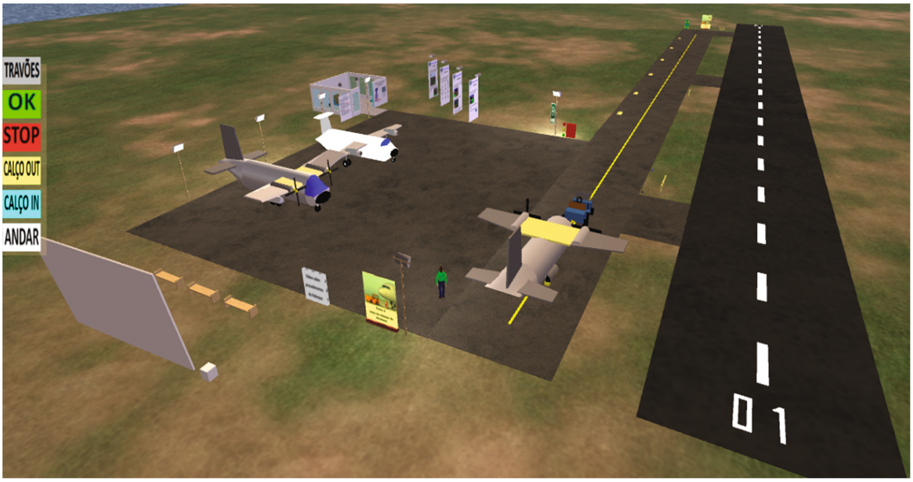

Fig. 1. The simulator scenario, with the aircraft to be towed and the airstrip. (Color figure online)

a runway, oriented 10º north, 190º south, a main apron and a taxiway parallel to the runway, linking the runway to the main apron. The set "tractor - tow bar - aircraft" parked on the taxiway is used in the simulation, and the remaining aircrafts are only for decorative purposes, with the intent of supporting the overall context. The scenario also has some user-support areas: billboards with topics on towing procedures, a training area for towing tractor practice, and an area with a video on towing procedures. The specific movements/gestures defined by ICAO were built with third-party software and loaded into the viewer for use by avatars. The name above the head of each avatar, combined with his/her uniform identified that avatar and the role he/she played. Trainee avatars wore a yellow shirt, light blue coat (optional) and black trousers, and the trainer avatar wore a white shirt with dark blue trousers. Each trainee had a specific task within the training setting.

5 Evidence Collection

Six avatars took part in the simulation (a trainer, a cameraman, and four trainees). At the beginning of the session, the trainer appointed a trainee as crew chief, who in turn, appointed the other crew elements (a tractor operator and two wing observers). Afterwards, they went to the aircraft to perform the aircraft towing procedures.

The interactions between avatars, and of avatars with objects in the simulator, enabled the collection of data. The observation of the evidences was made directly from the case and followed the process used by Cruz et al. [13]: "each reference to the use of a feature or behaviour was accounted for, relating to one or more units of analysis, according the impact of the evidence described in the unit". Collected data were organized for the case study in a two-table database [15] (Tables 1 and 2).

Table 1. Evidences of the units of analysis related to the avatar

Units of analysis	Evidences
Appearance	All avatars were dressed with uniforms
	All trainee avatars wore the same uniform, but a different one from the trainer
	The trainees positioned themselves close to each other and turned to face the trainer as he gave explanations about the session
Gestures made	The avatars performed several gestures during the session
	Beams of coloured balls were seen leaving some avatars' hands towards objects, and subsequent changes in their responses
	Circular beads of coloured balls were seen next to the objects with which the avatar was interacting
	Some avatars made gestures depicting writing on a keyboard, indicating to others that they were communicating by text using the instant messaging (IM) avatar-to-avatar communication system
	After the crew chief made the sign "chocks out", beams came out of the hands of some avatars towards the main landing gear
	At the end of the tow, after the crew chief made the sign "chocks in", beams came out of the hands of some avatars towards the main landing gear
	The avatars used various gestures defined by ICAO to communicate with each other without using audio or IM channel. Gestures were used to pass the following messages: "chocks out", "chocks in", "stop", "go ahead", "ok/free"
Observation	After an avatar raised his arm and waved with his hand, the trainer interrupted his activities, turned to him, and asked him to present his doubts
	After the observer avatars made the gesture "ok", upon finishing the airplane inspection, the avatar crew chief also made the gesture "ok", returning the communication
	During the tow, the crew chief saw an obstacle and made the gestures to signal that the crew should stop the aircraft towing
Direction of movement	At the beginning of the training session the trainer addressed the trainees who gathered close to each other near the meeting point
	After being named, each avatar went to the place previously defined in the theoretical content (crew chief to the front of the tractor, tractor operator next to the crew chief, and observers near the wing tips of the aircraft)
	After an order of the crew chief, the avatar operator sat on the tractor
	At the beginning of the tow the avatar crew chief made the gesture corresponding to the tractor moving forward, and the operator set the tractor in motion towards the crew chief
Avatar placement	At the beginning and at the end of the session, the avatars trainees gathered in front of the trainer avatar to listen to their explanations
	The avatars moved within the scenario and positioned near the objects (tractor, aircraft, etc.) with which they interacted

Table 2. Evidences of the units of analysis related to the physical space

Units of analysis	Evidences
Animated visual artifacts	The set "tractor – tow bar – aircraft", through interaction of the avatar, moved forward/backward, etc.
	In the support area, near the meeting point, there was an instruction panel and a tractor that allowed training of the use of the tractor by the avatar
Non-animated visual artifacts	The cockpit, the nose landing gear, and the main landing gear, visually changed (or displayed messages) when an avatar interacted with them
	A coloured panel at the beginning of the taxiway, indicated whether it could be used (green panel) or if it was interdicted (red panel)
	All avatars presented their names above their heads
Non-visual artifacts	The interactions by avatars caused some scripts to run and execute actions in response to those interactions
	The session was scheduled by an e-mail sent to trainees
	Avatars communicated through Google Hangouts audio group and sometimes avatars used OpenSimulator text IM
Visual environment	The session took place in a space simulating part of the area of an airfield: a main apron containing aircrafts, a runway, and a taxiway where the aircraft tow took place. In the taxiway is a set "tractor, tow bar, aircraft" to be towed from point "A" to point "B"

6 Evidence Analysis

The analysis of results was accomplished according to the general analytical strategy defined by Yin [14]. That is, linking the collected data to the stated propositions, thus creating one or several chains of evidence for each proposition. To accomplish this, Table 3 was constructed with the chain or chains of evidence that support each proposition defined by Cruz et al. (evidences, related evidences, additional evidences) [4]. A chain of evidence starts with a reference to a unit of analysis extracted from the case, and in the other columns are provided evidences of behaviors that are suspected to be caused by that reference to the unit of analysis, or by a behavior provoked by that reference. Thus, a chain of behaviors is created. Those evidences are also extracted from the case. In this table, each proposition is related to the chains of evidences that support them, by assigning the chains to the propositions if the reference to the unit of analysis in the beginning of each, is itself, related to the proposition in cause. The chains of evidence marked with "*" are new, the others match those already identified by Cruz et al. The new chains bring new data about non-verbal communication in 3DVW.

Table 3. Propositions and related evidences/units of analysis

<table>
<tr><td colspan="3">P1: The aesthetics of the avatar influence the perception by others of the role of the avatar and/or his attitude</td></tr>
<tr><td>All avatars were dressed with uniforms</td><td>All trainee avatars wore the same uniform, but a different one from the trainer</td><td>The theoretical module provided in Moodle showed the functions and activities that the trainees should perform coordinated by the trainer</td></tr>
<tr><td colspan="3">P2: The gestures and sounds that the avatar does, influence the perception by others about how the avatar's user wants to collaborate or how he/she wants others to collaborate</td></tr>
<tr><td>Avatars made several gestures during the session</td><td>At the beginning and end of the session, the trainees' avatars gathered in front of the trainer avatar to listen to their explanations</td><td>The users communicated through Google Hangouts audio group, and sometimes avatars used IM, communicating via text</td></tr>
<tr><td colspan="3">P3: The eye gaze/face direction, direction of movement, and avatar placement provide cues about what the user is playing attention to, or what the user would like to direct others' attention to</td></tr>
<tr><td>The avatars moved within the scenario and positioned themselves near the objects (tractor, aircraft, etc.) with which they interacted*</td><td>Beams of coloured balls were seen leaving avatars' hands towards objects and subsequent changes in position or movement</td><td rowspan="2">After the crew chief made the sign "chocks out", there were beams coming out of the hands of some avatars towards the main landing gear*</td></tr>
<tr><td>Avatars used ICAO gestures to communicate without using audio or IM text channel*</td><td>Avatars performed several gestures during the session (sending messages; communicate operation completion)*</td></tr>
<tr><td colspan="3">P4: Interaction of the avatar with specific objects provides cues about which objects are intended to be used by others in the collaboration process</td></tr>
<tr><td>After an order of the crew chief, the avatar operator sat on the tractor*</td><td>Crew chief made the gesture corresponding to the tractor moving forward, and the operator set the tractor in motion towards the crew chief*</td><td>The set "tractor – tow bar-aircraft", through interaction of the avatar operator, showed movement forward/backwards, etc.*</td></tr>
<tr><td colspan="3">P5: The arrangement of objects (e.g. their grouping or alignment) provides cues of their purpose for collaboration</td></tr>
<tr><td>The set "tractor – tow bar-aircraft", moved forward/back, etc.*</td><td>Cockpit and nose & main landing gears visually changed (or displayed messages) when an avatar interacted with them*</td><td>The interactions by avatars caused some scripts to run and execute actions in response to these interactions*</td></tr>
<tr><td>A coloured panel at the beginning of the taxiway</td><td>Circular beads of coloured balls were seen next to the</td><td>At the beginning of the tow, the avatar crew chief made</td></tr>
</table>

(*continued*)

Table 3. (*continued*)

indicated whether it could be used (green panel) or if it was interdicted (red panel)*	objects in which the avatar was interacting: The panel turned green after trainer interaction*	the gesture corresponding to the tractor moving forward, and the operator set the tractor in motion towards the crew chief*
P6: The exchange of visual artifacts (i.e., “objects”, “clothes”, “tools”), with the specific visual features and explicit purposes, helps define the team, contributing to group awareness, and perception of collaboration roles		
All the avatars showed their name hovering over their heads	The trainee avatars positioned themselves close to each other and turned to the trainer as he gave explanations about the session	The trainer named the crew chief, and the crew chief named the rest of the team*
P7: The virtual spatial environment, including lighting, sound or music, and visual effects, influences the attitudes of collaborators.		
The session took place in a space simulating a partial area of an airfield: a main apron containing aircrafts, a runway, and a taxiway where the aircraft tow took place	After being named, each avatar went to the place previously defined in the theoretical content (crew chief to the front of the tractor, tractor operator next to the crew chief and observers near the wing tips of the aircraft)	The trainees identified, per the theoretical content they had studied in Moodle, the actions they should take, as well as the precautions to be taken to ensure safe aircraft towing*
	The aircraft was towed from point “A” to point “B”*	

7 Conclusions

Cruz et al. provided the analysis of several cases that supported the propositions but some of their propositions had just a few chains of evidence or even a single chain. The point of having chains of evidences is to see if the related reference to a unit of analysis causes the behaviors stated by the proposition. If so, the proposition can be considered as true, or else it might be considered false. With our new data we found chains to support all propositions, some which reproduce Cruz et al.’s findings, and some which are entirely new, increasing the support to the validity of those propositions. All chains could be assigned to the propositions stated, meaning there is no need to created new propositions to fit the new data.

The existence of new chains makes us suspect that new cases might yield further chains. Hence, we deem it worthwhile to analyze more cases in search of chains of evidences that may lead us to create new propositions, or to the reformulation of the current ones, with possible impact in the answers to the research questions. Only when the analysis of more cases does not bring new chains of evidences, will we be confident that the set of propositions is consolidated.

This work started from the problem of lack of empirical data characterized by Cruz et al. [4] and applied the protocol created by these authors to a new case study. A simulator was developed, using OpenSim and a collaborative activity developed in an aeronautical maintenance scenario: the towing of an aircraft by a maintenance team. This simulator allowed, in a simple and low cost way, to apply the protocol and use this study the approach employed in the pilot case carried out by Cruz et al., i.e., using the same process in an unexplored topic. This drew our attention towards an aspect that wasn't considered earlier: many of its chains of evidence included gestures that were part of the learning content itself, e.g. "the gesture corresponding to the tractor moving forward". We wonder if Cruz et al.'s approach of broadly looking at all non-verbal elements shouldn't take into consideration two different aspects: non-verbal elements that are related to the learning content and non-verbal elements that not related to the learning content (e.g., spatial positioning identifying groupings or assemblies of participants). The implications of this are not clear and warrant further reflection and research towards a better understanding and framing of virtual worlds within the CSCW theoretical framework.

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The Development of Transactive Memory Systems in Collaborative Educational Virtual Worlds

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Abstract. The use of 3D virtual worlds in the form of cyber campuses has been introduced in higher education over the past decade to support and enhance students' online learning experiences. Considering that students learn in socially constructed ways and through peer collaboration, the development of Transactive Memory System - the collective awareness of the group's specialization, coordination, and credibility - is found to be beneficial for educational purposes. This paper presents the results of a study investigating the extent to which a TMS can be developed within a 3D virtual world educational setting.

Keywords: Virtual worlds · Cyber campuses · Transactive management systems · Online learning

1 Introduction

According to Bartle [1]: *"virtual worlds are places where the imaginary meets the real"*. These are synchronous and persistent environments facilitated by networked computers in which users are interacting with each other and the environment, through the use of their avatar [2]. The avatar is the user's visual embodiment, presence, and viewpoint of the virtual world, and acts as a mean of social interaction [3, 4]. Over the past few years, 3D virtual worlds have been utilised for training, e-commerce, marketing, holding events, meetings, as well as for teaching and learning in immersive and creative learning spaces [5]. In particular, the use of virtual worlds in higher education are commonly referred to as 'cyber campuses', in which the students can connect and gather, communicate, collaborate and exchange information through a 3D environment [6]. Along this line, collaboration and knowledge sharing in small teams is inevitable especially in education. A Transactive Memory System (TMS) represents the collective awareness of the group's specialization, coordination, and credibility [7, 8]. The concept initially conceived by Wenger [7] in Group Psychology research who observed that members of long-tenured groups tend to rely on each other to extract, retain and communicate information from different knowledge domains. TM is concerned with: *"the prediction of group and individual behaviour through an understanding of the manner in which group processes and structures information"* [7].

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Following the above definitions, this study is set up to investigate the development of TMS within a cyber campus environment, built to facilitate group activities in a blended learning approach. In the following sections, we will provide a literature review related to cyber campuses and TMS (Sect. 2). Section 3 will give an overview of the methodology followed and the settings of the study, while the results and discussion are provided in Sect. 4. Limitations and Future work will conclude the paper (Sect. 5).

2 Background

In this section, we will provide background on the thematic areas involved in this research and also position our work within the existing literature.

2.1 Cyber Campuses

Many scholars have been investigating virtual world and virtual reality environment practices since the 80's, to provide innovative learning experiences to their students [9, 10]. The use of virtual worlds in the form of cyber campus environments has been utilised from many higher education institutions to support teaching and learning for over a decade. [11]. These environments can enable educators to replicate pedagogical activities that happen in the real world classroom [12], and provide opportunities to support experiential learning, in which students can engage in problem based solving activities [13–15]. Cyber campuses also have the potential to effectively support participation in online learning activities for all students, even those experiencing barriers hindering access to education [16]. A cyber campus can provide access and synchronous participation in immersive online learning activities characterised by social interactions [17], making learning more interesting [18], and engaging students in educational activities [19]. In virtual worlds anything is possible [12] and cyber campuses allow experiencing situations or conducting activities that can be difficult, expensive, hazardous, or even impossible to perform or experience in the real world [20, 21].

Around mid 2000, there was a strong hype around the use of virtual worlds and cyber campus environments, and a belief that such environments would have been the future of online learning. However, these high expectations have never been met to the extent that many virtual worlds enthusiasts were hoping of, and their popularity has been decreased [11, 22], similar to the hype of web-based education [23]. Nevertheless, cyber campuses are still of interest for tutors who are looking to expand and experiment with their ways of teaching, as these environments provide a range of possibilities to support and enhance learning that cannot be found in other online learning support tools [24].

Virtual worlds are not better or worse than other online learning tools but are different [25], and there are many studies indicating that virtual worlds are unique and flexible learning environments [10, 15, 26]. The educational efficacy of cyber campuses to support online educational activities has been previously evaluated with very positive results [16, 17, 27–31]. These environments provide a number of unique characteristics that can contribute to the student's online learning experience [32]. Some of these characteristics are based on the user's immersive feeling of presence in the virtual world, communication and sociability between students and learning teams, and awareness of the existence and actions of others [29]. In addition, the ability to provide realistic and/or abstract experiences, student anonymity, and synchronicity in learning are also found to be contributing to the environment's educational efficacy [16]. These unique characteristics can be exploited to enrich, enhance and make learning more engaging and enjoyable [16]. Based on the unique characteristics of virtual worlds, they considered as media for engagement and learning [33]. The educational community can utilise these environments to develop effective and innovative approaches to teaching and learning [26]; however, careful planning and design is required and furthermore, the virtual environments are not suited for all disciplines [12].

2.2 Transactive Memory System

The notion of Transactive Memory (TM) and the development of a TMS have proven to be very promising for the functioning of teams and groups at several contexts in face-to-face and online communication, supported usually by repository tools [7, 8, 34, 35]. TM deals with the relationship between the memory system of individuals and the communication that occurs between them [7, 36]. The focus is on encoding, storage and retrieval of information. Therefore, a TMS can provide the option to recall previously visited areas and subjects, and to identify relevant knowledge [7, 8]. Furthermore, TM helps group members to be aware of one another's expertise and to divide responsibilities with reference to different knowledge areas.

The key element behind the ability of a TMS to function is for the divergent information held in members' head to be known by the other members. To illustrate this we assume that member A's memory can act as an extension of member B's memory. If B is aware of what A knows, he/she should be able to get access to A's knowledge and the information possessed by A.

Teams can benefit from a TMS since members will become aware of the knowledge held by other members. Furthermore, the promotion of TM creates awareness on who is knowledgeable in what and facilitates the identification of complementary knowledge. To this effect, the opportunities for collaboration among team members are potentially enhanced and the result is of better quality.

Studies coming from the fields of organizational psychology, behavioural sciences and management, examined the development of a TMS and how it affects the behaviour of a virtual team [37–39]. Several angles and viewpoints have been adopted, but results converge in that information, communication and technology tools: e.g. resource repositories, bulletin boards [40], search, information access and adaptive interventions [41] demonstrated to improve the development of TMS within a virtual team. Furthermore, evidences show that decomposing TM into (i) knowledge sharing, (ii) communication quality and (iii) technical achievement of the team provides a better understanding of the aspects that affect the development of a TMS [42]. Although, there is a huge body of work that investigated TMS development in collocated and virtual teams, TMS within teams in 3D virtual worlds has not attracted much attention, with the exception of the work of Kahn and Williams [43] who studied TMS relating to virtual teams in 3D virtual games and Kleanthous et al. [44] who pilot-studied TMS in small task-oriented teams.

In their work Kleanthous et al. hypothesized that bringing together people with diverse-expertise and providing them with the necessary communication mediums of a 3D virtual world, within a task specially designed for this purpose, will allow them to develop a TMS within their teams [44]. The results of this initial pilot study with 14 participants revealed that diverse knowledge helped members through brainstorming ideas on how to approach a task. Similarly, holding unique information and skills helped team members to feel valuable to their team for completing the task. The strategies they followed in their teams, through the virtual world, for resolving these problems helped them to coordinate the execution of the task better. This is an indication that the knowledge and skill diversity of the team members allowed them to develop a sense of credibility as persons in the team and also the actual role assignment session added positively to the overall coordination of the team. Regarding the communication tools available to the members, the results are implying that chat discussions (the only medium that was available for communication) are adequate for communicating and coordinating a virtual team and the 3D virtual environment along with the avatar and gestures are empowering the development of credibility and trust within the team.

Building upon the work of Kleanthous et al. [44], and given the gap in the literature in investigating TMS in collaborative settings in 3D virtual environments, this study aims to further examine the development of TMS within a 3D virtual world in a blended learning scenario in self-created teams.

3 Methodology

The study described in this paper is advancing the work of Kleanthous et al. [44] in that it involves more participants and a number of different carefully designed group learning tasks. To conduct this investigation the following research question has been set up:

To what extend the three parameters of TMS (i) specialization, (ii) coordination and (iii) credibility can be developed among students, through long term collaborative task execution within a 3D virtual world?

Consequently, the following objectives were set:

1. Develop and set-up a cyber campus environment to support the module learning outcomes
2. Design group learning activities that would promote collaboration and communication among students
3. Collect relevant empirical data using qualitative and quantitative instruments.

What follows will describe in detail the realisation of the above objectives.

3.1 VirtualSHU

To conduct this investigation, the VirtualSHU cyber campus has been developed using Opensim[1]. The design is based on the cyber campus design suggestions proposed by

[1] http://www.opensimulator.org.

Nisiotis [31], other examples and suggestions from the literature [29, 45, 46]. The environment has a realistic look with recognisable facilities and surroundings to provide consistencies between the experiences in real and the virtual world (Fig. 1). The layout of VirtualSHU includes the main campus, indoor and outdoor lecture rooms, and collaborative zones varying in size. Each collaborative zone is an activity area for each of the topic discussed during the semester (Table 1). An orientation area is also provided to allow students to orientate and learn the basic functionality of the environment. A courtyard to act as the main meeting point for the students to meet before setting off for tasks, and recreational areas for socialisation are also provided. Furthermore, a sandbox and fantasy area in which the content design and flying restrictions of the environment are lifted are also available, together with a quiet area in which students who are away from their keyboard but remain connected is also provided. Access to the environment for students was provided from both on and off campus.

Table 1. Learning activities

Topic	Week	Task description
Orientation	1	Students created their VirtualSHU account and spend time to familiarise with the environment, the viewer controls, the environment layout, and to customise their avatars
Introduction to ICT	2	Students were allocated in teams. A general discussion was established to discuss the impact of ICT in the society
The internet and the World Wide Web	3	Students were allocated a virtual room and assigned a topic of research. In that room they met with a remote group from the other class. Students reviewed in world information, performed their own research, and each group created a 10 slides presentation
	4	Groups spend time to review their remote peers notes from the previous week session to improve their own group work. The groups then presented their work in class
Communication networks	5	A number of questions were assigned to each group. Students reviewed in-world materials, performed individual research and created group notes to answer the questions
	6	Students completed an interactive quiz through the virtual world. However, for some students the quiz did not work as expected due to lag issues, and they completed it offline
Classroom discussion	7	Similar to week 3, students were assigned a topic of research, and created a shared cloud document to keep notes
	8	Similar to week 4, students presented their notes in class. Note that two sessions were delivered entirely through VirtualSHU as a tutor was absent due to sickness, but the students attended the tutorial session under supervision
The Internet of Things	9	Similar to week 5, students reviewed in-world information and performed individual research
	10	In-world and classroom discussion to discuss the assigned topics of each group

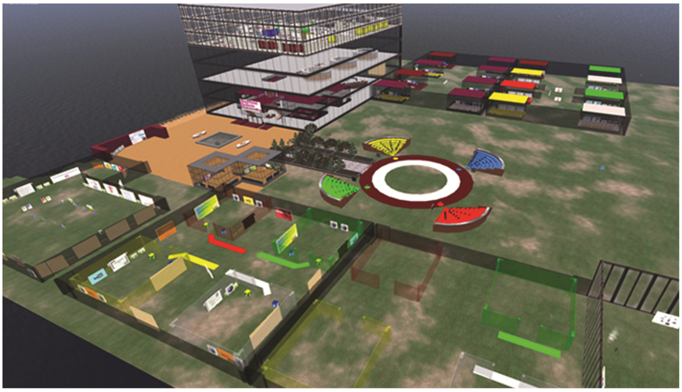

Fig. 1. The VirtualSHU cyber campus

3.2 Context and Procedures

An experiment was conducted for a period of 10 teaching weeks. The participants of the experiment were the Business and Enterprise course first year students at Sheffield Hallam University (United Kingdom) undertaking the Introduction to ICT module. Students have experienced the VirtualSHU for conducting collaborative learning activities during the tutorial sessions, and as a mean of information repository. There was a session that lasted 60 min each week. There were 4 tutorial classes with approximately 20 students each. Each 2 tutorial classes were running concurrently, and students were meeting within the virtual world. Students were allocated in groups of 3 and 4 students, and collaborated through the virtual world conducting a series of learning tasks (See Table 1). Each student had a computer at his/her disposal. The teaching approach was focussed on a blended learning mode that included face-to-face and interaction through the virtual world to improve and enhance the students learning experience. Tutors and students used the Nearby Chat and Instant Messages to communicate with their remote peers and tutors. Students were encouraged to create group chats for communication and note taking. Information was provided through PowerPoint slides, informational signs, websites and YouTube videos in the virtual world. Students were also able to connect to the VirtualSHU from home for materials reviewing and to prepare for their end of semester exam.

To collect empirical data for this study, the Transactive Memory System Scale proposed by Lewis [42] has been used. This survey investigates the factors of specialisation, credibility and coordination, which are measured by 5 items each. The statistical interpretation of the scale suggests that when a TMS exists, it causes specialised knowledge, trust in each other's knowledge and coordination in tasks processing. This is a Likert scale survey ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). In addition, we have collected data based on students' expertise with computers, the Internet, and their previous experience with virtual worlds. The survey was administered online, over a 3 weeks data collection period. From the total number of 87 registered 1st year Business and Enterprise students who have experienced VirtualSHU as part of the

Introduction to ICT module, 46 have agreed to participate in the data collection (Figs. 2 and 3).

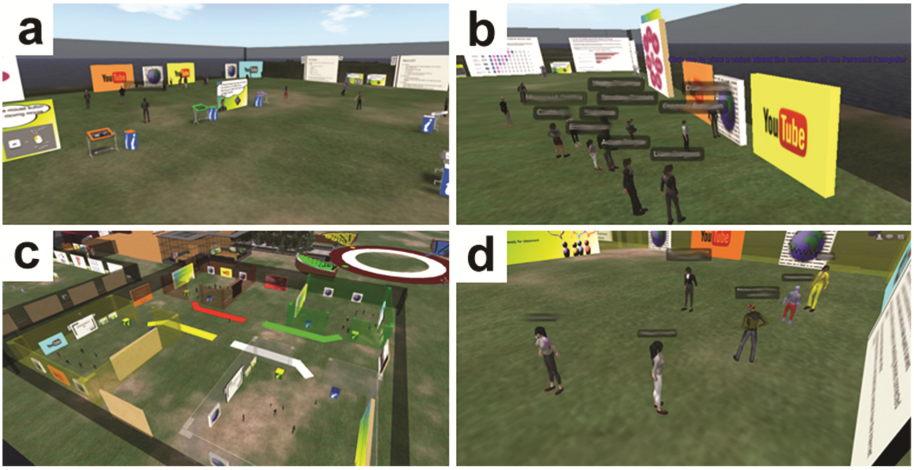

Fig. 2. Examples of activities in VirtualSHU

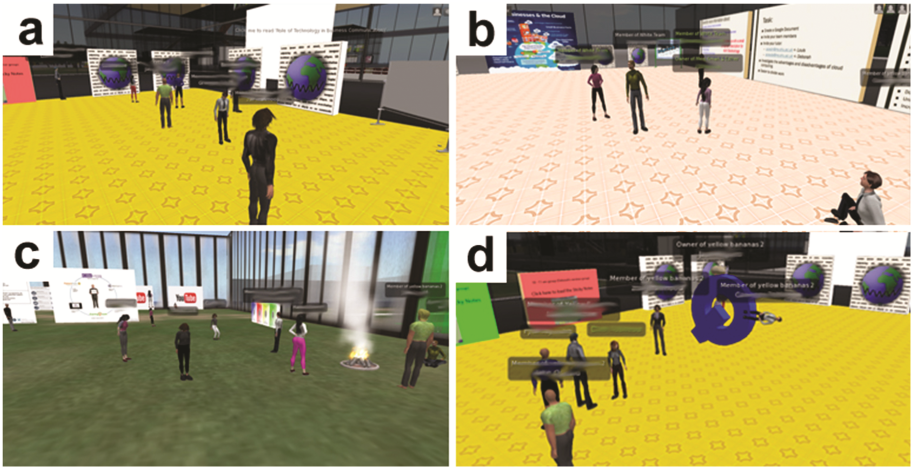

Fig. 3. Examples of activities in VirtualSHU

4 Results and Discussion

In total 46 students, 12 females and 34 males, replied to the questionnaire examining TMS building within participants. Initially we run descriptive and frequency statistics to better understand the participants. 56.6% of the participants stated to be experts in computer usage while 17.4% consider themselves as non-experts. Similarly, the majority of the participants (82.6%) stated experts in Internet usage, while 45.7% had previous experience in 3D virtual worlds prior to the study.

The analysis of the TMS questionnaire followed the method described in [42] for extracting a score for each of the three parameters: specialization, coordination, and credibility and for the overall TMS, for each participant in our study. We have also tested the reliability of the scale using the Cronbach's alpha reliability test, revealing high internal consistency between the items comprising the scale. The data were also passed the Shapiro-Wilk test for normality, thus the collected data for specialization, credibility, coordination, are normally distributed.

With regard to the TMS scale on the three parameters, the results denote development of overall TMS (Mean: 11.04, Std. Dev: 1.54). Individual parameters were also extracted: Specialization (Mean: 3.56, Std. Dev: 0.58), Credibility (Mean: 3.70, Std. Dev: 0.62) and Coordination (Mean: 3.78, Std. Dev: 0.65). We can see that the virtual campus employed in this study, along with the learning tasks that were implemented through the virtual campus, support the development of TMS; actively encourages the utilization of specialized knowledge of individuals; supports the coordination of activities within group learning tasks; and promotes the building of trust and credibility of individual group members by their peers. Consistent with previous work [44] that investigated the development of TMS in small teams with few participants (14 adults) within a virtual world in a single task, in our study we also observed and statistically captured the development of TMS involving more participants in diverse types of tasks. Having efficient coordination within a team allowed members to effectively and efficiently distribute tasks and sub-tasks among members, resolve conflicts and communicate information. Similarly, the development of credibility for each member encouraged trust to build and members to value the knowledge, opinion and decision of other team members. Specialized knowledge that members possessed affected the collaboration within the team. Distinct knowledge is beneficial to other members especially when the task requires it, and allows the member who possess this knowledge to feel valuable to the team and develop a sense of importance to the others. These results can be considered significant in the context of collaborative learning where participants are active learners in a running course and the implemented tasks were part of their learning experience.

Furthermore, we were interested to examine how the three TMS parameters correlated to the participants experience in computer and Internet usage, since the overall settings of the study required working through the Virtual SHU for several tasks throughout the semester. The results reveal a significant correlation of the participants' perceived expertise in computer usage with the elements of overall TMS ($r = 0.309$, $p = 0.037$ at 0.01 level) and coordination ($r = 0.351$, $p = 0.017$ at 0.01 level). This outcome indicates that being computer literate helps in utilizing the tools within the cyber campus to coordinate group activities and thus improving the overall TMS of a person. No correlation is found between any elements of TMS or TMS and the experience participants have on Internet usage or previous experience with virtual worlds.

The above results add to the previous study [44] performed by the authors in examining TMS building within a 3D virtual world. The previous work examined the development of TMS in a completely virtual setting while this work used a blended approach. In addition, the teams investigated in [44] were diverse knowledge teams in contrast to the teams investigated in this study that were randomly created. However, the results obtained regarding the development of TMS in this paper are consisted with the results described in [44].

5 Conclusion, Limitations and Future Work

The study described in this paper has been performed in real settings, with a significant number of participants (46) and in a long period of time (10 teaching weeks). The development of TMS has been facilitated through the VirtualSHU through carefully designed group tasks that required members to become aware of each other's expertise and skills, build trust within their teams and the knowledge that their team members' possessed, and to use the communication and other tools provided within the Virtual SHU to coordinate their actions and complete their activities. Based on the observations and experience we have developed during this project, we are suggesting the following recommendations to aid virtual worlds practitioners:

(i) When tutors prepare group activities, it is suggested to design them in such ways that will require multiple tasks to be accomplished, so that students can delegate them according to their specialized areas or areas they feel confident performing. (ii) Activities should be simple but yet intellectually challenging to execute, to ensure that there will be no confusion or misunderstandings between group members, or having to frequently restart, as these could cause frustration. (iii) Students need to be encouraged to communicate and socialize while performing activities; to start valuing each other's input to improve the credibility of the information shared across the group.

We acknowledge that there are limitations that need to be taken into account in future work. For example, the students were conducting co-located activities, in addition to activities through the virtual world. However, this was a conscious approach, as we aimed to facilitate a blended collaborative learning approach.

Another limitation of this research project is the fact that we were not aware of students' previous specialisation areas. Students were 1st year, we have never met them before; we did not know their skills and previous knowledge, as well as their tendency to get involved with activities. Thus, we were not able to put them in groups based on their skills and experiences, and we have randomly allocated them instead, and this prevented us from intentionally creating diverse expertise teams.

Continuing in the same settings and following the above results, further investigation is needed to identify how the tools provided through Virtual SHU correlate with the long-term development of TMS. Future work is on its way to further investigate TMS development in the cyber campus and among students using qualitative results. Furthermore, we are in the process of collecting data based on additional attributes of the environment such as presence, collaboration and socialisation, to further investigate potential correlations with the development of TMS in such environments.

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Towards Observing and Assessing Collaborative Learning Activities in Immersive Environments

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Abstract. Immersive environments such as 3-D virtual worlds have shown great potential for learning since they have many features that distinguish them from other learning systems. They support explaining difficult phenomena by visualising objects and their relationships. Additionally, they enable collaborative learning by connecting students in real-time and increase engagement and exploration between them. However, assessing learning outcomes in these environments involves many challenges such as dynamically capturing and analysing the actions of users and translating these actions into learning evidence. This paper focusses on significant aspects of the learning process: observation and assessment. It presents a virtual observation model that maps observing learners in classrooms with observing and assessing students in 3-D virtual environments. In addition, it demonstrates the implementation of the observation model and provides examples of its application. In general, the paper aims to enhance the learning affordances of the 3-D virtual worlds by recording all in-world learning evidence and visualising students' assessments to improve learning.

Keywords: E-learning · Multi-Users virtual environments · 3D virtual worlds · Assessment · Virtual observation · Collaborative learning · Learning evidence

1 Introduction

In the 21st century, various educational technologies have been developed to support and enhance collaborative learning such as Multi-Users Virtual Environments (MUVEs), also known as 3-D virtual worlds (3-D VWs). Open Wonderland[1], Second Life[2], Active Worlds[3], and Open Simulator[4] are examples of the platforms that have been recognised to create MUVEs. These environments have shown great potential for learning [1–3], because they have many features that distinguish them from other online learning systems. They support explaining difficult phenomena by visualising objects and their relationships. Additionally, they facilitate exploration and practice-learning

[1] http://www.openwonderland.org/.
[2] http://secondlife.com/.
[3] https://www.activeworlds.com/.
[4] http://opensimulator.org/.

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activities that cannot easily be done in physical environments [2]. Furthermore, they enable collaborative learning by connecting students in real-time, increasing engagement and analysis between them [4, 5]. Through arranging collaborative learning activities in these environments, students can share their experiences which help to improve knowledge and skills.

Assessing students is a critical aspect when organising learning activities. Usually, learners acquire new information or skills while practicing individual or collaborative activities. Thus, the evaluation of students should be considered from the beginning of the learning process and not just at the end. For example, Wells [6] indicated that educators should assess the whole process when performing group activities rather than assess the final product as learning evidence. However, observing and assessing learning outcomes in the 3-D world could produce some difficulties such as dynamically capturing and analysing the behaviours and actions of users. Additionally, observing evidence about acquiring specific skills such as cognitive skills is challenging. Therefore, an approach is needed to identify learning evidence data, and for analysing the data to assess the learning outcomes of the collaborative activities in any environment. According to Gardner and Elliott [7], 'learning within technology creates a pedagogical shift that requires teachers to think about measuring outcomes in non-traditional ways.' Moreover, virtual environments need more examination to discover their learning potential and to enhance their affordances for teaching and evaluating students [3].

In our previous work [8, 9], we proposed the conceptual models, the virtual observation model (OLens) and the mixed agents model (MixAgent), to support collecting learning data and analysing the data to assess the performance of students. This paper focusses on the work we have done to take existing observational techniques from the real classroom and map them to a MUVE so that they can be used to recognise the learning outcomes from collaborative students. In particular, it represents the continued development of the OLens model and its implementation in a MUVE, as an example of an immersive learning environment. We also demonstrate how this model could be used when evaluating the interaction, performance, knowledge and skill of the learners in collaborative learning environments. The rest of the paper is structured as follows: Sect. 2 (assessments in immersive environments) discusses techniques and previous studies that have assessed the learning of students in virtual worlds. The third section (virtual observation model) introduces the OLens model and the observation layers used within the model. The fourth section (virtual environment) explains the application of the lenses and shows examples of the implementation. Finally, the last section presents the conclusion and the future work.

2 Assessment in Immersive Environments

The assessment of students in general has been defined by Angelo [10] as "an ongoing process aimed at understanding and improving student learning. It involves making expectations explicit and public; setting appropriate criteria and high standards for learning quality; systematically gathering, analysing and interpreting evidence to determine how well performance matches those expectations and standards; and using the resulting information to document, explain and improve performance". Assessment should measure the learning of students based on different aspects such as learner performance, success, knowledge, and skills. On the other hand, observing the essential differences of various categories requires different methods to be applied. For instance, knowledge can properly be assessed by traditional exams, but evaluating skills requires more complex activities and techniques that can demonstrate them. MUVEs can achieve this objective through creating complex situations and supporting exploration of phenomena that do not exist in the physical world [2]; which allow the enhancement of skills and competencies. Providing assessments and feedback in the learning process can enhance student learning and improve their performance.

Several approaches have been used to assess students learning in MUVEs. Firstly, the traditional school test approach, which involves giving paper tests to students or generating automated questions and multiple choices during or after finishing the learning activity to assess learning. For instance, in Second Life, most educators use an extension of classroom summative tests to provide final assessment [11]. Another example is the quizHUD project [12] in SLOODLE [13] that uses a multiple choice interface to assess students' knowledge. This approach could be useful when the environment is used to give lectures, imitating the physical classroom setting, where the evaluation objective is to assess the student's knowledge. However, traditional school tests should not be applied to measure learning outcomes when the virtual environment offers hands-on or experimental activities to teach students. In these settings, summative tests do not provide a full perspective of the student learning and cannot adapt to the needs of learners, nor provide them with immediate feedback while they are working. MUVEs enable significant learning opportunities for distance learners through distributed systems in collaborative and cooperative activities that require new assessment methods to meet today's complex learning requirements. Thompson and Markauskaite [14] stated that 'educators need to move beyond traditional forms of assessment and search for evidence of learning in the learner interactions with each other and the virtual environment, and artefacts created.'

A second approach that has been applied to assess learning is analysing the actions of students. It is regularly based on the cognitive task analysis method which consists of creating logical rules to track students' behaviours and to distinguish specific levels of the skills of learners [15]. An additional technique to analyse the actions of students is to extract the performances of students from generated log files by applying machine learning or data mining approaches. For instance, Kerr and Chung [16] analysed the log data of users by applying cluster analysis algorithms to define the key feature of the performance of students in educational game environments. In addition, Bernardini and Conati [17] applied cluster methods and class rules on the log data of users to find out the models of learners using successful and unsuccessful strategies within the learning environment. Even though these studies are investigating the behaviour of users, they are limited to studying the relationships between the data and identifying the quality of the learning outcomes from the log files. Moreover, it is more challenging to identify learning evidence for collaborative learning activities where there are many contributing users. The log files keep all actions of users to problems, and this generates a large amount of data and delivers a serious obstacle for researchers when collecting learning evidence to recognise various learning outcomes [18]. Capturing the data of users without identifying how they are scored is not an effective process for creating assessments. It is more preferable to develop the learning environment from the beginning to gather learning evidence and assess students learning [19].

According to Gobert [20], educators encounter serious issues when assessing learning in immersive environments. The first issue is that there is an absence of theoretical guidance to analyse streams of data generated from the performances of learners. The second issue is the lack of theoretical foundation in literature in the learning assessment and assessment approaches. Conversely, some studies have applied the Evidence-Centred Assessment Design (ECD) framework introduced by Mislevy and Riconscente [18, 21]. ECD is a general framework created to assess students learning in computer-based tests, and it consists of different models: ‘student model’ (what to measure either student skills, knowledge, or abilities), ‘evidence model’ (how to measure), ‘task model’ (where can we measure it). Others have used ECD to assess students in simulation environments to assess learning skills [22]. Shute [23] developed the Stealth assessment based on the ECD which applies an AI approach (Bayesian network) to model the student actions in a learning game and infer the level of problem solving skill. He proved that the inferred learning events closely matched with actual students learning. However, these studies applied the assessment in-game context to assess a specific competence or skill based on the behaviour of a player. On the other hand, there are no standardised assessment models or guidance to observe the learning activity and assess all learning aspects such as student interactions, success, knowledge, and skills. Furthermore, most of these studies focus on assessing individuals, but one of the most important features of MUVEs is allowing collaborative activities and sharing knowledge. To measure collaborative learning activity, we need to evaluate the learning of the group as well as the learning of individuals. Nevertheless, there are few studies that present theoretical guidance to assess such activities. Accordingly, this paper continues our previous work on the virtual observation lenses model (OLens), which provides solutions for assessing students, by presenting the mechanisms and aspects that should be considered when assessing collaborative learning activities on immersive environments.

3 Virtual Observation Lenses Model (OLens Model)

The OLens Model [8] defines the frames of observing, capturing, and analysing data to assess collaborative learning activities in immersive environments. The model has been derived from observations in physical classrooms where teachers should observe many aspects of learning to understand the behaviour of students. Thus, we adopted the observation lenses in [24] that focuses on student learning, and modified and applied these lenses to work on 3-D virtual worlds (3-D VWs). The OLens model states the granularity levels for observing the actions of students and clarifies what could be monitored. Moreover, it defines the learning evidence of collaborative learning, starting with high-level to low-level observation (see Fig. 1). The OLens layers are events detection, learning interactions, success of students and performance outcomes.

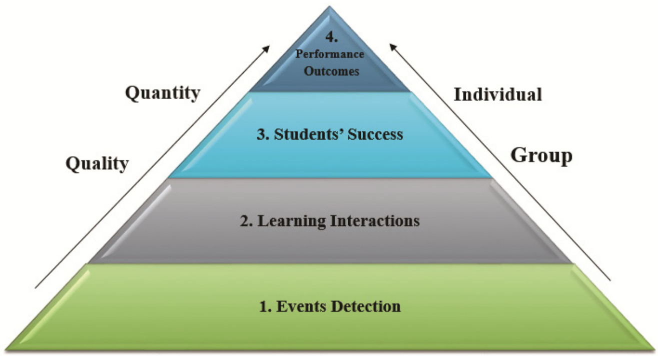

Fig. 1. Observation Lenses Model (OLens Model)

The Events Detection Lens. This lens simulates high-altitude observation, similarly to when a tutor watches a collaborative activity without analysing deeply into what is happening. To apply this in the VW, the system monitors the activity by recording and capturing the sequence of events without assessing learning. This level focuses on collecting all implicit and explicit learning events that are produced by students such as saving the actions and logs of users to support the other lenses that are responsible for analysing these actions to assess learning.

Learning Interactions Lens. This lens reflects a deeper observation of environmental and social interactions. Social interactions relate to interactions between the group members, and environmental interactions involve interactions between users and the VW. Furthermore, this lens focusses on evaluating the quantity as well as the quality of interactions to infer whether the students are active and valuable members in their groups. Examples of factors that measure how many interactions happen are the number of actions of a learner during a period and the number of actions of a group

Students' Success Lens. This level symbolises when educators are observing students' success in the classroom, and extends it to recognise learners' success in VWs. Student's success can be measured by the percentage of the correct responses they achieve to the questions, exercises, or assignments [24].

Performance Outcomes Lens. This level focusses on observing students in-depth to identify the outcomes during the learning activities. In this lens, educators can observe any type of learning outcomes they would like to assess. According to [25], the outcomes of learning involves what a student understands, knows, and is able to do to complete the learning process. They are defined as knowledge, skills and competence. By studying the literature and expert reviews, we can understand the evidence to be collected from learners to measure specific skills and competencies.

The OLens frames support measuring the performances of users and the quantity and quality of each learning outcome. The following Sect. 4 explains the virtual environment that we have used to apply these lenses and gives examples of how these pedagogical lenses can be mapped to assess students' performance in VWs. More details about applying these lenses are presented in Sect. 4.2.

4 Virtual Environment

To make the OLens model come alive in an immersive environment, we present an example of applying the model levels on the Interreality Portal, a 3D virtual environment developed at the University of Essex [26] (See Fig. 2). The environment is built using Unity3D[5], a flexible development platform for assembling 2D and 3D collaborative games and environments. We use the Interreality Portal as our learning platform because it supports collaborative learning activities between online students using hands-on activities. The Interreality Portal allows students to collaboratively program different sensors and actuators by creating IF-THEN-ELSE rules in real time. It was designed to teach students the concepts of embedded systems and their functionality in smart homes.

Fig. 2. Graphical User Interface (GUI) – InterReality Portal [26]

4.1 The Learning Scenario

Students were grouped and asked to log on the online virtual environment (a group is formed by two to four students). Each student had their own avatar and they worked collaboratively in given learning tasks to solve numerous problems. These tasks teach them the functionality of embedded systems (sensors and actuators) and how they can create and programme rules using the programming board and icons. Thus, if they create syntactically correct rules, the result is reflected on the virtual smart home (Fig. 3).

To communicate and exchange ideas to accomplish the assigned tasks, learners can use a chat box in the GUI. While participating in the learning activity, the system provides them with the opportunity to rate each other, with the aim of evaluating the quality of their actions and those of their fellow students, using the rating tool (Fig. 3). Moreover, the environment tracks the actions of the users and saves all the triggered events in the repository. While the students progress through the different collaborative tasks, the system captures learning evidence and analyses the actions of the users. Then,

[5] https://unity3d.com/.

Fig. 3. Students collaborating in the virtual environment

when the learners finish the assigned tasks, they receive an automated dashboard displaying the final analysis of their individual and group performances, summarising the learning outcomes. In addition, the instructor and each learner can review their work through recorded videos that show their performance compared with the provided assessments.

4.2 Applying the OLens Model

In this section, we provide examples to clarify the methods that apply and map the pedagogical lenses to collect evidence and to create rules and queries that can be implemented on the VW.

Event Detection. This level is where the system starts collecting the actions of students and saving them to the database simulating teachers watching from high view without inferring or assessing students. We have proposed the use of a mixed agents model (MixAgent) [8, 9] which identifies real-time events and captures learning evidence to assess the quality and quantity of the performance of students in virtual worlds. MixAgent combines software agents and natural agents (users) to provide better assessments results. Software agents monitor the behaviours and logs of learners, transform actions into data, and then send the data to the repositories. While the natural agents are the students who evaluate their fellow students to capture implicit evidence that is challenging to identify with simple technology [27], students are able to see the quality of the performance of others and evaluate the collaborative learning skills of their peers. Thus, we provided users with a rating tool (Fig. 3) to regularly rate their peers and give them scores from 0 to 2 (Negative = 0, Neutral = 1, Positive = 2). These scores are stored in the repository, and all the data from both agents are used by the OLens model for assessment.

To apply this level and collect evidence from both agents, we created a data repository to save all users actions while working together. Also, we recorded the rating points that the natural agents gave to each other. Examples of the collected data in the VW are as follows:

– User Log: <UserId, UserName, SessionId, IdActivity, ObjectType, ActionType, Service, ServiceInfo, IpAddress, TimeElapsed>
– Session Log: <SessionId, SessionName, StartTime, EndTime >
– Chat Log: <UserId, Room, ChatText, TimeElapsed >
– Programme Log: <UserId, IdActivity, Programme, TrueOrFalse, TimeElapsed>
– Rating Log: <UserId, RatedUserId, Score, TimeElapsed >
– Skills Scores: <UserId, RatedUserId, Skill1_Score, Skill2_Score, Skilln_Score>

Learning Interactions Lens. To implement this level, we build APIs to query the data stored to assess the quantity and the quality of the general contribution of learners in the virtual environment. Table 1 provides examples of the quality and quantity indicators that measure the effectiveness of interactions for individuals and groups which can be applied to this VW.

Table 1. Interactions Indicators

	Quantity indicators	Quality indicator
Individual	–The amount of actions in the chat log during a period. –The amount of actions in using the virtual objects during a period. –The amount of actions in creating programmes during a period.	–The average rating scores for a student from other members in a period. Rating scores: Negative = 0, Neutral = 1, Positive = 2
Group	–The sum of all the actions of all the members in a group actions in chat log, objects log, and programme log during a period.	–The average rating scores for all members in one group in a period. Rating scores: Negative = 0, Neutral = 1, Positive = 2

Student Success Lens. This level extends the decisions of teachers determining the success of students in classrooms to 3D virtual environments. As mentioned, success of students can be measured by counting the percentage of the correct responses the students achieve to questions and tasks [24]. Table 2 gives examples of the indicators that measure the task success in this lens for the group and individuals.

Table 2. Task Success Indicators

	Quantity indicator	Quality indicator
Individual	–The amount of correct/wrong answers during a period. –The amount of completed/ uncompleted tasks on time.	–The rating scores from other members about the quality of a student work when doing a task.
Group	–The amount of the group correct/wrong answers during a period. –The number of completed/ uncompleted group tasks on time.	–The sum of the rating scores from all members about the quality of the group work when completing a task.

Performance Outcomes Lens. This lens is a summative assessment that focuses on evaluating the quantity and quality of the learning outcomes at the end of the learning activity rather than evaluating just the correct answers. Since the activities between students focus more on collaborative learning, it is necessary to assess the learning outcomes based on their collaborative skills. Johnson [28] identified different collaborative skills including communication, maintaining trust, leadership, and creative conflict. However, most of these skills cannot be measured easily by the data collected from the system. They need more feedback from the actions of students with peers and environments. One approach of measuring these students skills is to use a peer evaluation technique to assess the performance outcomes of the learners [29]. Adopting this approach can obtain deeper insights regarding the quality of collaborative skills the students apply on the learning activities. Students were asked to rate the performance of their group members during and after the learning activities. Figure 4 shows a screenshot of the rating scene that includes the collected data from student at the end, and Table 3 gives examples of the learning outcomes indicators to assess students in this lens.

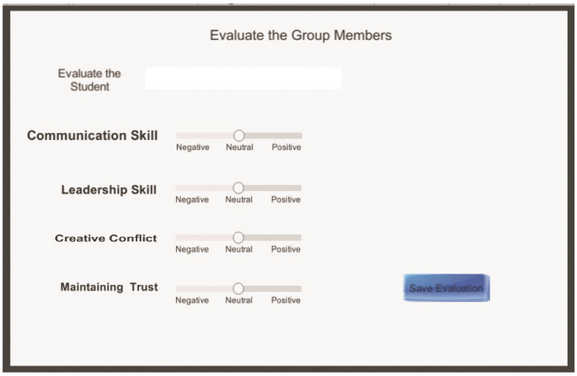

Fig. 4. Final rating screen to evaluate each group member skills

Table 3. Learning Outcomes Indicators

	Quantity indicator	Quality indicator
Individual	Summative results at the end of a session: 1–The amount of interactions of a learner from the interactions lens. 2–The amount of a success tasks of a learner from the success lens.	1–The rating scores for the collaborative skills. 2–The average rating scores for a student during the learning activity.
Group	Summative results at the end of a session: 1–The amount of the group actions from the interactions lens. 2–The amount of the group success from success lens.	1–The rating scores of the skills for all the group members 2–The average rating scores for a group from all members.

4.3 Assessment Feedback

After finishing the session, students and teachers can view their work through the dashboard showed in Fig. 5, which demonstrates the quantity and quality of groups and individuals' interactions by time. As shown in Table 1, for the quantity of interactions, the system counts the number of users' actions during the learning activity. In addition, to measure the quality of the contribution of a student, the system calculates the rating scores for each student using the feedback from the other members, to determine if the student contributions in the learning task are valuable. Figure 5 is an example of the assessment screen that appears after the learning session finishes. The left section represents the data from automated agents (the quantity of interactions), and the right section represents the data from natural agents (the quality of interactions). Then, the learners can review their work through recorded videos to follow their performance compared with the assessments dashboard, as shown in Fig. 6. For example, if the chart shows that the student has low interaction at the beginning, he or she can watch the video to understand this result and know how to increase the performance later.

Fig. 5. Dashboards show a student interactions by time in the learning activity.

Fig. 6. Video recording to review the student performance.

5 Conclusion and Future Work

Real classroom observation and assessment is well documented in the literature. Nevertheless, in immersive environments, observing students and assessing them based on their performance is still in the preliminary phase. Consequently, the paper extends the learning affordances of 3-D VWs, which is the ability to capture all in-world events automatically, and this is very difficult to perform in the real world. Thus, to capture all events, we present the virtual observation model (OLens) which could play important roles to understand the actions of learners during the learning activity and to evaluate their learning in the VWs. The OLens model consists of different levels, including events detection, learning interactions, success of students and performance outcomes lenses. Each lens emphasises evaluating students learning from different aspects. Assessing students is an important phase of the learning process, because it can determine whether the learning objectives have been achieved. Additionally, it can help to understand the performance of learners and provides more awareness about improving the collaborative activities. Moreover, the peer assessment approach that was used provides greater understanding of the value of the contributions of students and give more insights about the collaborations quality.

Also, this paper contributes to enhancing the learning affordances of 3-D VWs by visualising students' assessment to improve learning. It demonstrates the implementation of the model lenses, provides illustrations of the data collected by each lens and gives examples of their applications on the virtual world. In addition, it presents a combination of the final assessment with video recording which can aid learners to recognise their weaknesses and strengths, allowing them to understand how they could improve their performances and enhance their learning. Providing such recorded events and feedback could also support saving them as evidence in students' lifelong learning portfolios.

Finally, this is a work-in-progress model and there is more work still needed to be completed. Currently, we are developing *Student Success* and *Learning Outcomes* lenses. Future work includes the validation of the model through expert-based and user-based evaluations, for which we aim to present our results in forthcoming events.

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Development of Cross-Curricular Key Skills Using a 3D Immersive Learning Environment in Schools

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Abstract. Pedagogical opportunities offered by 3D immersive environments are not restricted to subject-based knowledge but also include non-disciplinary and cross-curricular key skills. This pilot study introduced a large 3D scene of a non-extant architectural exhibition into teaching and learning activities at three UK schools. From observation and qualitative data capture, a comparative case study identified a number of pedagogical opportunities and challenges. Despite diverse teacher and student approaches, a number of common factors were identified including constructionist teaching methods and the suitability of 3D environments for developing cross-curricular key skills and capabilities. In relation to the literature, this paper analyses how subject-aligned use of the 3D model met with differing levels of success, identifies four key skills that emerged from student use of the model across all three schools, and considers how challenges might be translated into further learning opportunities.

Keywords: Pedagogy · 3D visualization · Cross-curricular skills · Game-based learning · Collaboration · Creativity · Self-directed learning

1 Introduction

Whilst there is a growing body of research that focusses on pedagogical opportunities of 3D environments for the enhancement of particular, curriculum-based learning outcomes, few empirical studies consider their role in developing key cross-disciplinary skills and attributes such as collaboration, creativity, leadership, and emotional maturity. These capabilities are recognized across national curricula as intrinsic to the development of successful learners. Through a comparative case study of the use of a 3D environment in teaching activities in three schools, this paper investigates how 3D environments within the classroom can provide opportunities for developing key cross-disciplinary capabilities.

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1.1 The REVISIT Pilot Study Methodology

Research Engagement through Virtual Immersive Tools for Learning (REVISIT) was a project with two primary aims: to develop innovative learning tools for schools using a dataset originally developed for higher education and research use; and to increase our understanding of the impact of immersive 3D environments for teachers and learners through a pilot study. The original dataset comprised a 2D digital collection and 3D model of the British Empire Exhibition which took place in Glasgow in 1938 [1]. The 3D scene re-creates over 100 individual building models (all but one of which are no longer standing) within the topology of Bellahouston Park, Glasgow, where the Exhibition took place. The digital collection includes photographs, architectural plans, ephemera, audio, and video.

For REVISIT, the 3D scene was delivered through VSim [2]. This (prototype) software was selected as it is specifically designed for pedagogical interrogation of 3D models; functionality includes real-time exploration alongside the ability to create narratives (linear 'tours' within the virtual space) and multimedia annotations, and the easy export of narratives and resources for classroom sharing and broader dissemination [ibid.]. Crucially when working with schools, VSim is free to use and standalone.

The existing 3D scene was optimized and converted to a COLLADA format, compatible with VSim. The archive of related cultural assets was organized into folders, targeting relevant curriculum areas as well as highlighting the most interesting items.

During the first phase of the project, teachers at three UK schools (one primary and two secondary) were introduced to the datasets and initial reactions and ideas for use were gathered through interviews. A firm aim of REVISIT was to avoid a 'top down' approach where university research data is simply delivered without being adapted to the new educational context, and is therefore of limited use. Therefore, the project sought to actively engage the teachers in the design of curriculum-aligned learning objects (i.e. VSim narratives) before delivery to the students. However, it was immediately apparent across all participating schools that there was a desire to use the Empire Exhibition 3D environment as a theme for cross-curricular learning, and for the pupils themselves to become co-creators of the narratives. Schools were therefore given autonomy in their use of the 3D scene and digital collection in lessons which reflects the constructionist approach recognized in other studies of teacher perceptions of 3D heritage data [3]. This resulted in three very different case studies, reflecting the different needs and approaches of the teachers and students who participated.

During the project's second phase, teachers organized teaching and learning activities which used REVISIT data (see Table 1). Qualitative data were collected including observations, interviews with teachers and focus groups with students. A survey was also performed with students at one secondary school (n = 33). Audio recordings were transcribed and coded in NVivo [4] to perform inductive thematic content analysis. Other data include the narratives and resources created by the pupils themselves.[1]

[1] Anonymized project outputs can be downloaded from http://research.gsofasimvis.com/revisit/.

Table 1. Summary of teacher and student engagement in the pilot study. School and person names have been changed for anonymity.

	Young's Primary (YP)	Hall's Secondary (HS)	Barrow Secondary (BS)
Pupil age	10–11	13–14	14–15
Pupils participating	26	106 participants (33 survey responses)	6
Learning context	Classroom, project-related activities	Classroom, 'creativity challenge'	Voluntary lunchtime club
Time period	Two months	3 days	Two 2-hour sessions
Teachers participating and input	2. High preparation, demonstration, and contextualization	8. Variable between teachers.	2. Low, some technical preparation, little pedagogical guidance

This paper focusses on a theme that emerged strongly from the content analysis, that is, the opportunities afforded by 3D environments for developing cross-curricular skills such as collaboration, leadership, creativity, and emotional intelligence.

2 3D Environments in Education

3D immersive environments are now accepted to have strong potential for creating engaging learning opportunities across a range of learner ages and situations. One review identifies pedagogical opportunities arising from these embodied experiences including increased motivation, the ability to contextualize learning objectives, and collaborative learning processes [5]. 3D models and environments have primarily been used in STEM subjects, however their growing use as surrogates for real-world environments is recognized, particularly where they model inaccessible historical or cultural spaces [6]. Although the majority of bespoke 3D educational environments still focus on particular disciplinary learning objectives, their value goes beyond increased cognition and also enhances motivation [7], and enables creative participation, digital/cultural production [8] and co-production [9].

In terms of immersive visuals, free exploration and interaction controlled by the user, and experimental, playful investigation, simulated 3D environments modelled on real places – defined by Dalgarno and Lee as "microworlds" [5, p. 18–19] – share many of the characteristics of video games. Indeed, like good educational games, 3D learning environments can provide emotionally engaging, contextualized spaces for learning, even where there are no game mechanics present, as "the learner is able to construct a personal knowledge representation and iteratively refine this representation as he or she undertakes exploration and experimentation in a manner consistent with cognitive constructivist learning theories" [ibid]. The VSim 'wasd' navigational controls (similar to many gaming environments) and first-person viewpoint for exploration imbues the 3D scene with 'game-like' qualities; indeed, when introduced to classes of students, their assumption was clear:

"It was all 'aaahs' and 'wows' and they asked "What game is this?" they believed it was a game, "What game is this?", "Where can I get this?"" (Daniel, YP, Year 6 teacher)

Due to their overlapping characteristics, much of the literature on educational digital games is also highly relevant to 3D immersive environments. In fact, some studies' definition of educational games fully encompasses 3D environments, despite their lack of overt game mechanics [10]. Similarly, most research on both games and immersive environments has moved on from questioning *whether* they can be fruitful tools for learning and now concentrates on *how* particular games, environments, and teacher practices can be best harnessed to meet curricular aims [11].

The microworld based on the real British Empire Exhibition of 1938 (Fig. 1) is highly appropriate for learning goals related to this particular subject, similar to other recent examples of subject-specific game-like 3D immersive environments [12, 13]. However, the REVISIT pilot study identified that such environments are particularly suited to the development of not only subject-based knowledge, but general key skills for learners, a topic currently under-served in the literature.

Fig. 1. VSim screenshot showing 3D scene with overlaid interactive narrative including tour nodes and multimedia annotations. Participants created their own 'tours' and annotations.

3 Challenges for Curriculum-Aligned Learning

The challenges of aligning learning activities in 3D environments are well documented [3, 5, 6] and were reflected in the findings of the REVISIT study. These include organizational support and the time required for teachers to prepare appropriate and contextualized learning activities, as well as the possible emergence of technological behaviors or goals that are unaligned with intended learning outcomes [10].

3.1 Curricular Flexibility

The varying success of the REVISIT pilot was highly correlated with the amount of institutional support and flexibility that teachers were (or were not) given. Particular challenges included several teachers feeling that using the 3D environment had been imposed upon them (by other members of staff) and/or simply did not have adequate time to plan for its effective use. At Hall's Secondary (henceforth HS), activities were planned as part of a three-day 'creativity challenge' towards the end of the school year, where it was seen to best complement the existing curriculum-based lesson plans. However this brought different challenges:

> *"If this was starting in September [it would be easier, whereas] we are at this stage where kids are doing exams in 3–4 weeks so they are going to be pretty stressed out about that."* (Isaac, HS Learning and Teaching Director)

Conversely, at Young's Primary (henceforth YP), despite being extensively used in lessons over a two-month period at the same time of year, flexibility in curriculum planning resulted in greater levels of satisfaction from both teachers and students. This was explicitly acknowledged by the class teacher as well as the head teacher.

> *"I know for a fact that had that flexibility not existed throughout the last six weeks there are certain members of the class who would not have achieved what they have achieved so whilst there's a rigidity that remains in education I feel the more this kind of thing happens it will become more flexible and children will become more rounded individuals."* (Daniel, YP Y6 teacher)

> *"As a leader you've definitely got to be supportive and make sure that there's time available for the teacher to be prepared, to find out more about it, to explore other things themselves, to talk with yourselves. That's got to be a whole school, high level decision."* (Catherine, YP Head teacher)

At Barrow Secondary (henceforth BS), rigid timetables were surmounted by offering voluntary access to the learning activities via lunchtime workshops. Facilitated by one, highly-motivated but busy, teacher, this model of engagement limited the time available to engage with the 3D environment but ensured that students self-selected whether or not they participated. Describing the curricular challenges when working with innovative but computationally-demanding 3D environments, the teacher also identified other important resource limitations.

> *"In my subject, in Geography, it would democratize possibly the ability for me to teach the curriculum. […] I think 3D would enable me to do exactly what some of the richer schools do on a Saturday morning. […] it might bring some of the processes to life in a way that I can't in a classroom in inner-city Glasgow [because of lack of resources]."* (Malcolm, BS Head of Humanities)

3.2 Constructive Alignment

Constructive alignment of learning activities with their intended outcomes is core to much of the literature across education. Specifically, reviews of the field note the importance of close integration of learning tools such as games and game-like environments into the curriculum in order to enhance learning objectives [15, p. 177, 198] as well as making efforts to align teaching activities with the preferences of students [15, pp. 160–161, 188]. The Empire Exhibition 3D immersive environment clearly possessed what the YP teacher called "the wow factor", however "To be effective, motivational tactics have to support instructional goals. Sometimes the motivational features can be fun or even entertaining, but unless they engage the learner in the instructional purpose and content, they will not promote learning" [16, p. 25]. Furthermore, the creation of relevant and meaningful learning activities enabled by 3D environments requires both adequate time for preparation and particular pedagogical skills [3] – a challenge when so few teachers have experience using 3D environments – and design of activities using heritage visualizations is affected by both a teacher's subject-specific confidence and their familiarity with cross-curricular themes [17].

Another challenge is the contextualization of both the learning activities themselves and the knowledge gained by students. "When using traditional computer-based learning tools, the teacher's role is recognized to be paramount in securing a successful learning experience. The outcomes of any lesson-based computer activity will depend on the introduction of the task, the interventions made during the activity and the way that the activity is set in the context of students' wider educational experience" [10, p. 11]. Or, as more succinctly offered by Daniel at YP: "I think spinning a topic is crucial." In terms of cognitive challenges when using 3D environments, not only is acquisition of subject-specific knowledge highly dependent on the time that teachers devote to familiarizing themselves with the learning tools [10], game-like learning tools have been criticized for only imparting superficial knowledge [14, p. 64] which then needs to be contextualized by a teacher. Therefore, to glean subject-specific knowledge from 3D environments, the continuing challenge is the need for teachers to become expert at not only using this technology but also in how their subject is presented through it.

It is worth restating at this point that the REVISIT 3D environment was initially created as research data and is not specifically designed to fit with school curricula. (The re-use of legacy research data in classroom contexts was a core research question of the project and will be covered in a separate publication.) As such, it posed challenges for the all-important curricular alignment in some learning situations and met with widely differing levels of success, dependent on the approaches of individual teachers. Whilst in some cases, curricular alignment was obvious to teachers and was implemented successfully, other teachers voiced concerns about the relevance of the dataset in terms of their subject and the exact curriculum:

> *"[Linking it to the curriculum was] a little bit artificial. I think things like when Sally was saying they took Tait Tower down because of the war beginning that was completely linked to the curriculum [but] history at school is punctuated by events like the First World War, the Second World War. […] Where does the Empire Exhibition fit into that?"* (Malcolm, BS Head of Humanities)

Other staff described the 3D environment in terms similar to Dede's "a solution looking for a problem" [18, p. 235]. As a school technician put it:

> *"Forcing the curriculum to fit with technology is never going to be the best way. Having a technology that is flexible enough for a teacher to customize it to their classroom, that's when it becomes valuable."* (Adam, HS Technician)

Teachers at HS also identified that their students were strategic learners, focused on their assessments. It is widely acknowledged that assessments strongly influence the approach taken by students in Higher Education [19, pp. 93–95; 20, pp. 67–72] and this was borne out by the responses of some students, particularly at HS.

> *"I've learned a lot… I've enjoyed doing it as a one-off but I'm not quite sure if it helped particularly in the overall curriculum. It wouldn't particularly help with an exam or something 'cause it's not subject specific."* (Jenny, HS student)

Therefore, although the qualitative data collected demonstrates that children at all three schools learned and retained a considerable amount of subject-specific knowledge about the Empire Exhibition, it was not always clear to them how this knowledge was relevant in terms of their day-to-day curriculum.

The success of enabling learning through 'customizing' 3D immersive environments for classroom purposes is dependent on a number of factors including the characteristics of the 3D data itself; the delivery software; teacher attitudes, competencies, and preparation time; and student learning styles. Possibly in response to some teachers having difficulties creating learning activities that were closely aligned with specific curricular goals, many of the teachers involved in the REVISIT study intuitively identified cross-curricular competencies that complemented subject-specific knowledge. These were based much more on the core characteristics of the Empire Exhibition as a 3D immersive environment, rather than on the subject of the Exhibition itself. The remainder of this paper considers the primary cross-curricular key skills and characteristics that were identified from the REVISIT pilot study and considers the factors for their success (or failure) in a classroom context.

4 Key Findings: Cross-Disciplinary Key Skills

4.1 Motivation to Learn

Whilst motivation to learn is not itself a key skill, it is widely accepted as being crucial to successful learning behaviors [16]. Motivation and engagement are core perceived characteristics of 3D environments, predicted by teachers and borne out by students' attitudes. Prior to developing learning activities, several teachers identified the value of the Empire Exhibition environment in motivating students:

> *"I think that for me the biggest selling point is the historical and the geographical knowledge but I think for the children one of the selling points is 'Hey this looks a bit like a game.'"* (Daniel, YP Y6 teacher)

> *"The idea of having a virtual exhibition where kids could upload photos, videos, CAD models, that kind of thing is actually quite motivating for our children."* (Lauren, HS Design teacher)

This enthusiasm for a novel learning style was echoed by students who displayed a high level of intrinsic motivation [21] when interacting with the 3D scene:

> *"I was really pleased we were going to do a fun topic, I didn't expect it to be this fun though, because you could engage with it really well and it was just, in a couple of clicks and you were on, so it was really fun, yeah."* (Mohammed, YP student)

"It was different because there's not many games – it's not a game but it's like… there's not many programs like that and it's very easy to control, many things to explore and it's very interesting cause [the Empire Exhibition] is not here anymore, it's not existing so it's good to find out what it was like in history and what they thought it was going to be like in the future." (Rowan, YP student)

In general, secondary school students were positive but less effusive and more focused on specific learning goals, although one boy from HS described using the 3D scene as "much better than school". In all three schools some students were motivated to carry on learning outside formal educational contexts. Motivation was perceived to be derived directly from the form of the learning environment itself, encouraging students to dig deeper into the subject-specific learning outcomes being presented.

"Some of them have asked if they can download it at home, some of them have asked if they can stay in at lunch times and play times and they have done. Some have created work in their own time. And again I don't think I would have got that if I had said 'There's a book about the exhibition' so it has been fantastic really […] It was mind-blowing really because it's taken learning home and I think you can't underestimate the power of a good hook into a topic and for me that was the main benefit of the [3D scene]." (Daniel, YP Y6 teacher)

Furthermore, several teachers recognized the deep learning that had taken place as a result of highly motivated learners combined with well-contextualized learning activities. The YP head teacher observed that "the children have been absolutely absorbed and engaged with it and at a quite high level I think of enquiry, of challenge."

4.2 Theme Learning

Debates around cross-curricular teaching and learning in the context of 3D environments are usefully summarized by Lackovic *et al.* acknowledging that confusions can arise from an insufficiently-defined educational purpose (as discussed above) [17]. Reflecting Lackovic's findings, teachers at all three case study schools quickly identified the Empire Exhibition scene as a 'hook' for cross-curricular teaching activities and identified a wide range of ways in which to link activities back to curricula.

"I was thinking Geography initially but then there's a historical side but also when you look at the different industries [represented in the Exhibition], you get a scientific slant in it as well. And also looking at the numbers and things, numbers of visitors and the cost and how long it lasted. I'd like to do some maths behind it…" (Daniel, YP Y6 teacher)

This approach derived from the nature of the research data itself as well as individual school policies for enabling study through project work and/or multidisciplinary 'themes'. One factor that became clear during the study was that, by providing immersive spaces for learning, 3D environments are particularly suited to integrating subjects together on a project with teachers identifying the benefit of wrapping up subjects perceived as 'dry' (such as maths, information technology, or the evaluation of sources in history) with activities seen by the children as being more fun.

"Because you can weave all the topics together it's so much easier. The other day I did a lesson and they had no idea they were learning. They did two geography objectives and two maths lessons and they had no idea." (Daniel, YP Y6 teacher)

Where the integration of the 3D scene was most successfully implemented, teachers highlighted particular characteristics of 3D environments and recognized that this theme-based approach allowed a different mode of learning to take place, thereby reinforcing the cognitive processes of more traditional teaching methods.

> *"I thought it's good for the kids as well to get away from the, what I call the tyranny of the words […] having a different sort of medium to look at ideas I thought was really interesting. […] It's good to get the kids just to think outside the box and it's interesting because […] they're used to studying in a particular aspect, in particular subjects. When you can do something completely different kids go "I hadn't realized you can do this in history." Well of course you can."* (Ralph, HS History teacher)

Within the primary school, the theme was used extensively for a period spanning two months. Acknowledging the critical factor of his own preparation of learning activities, the class teacher (who had no prior experience with 3D models of any kind) described the Empire Exhibition theme as the most successful he'd ever seen and went on to describe not only the way in which the 3D scene had been used to deliver the curriculum but also its longevity as a teaching tool.

> *"I just went through the national curriculum and looked at the expectations for the children and was able to plan a curriculum fully centered on the project and I think it's been highly successful. […] If you choose the right stimulus you are able to maintain a topic for a prolonged period of time and I think this has been going for seven weeks now and they are still going and they are still enthusiastic."* (Daniel, YP)

However, 3D immersive environments are not only suited for theme learning but also encourage teaching and learning of non-disciplinary key skills, a fact which was recognized by teachers even where the integration of the 3D environment into their curricula was more problematic. Lackovic *et al.* identify three particular non-disciplinary benefits to the use of 3D models: relevance, scaffolded immersiveness, and encouraging constructivist learning experiences [17]. The REVISIT study resulted in significant evidence that use of the Empire Exhibition 3D environment had strong impact in developing the following four key skills.

4.3 Collaboration

The potential for fruitful collaboration between learners was identified early on, particularly in subjects which incorporate group working into the curriculum.

> *"It's got scope for teamwork because then they could create work as teams and then actually put an exhibition together. […] It's the collaboration and the fact that they can upload different media. I do really like that."* (Lauren, HS Design teacher)

The three case study schools demonstrated different approaches to encouraging collaborative learning. At YP the theme learning approach led to a large number of teaching and learning activities including guided tours of the scene and related cultural archive by the teacher (using an interactive whiteboard), free exploration by groups of children, digital co-production, and grouped and individual creative or cognitive tasks that took place outside the 3D scene but were closely related (for example, calculations of visitor numbers and making models of pavilions). HS used a different approach where students were split into groups wherein only a few of the most engaged children worked directly with the 3D environment whilst others created digital material for the chosen narratives. BS students each worked individually on a single narrative within the virtual environment, collaborating informally between computers.

Collaboration appeared to be inherent in the student's use of the 3D environment, even where learning activities had not been explicitly designed to encourage it. A large factor was in learning how to use VSim itself. Although some had played computer games, the vast majority of students and teachers had never used a 3D model or environment within the classroom before. As noted with regard to digital games: "A period of learning **about** the game was required before learning **through** the game could become possible." [10, p. 17] and strong collaboration between students learning how to use the software was evident across all three schools.

> Hannah: *"I just learned the simple controls at first but then some people told me more about flying, how to go in fast mode –"*
>
> Louie (interrupting): *"We were like interacting with each other and helping each other with stuff like that […] we learn off each other."* (YP students)

Collaboration was not restricted to sharing technical expertise; students collaborated on navigating the scene to find certain buildings and shared their discoveries with one another, outside the parameters of the particular activity being worked on.

> *"Somebody found something and he gets really excited and he tells everyone else and everyone else gets really excited"* (Rowan, YP student).

The focus groups and survey undertaken with HS students indicate that using the Empire Exhibition 3D scene in their lessons increased collaboration with other students (63% agreed) and also identified collaborative working as one of the most enjoyable aspects of their participation.

4.4 Leadership and Self-directed Learning

As noted above, a major challenge for using 3D environments in the classroom is the requirement for teachers to become expert users. Whilst this can certainly create problems, REVISIT data demonstrated that occasional frustrations from students regarding a teacher's lack of technical knowledge were far outweighed by opportunities for developing leadership skills in students. A case study of teaching with Minecraft identifies how such a challenge can be explicitly converted into a learning opportunity: "The teachers here position themselves as not-knowers of the game, which creates space for the students to position themselves as experts. By explicitly positioning themselves as 'learners' of the Minecraft game mechanics, the teachers provide authority to the students and open up for a multivoiced dialogue." [11, p. 270]

Across all three schools, some students were allowed to flourish as experts when using the 3D scene, guiding others (and in many cases, their teachers as well).

> *"Some of the children are better on computers than I am and they quickly figured out a way to do things and that allowed me to have some children who were leaders and so they could help others so they were playing teacher."* (Daniel, YP Y6 teacher)

As has been noted elsewhere [10, p. 15] this allows certain students, who are perhaps not used to leading in academic situations, to become ‘champions’, acting as guides and tutors to others, developing confidence and authority, not only in terms of navigating the 3D environment but of discovering the content within.

> Mohammed: *“Mr W. like he knew the most so he was teaching us but the more we got to do it like without him, like now we know more than him about it so –”*

> Samir: *“We also got to know all the buildings without Mr W. starting to tell us. The first thing we did when we was learning, we went on and just messed about and ‘cause we were messing about we knew what buildings there were.”* (YP students)

Exploratory, immersive 3D environments also allow students to actively lead their own learning. In fact, even where guidance material had been prepared (for both technical and subject-based learning outcomes), the nature of the 3D environment appeared to encourage students to reject the worksheets and learn in their own ways, recognizing freedom and independence as both enjoyable and fruitful.

> *“You can’t really teach it to people, it’s more effective if people teach it to themselves when it comes to technology and stuff.”* (Mandy, BS student)

> *“Personally for me it’s more engaging, like, being able to explore yourself, at your own pace. […] It’s independent learning – that works for me.”* (Jenny, HS student)

This key skill was also acknowledged by teachers at all three schools and self-directed, independent learning was encouraged in learning situations, allowing students to direct curricular goals as well as technology-centered goals.

> *“I said “What do you want to know?” and then they wanted to know facts about the exhibition and so the very first maths lesson was real facts and figures from the exhibition, attendance figures, the cost.”* (Daniel, YP Y6 teacher)

> *“The idea of being able to move around without the teacher guiding them is something that is very important and we’ve tried to that in our faculty for a few years.”* (Malcolm, BS Head of Humanities)

Allowing students to lead their own learning not only increased self-determination in lessons but also the students’ ownership and pride over the narratives produced as part of learning activities. Before planning his lessons, the YP teacher stated:

> *“I’d like to think this is going to be very child-centered and that I more the facilitator walking round troubleshooting rather that standing at the front saying ‘do this’. I want them to come up with something that they own and that they are proud of.”* (Daniel, YP Y6 teacher)

The validity of this approach is confirmed by observational and qualitative data collected from students, with many demonstrating a high level of commitment to producing high-quality work for the virtual narratives (‘tours’):

> *“I was like John and Dania, proud of the fact that we could make such a tour.” (Imran, YP student)*

4.5 Creativity

Incorporating creativity into learning was also identified as a core benefit. HS students returning the survey conclusively agreed (80%) that the 3D scene made learning more interactive and creative engagement was seen as the second-most enjoyable characteristic (after collaboration). Students identified creative activity at a number of levels in the designed learning activities, from the very nature of free exploration leading to playful engagement, to the ability to create their own digital and non-digital products using the content and inspiration provided by the 3D learning environment.

> *"Without the tour I think it would be a bit boring 'cause all you could do is just go around in the Scottish buildings and do nothing with them. But making your own tour you could feel proud of what you'd done, it's an achievement."* (Rowan, YP student)

The capacity and desire for playful engagement was recognized by teachers as a core element of self-directed discovery and experiential learning.

> *"The fact that you could fly to the top of buildings it just made children feel like they were almost being naughty but in a constructive way. […] One child discovered that he could walk up the slide and slide down in the little playground that's hidden behind the building."* (Daniel, YP Y6 teacher)

Creative engagement was seen as particularly relevant where creativity itself plays a role in developing the learners along curricular lines, for example, in design and computing at the secondary schools.

> *"We always build creativity into the curriculum, it's really, really important because otherwise if the kids don't have that confidence then when they get to A-level they'll just fall flat,"* (Lauren, HS Design teacher)

Students also independently linked their creative activity whilst producing narratives with learning outcomes, demonstrating, to a greater or lesser extent, their ownership and understanding of the value of the constructivist approach to learning.

4.6 Emotional Intelligence

The final key skill that was explicitly highlighted by teachers was the effect of using the 3D environment on their students' maturity and emotional intelligence.

> *"There is the academic side that they are learning the objectives fit for the national curriculum, fit for their age group, but also their emotional intelligence is growing, their artistic, cultural intelligence is developing so they are becoming more rounded by doing the project theme."* (Catherine, YP Head teacher)

This perception held true, even when teachers were not fully convinced of the value of the 3D scene to their subjects. The HS Information and Communication Technology (ICT) teacher proposed that "They like the freedom and it builds their maturity and it builds their teamwork which is fantastic. […] They will grow from this as people more than they will grow from this as computer scientists."

Teachers noted that some children not only demonstrated leadership, as discussed above, but took on wider responsibilities in the context of lesson delivery, such as setting up the lab. Some also discussed the project outside school, bringing back further insights to share with other students. The widely-stated view that children were becoming more 'well-rounded' during the pilot is inherently tied in with the experiential learning delivered by 3D environments. Boydell's assertion that experiential learning "involves the learner sorting things out for himself" [22, p. 19] was almost directly repeated by one student when he said "We mainly try to sort it out ourselves."

Another aspect of emotional intelligence, resilience, was raised in response to the VSim prototype crashing. Whilst this was certainly not ideal, several teachers noted positive side-effects (including the fact that the 3D immersive environment was intrinsically motivating [21] and increased resilience and persistence in pursuing learning tasks) alongside resilience in dealing with the frustrations of losing work.

> *"The children differ in mental strength and also in resilience and some children were like "Oh I have to start again" where others they were a little bit upset because they'd put work into it and that disappeared. But then trying to turn everything into positive, I used that as a teaching point how even when you are an adult you need to save your work after every small part that you do so that you don't lose any."* (Daniel, YP Y6 teacher)

Linking back to curricular alignment, the 3D scene was seen to have high cognitive authenticity [23, p. 376, 388] to the learning domains the children function in, even in those cases where subject alignment was more tenuous or problematic. Most teachers acknowledged that close engagement with digital learning environments is very useful for children as they develop into adults with many noting that the advantages (and problems) of such tools "readies the children for life outside of school which is far more important than passing tests" (Daniel, YP Y6 teacher).

Finally, there was evidence that the mode of engaging and interacting with the scene (alongside the 2D archive of related media) increased imagination, identification, and emotional engagement for both teachers and students.

> *"I enjoyed the most about like you could just go anywhere, there was not boundaries, you could just explore everywhere, […] you could just imagine how it would be if you was there and many other people were there."* (Rowan, YP student)

5 Conclusion

Technological innovation in classrooms is rich with opportunity but also accompanied by both pedagogical and technical risk. The REVISIT pilot study demonstrates the diverse approaches, successes, and difficulties of incorporating a 3D learning environment into lessons at three different schools. However, it also reveals that this game-like mode of learning is highly suited for the development of non-disciplinary key skills, in particular, collaboration, leadership, creativity, and emotional intelligence. The research identifies areas where the well-documented challenges of integrating 3D environments into school curricula can be converted into opportunities for enabling and encouraging these key skills. The results of this pilot study indicate that 3D environments can function as effective contexts for constructivist learning and co-creation activities, and may be more intrinsically motivating for some students. A fruitful further study would be to compare this model with other modes of learning known for developing cross-curricular key skills and to examine the specific affordances of 3D environments within this context.

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Investigating Social Presence and Communication with Embodied Avatars in Room-Scale Virtual Reality

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Abstract. Room-scale virtual reality (VR) holds great potential as a medium for communication and collaboration in remote and same-time, same-place settings. Related work has established that movement realism can create a strong sense of social presence, even in the absence of photorealism. Here, we explore the noteworthy attributes of communicative interaction using embodied minimal avatars in room-scale VR in the same-time, same-place setting. Our system is the first in the research community to enable this kind of interaction, as far as we are aware. We carried out an experiment in which pairs of users performed two activities in contrasting variants: VR vs. face-to-face (F2F), and 2D vs. 3D. Objective and subjective measures were used to compare these, including motion analysis, electrodermal activity, questionnaires, retrospective think-aloud protocol, and interviews. On the whole, participants communicated effectively in VR to complete their tasks, and reported a strong sense of social presence. The system's high fidelity capture and display of movement seems to have been a key factor in supporting this. Our results confirm some expected shortcomings of VR compared to F2F, but also some non-obvious advantages. The limited anthropomorphic properties of the avatars presented some difficulties, but the impact of these varied widely between the activities. In the 2D vs. 3D comparison, the basic affordance of freehand drawing in 3D was new to most participants, resulting in novel observations and open questions. We also present methodological observations across all conditions concerning the measures that did and did not reveal differences between conditions, including unanticipated properties of the think-aloud protocol applied to VR.

Keywords: Room-scale virtual reality · Copresence · Non-verbal communication · Collaboration

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1 Introduction

Embodied room-scale virtual reality endows users with a very different relationship to their own avatars and virtual environments than analogous non-immersive systems, which use input from keyboards, mice, gamepads, and joysticks. Users *embody* their avatars in a direct way – movements are one-to-one at physical scale, and they move and reach naturally in order to interact with objects. One dual implication of this fact is that when observing others' avatars in the virtual environment, they *look* human. That is, the same precise measurement of movement that is required to deliver the first-person VR experience allows these movements to be made visible to others with great fidelity as body movements. Consequently, when two people share a virtual space in this fashion, they each have a strong sense of being present with another human. Prior works have established the general principle that high *movement realism* achieves a strong sense of social presence, using comparatively low information-bandwidth.

Our system allows two users to interact in room-scale VR (i.e. six degree-of-freedom tracking of head and two handheld controllers) in the same-time, same-place setting, and is the first of its kind that we are aware of in the research community. The goals of this paper are to (1) establish the basic feasibility and utility of this kind of multi-user interaction, (2) pilot methodologies for studying behavior in this setting, (3) offer early results related to similarities, differences, advantages and disadvantages compared with face-to-face, (4) explore the use of freehand drawing in 3D for communicative interaction, and (5) propose future research directions. We made the choice to use minimal avatars to avoid complicating our results with effects related to the choice of body representation (Fig. 2).

Fig. 1. Same-time, same-place interaction in room-scale VR

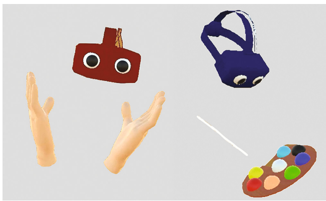


Fig. 2. Avatars for Charades and Pictionary

We designed a set of goal-oriented, communicative activities for pairs of participants to perform in an experimental setting. These were popular word-guessing games based on gesturing and freehand drawing that could be directly compared in face-to-face and VR settings. The different words that participants attempted to communicate represented a broad array of concepts and corresponding symbolic gestures. We view these as proxies for various communicative face-to-face activities. To explore the use of 3D drawing in communicative interaction, we had participants play an analogous game using freehand drawing in 3D instead of 2D. We evaluated the experiences using a combination of methods and metrics: the VR system itself provided data on movement; electrodermal activity was captured to measure engagement; users completed questionnaires measuring perceived mental load, presence, and other aspects of the experience; participants did think-aloud reflection while reviewing recordings; and semi-structured interviews were conducted with participants to gain further qualitative insights.

In the sections that follow, we first discuss related work, then we briefly describe the system that we built for collaboration in room-scale virtual reality in the same-time, same-place setting. Next we discuss the experiment we carried out, which required extensive modification and adaptation of the basic system, and present the corresponding results. Then we discuss the implications of the quantitative and qualitative results of the experiment. Finally, we conclude and highlight promising directions for future research.

2 Related Work

Two related bodies of research focus on (i) the psychological experience of interacting with human avatars or agents in immersive virtual environments, and (ii) methods and affordances for computer-mediated communication and collaboration. Studies of the psychological experience of interacting with *embodied agents* or *avatars* in immersive virtual environments have focused on *agency*, *presence*, *copresence* (or *social presence*), and *social influence* [2,3,6]. They employ self-reports, behavioral metrics, cognitive metrics, and qualitative methods to gain insight. Two factors shown to influence all of the above are *behavioral realism* and *photorealism* of the agent or avatar representations [1]. Importantly, a recent meta-analysis [6] showed that avatars have greater social influence than agents. That is to say, people react more strongly to other people than to non-human agents that purport to be people. In the present work, we are only concerned with the case of real-time interaction between people, so the upshot is that our use case resides at the end of the spectrum where social influence tends to be larger. A relevant study by Garau et al. [7] considers this case, also through the lens of behavioral and photo-realism. In their system, users' headsets and a single handheld controller are spatially tracked with six degrees of freedom. The authors define a metric for the *perceived quality of communication*, and test how this depends on *type of avatar* and *type of gaze*. The former refers to three different levels of realism, and the latter refers to two different methods for generating avatar eye gaze behavior. Results show a positive effect when gaze behavior mimics natural behavior. However, the said "natural behavior" is inferred from a model of speaker turn-taking, and not directly controlled by the user's real eye gaze. In contrast, our system does not use any indirect inference: it displays only the head orientation, and does not purport to represent eye movement. It also displays hand positions, supporting the use of unintentional and symbolic gestures.

The related work in the field of computer-mediated communication investigates the merits of different communication affordances from the perspective of collaboration. Isaacs and Tang [10] perform a systematic comparison of audio, video, and face-to-face as mediums for communication. They note increases in communication efficiency in video over audio-only communication due to the ability to indicate agreement using a nodding gesture, without interrupting the speaker. They note the great value of being able to point in the shared environment, as in face-to-face communication, but also highlight that video can be more efficient than face-to-face in cases where it removes distractions. Our system supports nodding to express agreement, and we also make observations about the removal of distractions in our somewhat different setup. In [12] from the same year, the authors focus on gaze and the representation of video avatars. They contend that the ability to judge which other participant is being gazed upon by each participant is important for group dynamics. Our system also allows each participant to see where other participants are looking through their head orientation, which we confirm to be an important feature. More recently, [11] uses see-through display augmented reality for remote collaboration. This work considers puzzle-solving as a collaborative task, and also underscores the importance of the affordance for pointing when collaborating in a shared space. Our system supports the ability to point in space, in a way that is directly analogous to the physical world except for the small physical disparity between the user's physical and virtual hands. The most similar prior work from the field of computer-mediated communication is *GreenSpace II* [4], a multi-user, six degree-of-freedom (or *6DoF*) system for architectural design review. Its two users would see stylized head and hand avatars (with one hand per user), and point in the shared space. Their physical movements were constrained to a small space – to make larger movements, they needed to use a 6DoF mouse. The paper demonstrates the feasibility of sharing an immersive virtual environment with spatially tracked head and hand avatars. A significant portion of the feedback provided in the qualitative evaluation focused on the limitations of the technology. The present work does confirm what is supposed there – namely that once the fidelity of the experience is improved (wider field of view, natural physical movement, better audio experience), the utility improves greatly, and the interaction feels natural.

3 System for Copresence in Room-Scale VR

We present a system to act as a foundation for exploring same-time, same-place collaboration in room-scale virtual reality. A later version of the system, described in Greenwald, et al. [8], is available for the community to use.[1] It allows each user to see head and hand avatars representing the other user, with their apparent virtual positions matching their respective physical positions, as illustrated in Fig. 1. The form of the head avatar corresponds closely to the

[1] CocoVerse, https://github.com/cocoverse.

physical headset. The hand avatars are customized according to the activity being performed.

The choice not to display a head or a body was made in order to be deliberately minimal – representing the hardware itself, so as to avoid making arbitrary choices that could significantly influence the experience. An entire field of related work (see e.g. [13]) concerns itself with how the representation of the body impacts the user's psychological experience, and we are just concerned with the baseline communication capabilities in the scope of this paper. Even so, we did opt for a few minor tweaks based on the results of preliminary testing. The headset is modified with the addition of simple, static eyes on the front, since users found that this dramatically increased the sense of social presence. In pilot testing, users had difficulty creating expressive hand gestures using a literal representation of a hand holding a controller. Instead, the default hand avatars are flat hands positioned vertically above the top of the controller, which proved to be more versatile.

Our system uses the HTC Vive, an off-the-shelf 6DoF VR system consisting of a headset, a pair of handheld controllers, and pair of tracking base stations. The Vive system requires one computer per headset, but several systems can share a set of base stations. Sharing is possible because the devices being tracked (headset and controllers) are receivers which observe optical signals from passive base stations. We calibrate a single coordinate system between the VR systems by sharing a set of configuration files between their host computers. Players' apparent virtual locations are made to match their physical locations, and the systems continually synchronize a virtual world representation over a local network. Our "naive" implementation sends updated headset and handheld controller positions from every user to every other user at 90 Hz, and has been tested with a maximum of five users in a single space. With that number of users two challenges arise: (i) with our "naive" implementation, network and graphics performance start to suffer, and (ii) physical cable management, with a cable running to each user's headset. Our environment was implemented in Unity, and we used a custom serialization protocol and TCP connection in the provided networking framework to synchronize the state of the environment between the host computers.

In order to be able to comprehensively study user interactions that take place in our system, we considered it an essential design requirement to be able to record and playback these interactions. Rather than screen recording, which is limited to one or two perspectives, we opted for recording of 3D paths of motion and orientation. This format supports visual inspection and quantitative analysis alike, allowing recordings to be viewed from any angle, and analyzed numerically. Viewing replays of VR interactions while actually in the VR space is a novel and insightful experience, and this topic will be discussed further in our experimental results.

4 Experiment Comparing Face-to-Face with VR

We sought reference activities to help us accomplish the stated goals of investigating advantages and disadvantages of VR vs face-to-face for communicative interaction, and exploring the use of freehand drawing in 3D in this setting. We identified the word-guessing games *Charades* and *Pictionary* that fit these constraints. These require the use of gestural communication that is both symbolic and expressive, and they are also composed of a sequence of short, goal-oriented subtasks exercising different means of non-verbal and gestural communication. Pictionary also has the property of being naturally extensible from its familiar 2D form into a 3D form – allowing for 2D and 3D interactions to be compared side-by-side as well, providing a baseline for investigating freehand drawing in 3D. In the Charades game, the focus of communication is on the body itself, while Pictionary makes use of a spatial medium to contain and convey drawings. This contrast should yield greater insight into the effectiveness of these two different communicative affordances, body movement and drawing, and allow us to conjecture what kinds of activities would be most amenable to this form of collaboration. It should also help identify the most limiting technological shortcomings, and hence provide recommendations about what improvements would be most worthy of effort. Overall, we see the communicative gestures and actions required by these two different word guessing games as a proxy for the many kinds of communication required for a variety of collaborative tasks. The tasks themselves are communicative, but only "collaborative" to a limited extent, since only one participant acts at a time. Isolating one-way communication in this fashion will act as a first step, paving the way for future research into more complex collaborative tasks using this configuration.

4.1 Method

To compare the effect of these independent variables (face-to-face vs. VR conditions, and the two game-based task settings), we conducted a user study. We designed our experiment following a repeated measures design with one independent variable: the word guessing game that is played (Charades or Pictionary) combined with whether the game was played in Virtual Reality (VR) or Face-to-Face (F2F). As dependent variables we measured the *Electrodermal Activity (EDA)* through sensors, *Task Load Index (TLX)*, *level of presence* as well as some other related aspects of the system usability through questionnaires. We counter-balanced the order of the conditions according to the Balanced Latin Square.

The two primary hypotheses related to the contrast between our independent variables were that (1) face-to-face and VR would be similarly effective, despite the ostensible differences in the richness of the communication channels, and (2) the games would reveal different quantitative and qualitative attributes of non-verbal communication across conditions, given their different uses of body movement vs. drawing.

4.2 Apparatus and Tasks

Room setup. Figure 3 depicts the physical space layout used for the experiment. Players act or draw in the *activity space*. Facilitators operate and control the game session from the *control space*. The *real-world whiteboard* is used for drawing during the F2F Pictionary game. Game play information such as the current word, timer, game mode etc. is shown on the *real-world display* during F2F conditions. The *camera* footage of the F2F games provides video for think-aloud review sessions.

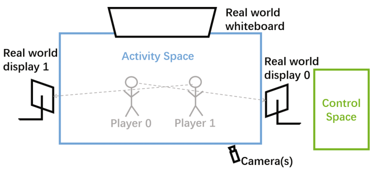


Fig. 3. Physical room layout for face-to-face and VR games.

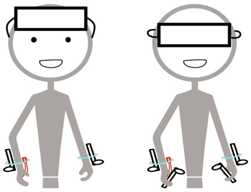


Fig. 4. Positioning of headset, controllers, and sensors during F2F and VR activities.

Positioning of devices on body. Figure 4 shows the positioning of the GSR sensors, VR controllers and headset on the body during F2F and VR activities, mounted with elastic velcro bands. The positional tracking devices worn during the activities collected movement data that could be directly compared between F2F and VR conditions. The GSR sensor was mounted to participants' dominant hand, with gel electrodes placed on the lower palm.

Quantitative data acquisition. Electrodermal activity data was collected using a *Shimmer GSR* sensor with *iMotions* software. After smoothing and detrending, *Coefficient of Variation (CV)* was calculated as a metric of arousal, as in [5].

Movement data was collected from the position of the headset and two arm-mounted controllers. The HTC Vive system provides positional data at a rate of 90 Hz. The sensors occasionally become momentarily occluded, causing tracking to be lost. We computed the average distance traveled per tracked frame (cm/frame) for each session and player.

Word selection for guessing games. The guessing words used during the study were selected from lists of varying difficulty provided by a game website.[2] For each game, we informally piloted candidate words, and observed the type of body gestures used while playing (fingers, hands, full-body, etc.), as well as the use of 3D space where applicable. Based on the results, we selected a final set

[2] The Game Gal, https://www.thegamegal.com/.

of words of varying difficulty that would sample a variety of gesture types and highlight different uses of 3D space.

Questionnaire design. We used the NASA Task Load Index (TLX) questionnaire and a custom set of questions. The TLX questions were presented using a slider with options from 0 to 100 in increments of 5, with the slider initially positioned at 50. Informed by our pilot tests, additional questions were presented to inquire about specific aspects of game play, the differences between F2F and VR, and the usability of the user interface.

4.3 Procedure

Subjects arrived in pairs, and experimental sessions began with a general introduction, before putting on VR devices and sensors. Pairs played through all five conditions (Charades and Pictionary 2D, each in F2F and VR, plus Pictionary 3D in VR) in the order dictated by their experimental group, with questionnaires administered as appropriate after each condition. At the start of each condition, participants were first given an opportunity to briefly familiarize themselves with the devices and physical or virtual space, and a simple warm-up task was provided. During game play, for each word the "acting" player was given 45 seconds to silently convey a word to the "guessing" player, with roles alternating as directed by the system. The facilitator determined when the word had been guessed correctly, and operated a control interface on one host computer to advance to the next word. After playing both F2F and VR variants of a game, participants would perform a retrospective think-aloud protocol and interview together. They reviewed the video and immersive VR playback (or just immersive VR playback, in the case of Pictionary 3D) in succession, in the order that they were played.

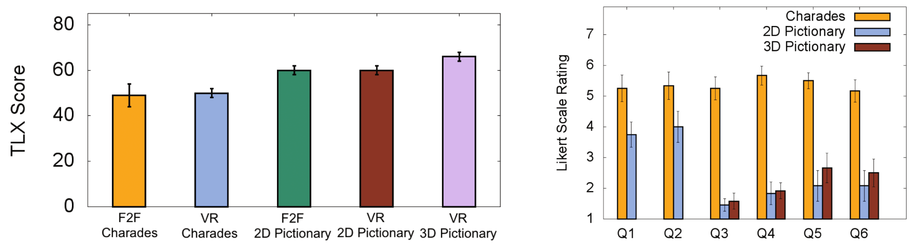
4.4 Participants

We invited 6 pairs of participants (4 female and 8 male) to take part in the study, with ages ranging from 19 to 50 ($M = 31.0$ years, $SD = 10.62$ y). The study took approximately 2.5 h, of which roughly 30 min were spent playing the games, 30 min reviewing recordings, 30 min filling out questionnaires, 30 min interviewing, and the remaining time used for breaks and setup. Participants were compensated with a $25 gift card.

4.5 Quantitative Results

Here we present the data that was collected during the user study. To analyze the NASA-Task Load Index (TLX), we used a one-way repeated measures ANOVA. For the questionnaire we applied a non-parametric Friedman test. Bonferroni correction was used for all post-hoc tests.

NASA-TLX. When comparing the TLX between the five conditions, the F2F Charades led to the least perceived cognitive load ($M = 49.33$, $SD = 18.6$), followed by the VR Charades ($M = 50.17$, $SD = 10.26$), the 2D VR Pictionary ($M = 60.34$, $SD = 9.55$), the 2D F2F Pictionary ($M = 60.58$, $SD = 9.26$), and the 3D Pictionary ($M = 66.17$, $SD = 9.60$). Mauchly's test of sphericity indicated that we can assume a sphericity of the data ($p > 0.05$). The one-way repeated measures ANOVA revealed a significant difference between the conditions, $F(1, 4) = 6.589$, $p < .001$. As a post-hoc test, pairwise comparisons revealed a significant difference between the VR Charades condition and the 3D VR Pictionary condition ($p < 0.05$). The effect size shows a large effect ($\eta^2 = .375$). Figure 5a shows the results graphically.



(a) (b)

Fig. 5. (a) The NASA-Task Load Index results of the user study for all conditions and (b) The quantitative results of the Likert scale questionnaire for the different games. Questions Q1-Q6 are explained in the text. All error bars depict the Standard Error.

When analyzing the Likert questions of the questionnaire, we used a non-parametric Friedman test. All Likert items were 7-point Likert items meaning: 1 = strongly disagree and 7 = strongly agree. For Q3-Q6 we used Wilcoxon signed-rank post-hoc tests with an applied Bonferroni correction for all conditions resulting in a significance level of $p < 0.017$. All results of the questionnaire are depicted in Fig. 5b.

Q1: *"Overall the experience playing the game in VR was different than playing F2F."* Participants found that the overall experience playing the Charades game in VR was more different from playing it F2F ($M = 5.25$, $SD = 1.49$) than in the 2D Pictionary game ($M = 3.75$, $SD = 1.42$). The Friedman test revealed a significant difference between the two games, $\chi^2(1) = 6.0$, $p = 0.014$.

Q2: *"Playing the game in VR was harder than playing F2F."* Further, the participants rated playing the Charades game to be harder in VR compared to F2F ($M = 5.33$, $SD = 1.56$), compared to the 2D Pictionary game ($M = 4.00$, $SD = 1.76$). The Friedman test did not reveal a significant difference between the two games ($p > 0.05$).

Q3: *"The absence of a body avatar was a problem in VR."* Considering the absence of a body avatar, the participants the participants rated the Charades game the most problematic ($M = 5.27$, $SD = 1.35$), followed by the 3D VR

Pictionary ($M = 1.55$, $SD = .93$), and the 2D VR Pictionary ($M = 1.45$, $SD = .69$). The Friedman test revealed a significant difference between the games, $\chi^2(2) = 18.0$, $p < 0.001$. The post-hoc tests showed a significant difference between 2D Pictionary and Charades ($Z = -2.825$, $p = 0.005$) and 3D Pictionary and Charades ($Z = -3.072$, $p = 0.002$).

Q4: *"The absence of facial gesture representations was a problem in VR."* When analyzing if the absence of facial gesture representations were a problem in VR, the participants rated the Charades game as the most problematic for that aspect ($M = 5.67$, $SD = 1.07$), followed by the 3D VR Pictionary ($M = 1.92$, $SD = .9$), and the 2D VR Pictionary ($M = 1.83$, $SD = 1.27$). The Friedman test revealed a significant difference between the games, $\chi^2(2) = 20.14$, $p < 0.001$. The post-hoc tests showed a significant difference between 2D Pictionary and Charades ($Z = -3.075$, $p = 0.002$) and 3D Pictionary and Charades ($Z = -3.089$, $p = 0.002$).

Q5: *"The absence of hand gesture representations was a problem in VR."* Considering if the absence of hand gesture representations is problematic in the VR games, the participants rated the Charades game as the most problematic ($M = 5.5$, $SD = .905$), followed by the 3D VR Pictionary ($M = 2.67$, $SD = 1.67$), and the 2D VR Pictionary ($M = 2.08$, $SD = 1.73$). The Friedman test revealed a significant difference between the games, $\chi^2(2) = 17.077$, $p < 0.001$. The post-hoc tests showed a significant difference between 2D Pictionary and Charades ($Z = -2.842$, $p = 0.004$) and 3D Pictionary and Charades ($Z = -2.952$, $p = 0.003$).

Q6: *"The absence of finger gesture representations was a problem in VR."* Finally, when analyzing whether the absence of finger gesture representation was problematic for playing the VR game, the participants rated the Charades game as the most problematic ($M = 5.17$, $SD = 1.267$), followed by the 3D VR Pictionary ($M = 2.50$, $SD = 1.567$), and the 2D VR Pictionary ($M = 2.08$, $SD = 1.73$). The Friedman test revealed a significant difference between the games, $\chi^2(2) = 11.73$, $p = 0.003$. The post-hoc tests showed a significant difference between 2D Pictionary and Charades ($Z = -2.739$, $p = 0.006$) and 3D Pictionary and Charades ($Z = -2.823$, $p = 0.005$).

Considering the players' analysis of their experience in both games we were asking additional questions comparing their VR and F2F experience.

Q7: *"Reviewing videos/the VR recordings helped me remember my experience during the games."* When analyzing where the participants found it better to review their experience, the participants found the VR recording of the games better ($M = 6.00$, $SD = 1.27$) than the video recording ($M = 5.58$, $SD = .51$). A non-parametric Friedman test could not find a significant difference between the video recording and the VR recording.

Q8: *"Reviewing videos in VR/ on video helped me gain new insights into my interactions".* Considering gaining new insights on the participants interactions during the game, the participants rated the VR recording to provide more insights ($M = 6.00$, $SD = 1.20$) compared to the traditional video recording

($M = 4.91$, $SD = 1.37$). A Friedman test revealed a significant difference between the two recording systems, $\chi^2(1) = 4.500$, $p = 0.034$.

Electrodermal Activity. Considering the analysis of the EDA using the CV, the results revealed that the 3D VR Pictionary led to the most EDA activity ($M = .24$, $SD = .18$), followed by the 2D VR Pictionary ($M = .20$, $SD = .20$), the F2F Charades ($M = .15$, $SD = .11$), the VR Charades ($M = .14$, $SD = .07$), and the 2D F2F Pictionary ($M = .11$, $SD = .04$). Mauchly's test of sphericity indicated that we cannot assume a sphericity of the data ($p < 0.001$). Therefore, we apply a Greenhouse-Geisser correction to adjust the degrees of freedom. Unfortunately, a one-way repeated measures ANOVA could not reveal a significant difference between the conditions ($p > .05$).

Head Movement. When analyzing the head movements the participants made during the different conditions, the 3D Pictionary ($M = .117$, $SD = .038$), Charades F2F ($M = .115$, $SD = .045$), and the Charades VR ($M = .111$, $SD = .041$) lead to similarly frequent head movements, followed by the F2F Pictionary 2D ($M = .105$, $SD = .045$). The Pictionary 2D in VR led to the least head movements ($M = .078$, $SD = .018$). A one-way repeated measures ANOVA revealed a significant difference between the conditions, $F(4, 32) = 2.670$, $p = .049$. However, a post-hoc did not reveal a significant difference.

Left Hand Movement. For the movements of the participants' left hands, we found that the F2F Charades led to the most hand movement ($M = .27$, $SD = .15$), followed by the 2D F2F Pictionary ($M = .21$, $SD = .10$), the VR Charades ($M = .19$, $SD = .05$), the 3D Pictionary ($M = .13$, $SD = .04$), and the 2D VR Pictionary ($M = .10$, $SD = .03$). Mauchly's test of sphericity indicated that we cannot assume a sphericity of the data ($p < 0.001$). Therefore, we apply a Greenhouse-Geisser correction to adjust the degrees of freedom. A one-way repeated measures ANOVA showed a significant difference between the conditions, $F(1.477, 14.771) = 8.775$, $p = .005$. The post hoc tests showed a significant difference between 2D VR Pictionary and all other conditions. Further there was a significant difference between VR Charades and 3D Pictionary (all $p < .05$).

Right Hand Movement. We found that the 3D Pictionary led to the most right hand movement ($M = .26$, $SD = .12$), followed by F2F Charades ($M = .24$, $SD = .11$), the 2D VR Pictionary ($M = .23$, $SD = .18$), the 2D F2F Pictionary ($M = .23$, $SD = .11$), and the VR Charades ($M = .21$, $SD = .06$). A one-way repeated measures ANOVA could not reveal a significant difference between the conditions ($p > .05$).

4.6 Qualitative Results

The questionnaire questions reported above captured many of the most salient trends we discovered during our prior informal pilots. The qualitative results presented in this subsection are focused on ideas that are either more complex and nuanced, or first became apparent in the main study. In this section we report factual aspects of this feedback, and save a discussion of its significance and relationship to our quantitative results for the *Discussion* section that follows.

One idea that was important but also very subtle to interpret was the degree of expressivity participants perceived in the gestures of others. This subject was always brought up in the interview at the end of the entire session. All participants agreed that, as expected, the smoothness and precision of the representation of movement in the space led to a high degree of expressivity and sense of being able to perceive some aspects of emotion or other non-verbal reactions. It was difficult for participants to describe this explicitly, because in the same-time, same-place setting, it seemed very natural that the other person's emotions could be interpreted through movement, and therefore not noteworthy on its own. For this reason it was primarily during the process of viewing VR recordings that participants were able to consider in isolation what kind of information avatar movements contained. Several participants found their own movements and those of their partners to be distinctive and recognizable. Other participants disagreed, and felt that they would not be able to distinguish a playback of their own avatar actions from actions of unknown others. This on-the-fence status was well summarized by one participant's comment that there were "glimpses of humanity" that would appear sporadically throughout the process of viewing. Another participant reported "they're very emotive" and "you can definitely tell it's you."

Recounting briefly some comments about the general relationship between the face-to-face and VR experiences, participants mentioned most frequently that VR Charades was challenging because of the lack of face and body avatars. After initial reports that the VR 2D Pictionary experience was qualitatively highly similar to its face-to-face counterpart, the facilitators questioned participants for more detail. Because participants rarely look to each others' faces for feedback during gameplay, the entire focus was really on the board, and they found the experience of drawing on the physical whiteboard versus the virtual whiteboard nearly identical. They cited several advantages for VR over face-to-face: the virtual board erases automatically between words, switching colors was faster using the VR color palette than physically switching markers, and in VR the body does not occlude the drawing surface, so it was never an issue that the actor's body was blocking the view. One corollary that came out in interviews was that VR offered the advantage of removing some aspects of face-to-face interaction that are distracting, awkward, or unpleasant. Attention to gender, ethnicity, body image, and certain visual social cues are impeded through the invisibility of the physical body.

Next, we review comments participants made about the process of reviewing video versus VR recordings. Several participants reported reviewing video to be unpleasant, mentioning they felt "silly" watching themselves play. In contrast, they described the experience of watching replays in VR as insightful and fun. In 3D Pictionary specifically, many participants reported that viewing the replay from a different perspective allowed them to see how their drawings were not as decipherable from their partners' perspective as from their own.

One last area of participant feedback that we'll highlight in this section is the description of 3D versus 2D drawing. Nearly all participants described drawing in 3D as challenging, but some enjoyed the challenge while others found it frustrating. There was broad agreement that drawing in 3D was typically slower, but there were cases where it offered advantages. The biggest challenge was becoming accustomed to considering multiple viewing perspectives. There was a weak consensus that drawing on a virtual 2D plane would be a winning strategy if emphasis was placed on finishing quickly. In contrast, participants in our experiment participants were given time limits, but were not otherwise incentivized to finish quickly. This observation is highly coupled to the specific task of Pictionary play, and may have been accentuated by the fact that the word list was designed for 2D Pictionary (Fig. 6).

Fig. 6. Expressive poses in F2F/VR acting out "blind" (left) and "beg" (right)

5 Discussion

The previous section presents a disparate set of results from our five data sources. In this section we highlight some salient relationships between these results.

We begin by observing that participants felt strongly that (1) the communication medium was not sufficient for Charades, while feeling that (2) the medium was entirely sufficient for Pictionary in 2D and 3D, as evidenced by the questionnaire responses. In the former, the absence of facial gestures, finer hand gestures, finger movements, and a body for non-verbal communication were considered highly problematic, while in Pictionary they were considered irrelevant. Further underscoring this was the response to Q1. At the Likert scale value of 3.75 participants were very close to "neutral" on the question. We interpret this as a strong statement about two aspects of the interaction: (1) the adequacy of the hand-held controllers at approximating the face-to-face experience of drawing on a whiteboard, and (2) the expressiveness of the avatars. We know that when the focus of the interaction is on the body itself, as in Charades, the simple avatars were inadequate. Despite participants' reports to this effect, even the most difficult words we tested were guessed correctly by a subset of groups – meaning that the communicative affordances were nonetheless powerful enough to admit creative workarounds. Furthermore, the qualitative feedback indicated that the avatars were perceived as quite expressive and emotive. Reconciling these statements, we propose the following guideline, pertaining to systems equivalent to ours: a collaborative task that is communicative, but with a central focus that is not on the face or body itself, when facilitated by well-adapted task-specific interface affordances, will yield an overall experience comparable to face-to-face. Stated more broadly, minimal avatars provide a powerful and versatile baseline set of communication affordances. Roughly speaking, the two games we tested define a spectrum between the worst and best-adapted activities for our simple head and hand avatars. We conclude that, when designing system for a certain form of collaboration in VR, one should ask whether it is more Charades-like or more Pictionary-like in order to decide whether the additional effort of embodying a more sophisticated avatar is justified.

Next, comparing movement, TLX, and EDA data for 2D Pictionary reveals an interesting correlation. In particular, it was a high-EDA activity, and a somewhat high perceived cognitive load (TLX) activity, while being the lowest-movement activity overall. This indicates a mode of mental engagement corresponding to decreased physical movement. If there were any coupling between physical movement and EDA, it would work against this result, hence it is interesting to highlight.

Now we review true advantages of VR over face-to-face that were shown in our results, beginning with those relating to efficiency of task performance. First, the virtual whiteboard did not need to be manually erased, and therefore decreased the time and energy required to perform an equivalent task in VR vs. F2F. Next, the transparency of the body in VR minimized occlusion of the virtual whiteboard – the drawing player could stand right in front of the board without preventing the guessing player from seeing the drawing. Next, a psychological benefit was reported in participants' observation that masking the physical body can be beneficial to focus and decrease social anxiety in collaborative interactions. All of these can be viewed as advantages of "programming" the virtual visual environment, by instantly changing its properties in ways that require time and effort, or aren't possible at all, in the physical world. Indeed, they "satisfy needs of communication," physically and psychologically, in a way that is not possible face-to-face, and hence go *beyond being there* [9].

Now we turn briefly to the methodological implications of this experiment. Although our EDA data did not uncover significant differences between our activities, it was close enough that we would conjecture that further refinement of the method to reveal significant differences would be possible – for instance subdividing overall games into smaller components, or applying peak detection algorithms. Next, discussing movement data, the only significant result was that the left (palette) hand stays very still during 2D Pictionary. While this is not exciting on its own, the prospect of doing more sophisticated analysis of body movement with absolute positional data rather than (or in addition to) accelerometry is very exciting. This is firm evidence that activity analysis and recognition can be applied to the positional data collected by the Lighthouse system, and certainly any other system with similar or greater precision that comes along. Finally, our significant result about the difference between video and VR review of games is worthy of note. Participants found VR review equally good (i.e. not significantly different) for *recall* of the experiment, but significantly better at providing new insights. Not only does this provide a basis for researchers to obtain highly nuanced qualitative feedback from participants, it also suggests that review of VR activities could be used in the context of learning or training – leveraging the reflective power of scrutinizing ones' own performance in a way that is demonstrably better than video.

6 Conclusion

Same-time, same-place interaction in virtual reality has been shown without any doubt as a practical medium for communication and collaboration, which carries with it a sense of social presence that is adequate for a variety of non-verbal methods of communication mediated by hand gestures, head gestures, and overall spatial movement. If facial gestures, torso, or leg movements are particularly relevant to the communicative task, the minimal system we built would need to be extended to support these in some fashion before being applied for the use case. It was shown that drawing in 3D is challenging but highly promising due to the new space for expression that it opens up. It was observed that interacting in VR has the advantage of masking aspects of physical appearance and the body that can be distracting during collaborative interaction. Reviewing interaction in VR allowed participants to gain new insight into how their own communicative processes did and didn't work, and this could be useful as a tool for reflection or coaching. We see all three of these as fruitful directions for future research in collocated and remote computer-mediated communication using room-scale virtual reality.

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Augmented Reality, Wearable Technologies

Do You Know What Your Nonverbal Behavior Communicates? – Studying a Self-reflection Module for the Presentation Trainer

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Abstract. In recent years, research on multimodal sensor-based technologies has produced different prototypes designed to support the development of public skills. These prototypes are able to analyze the nonverbal communication of learners and provide them with feedback, in cases where human feedback is not available. One of these prototypes is called the *Presentation Trainer* (PT). Experts in public speaking claim that ultimately there is not such thing as the right way to do a presentation. They pointed out that it would be useful for tools such as the PT to present learners with the opportunity to become aware of their own nonverbal communication. Following this suggestion we developed a self-reflection module for the PT. In this study we conducted user tests exploring the use of this module. Results from these tests showed that participants perceived that the self-reflection module helped them to reflect about their performance, and point out research paths to further investigate the influence of self-reflection in the learners' performance.

Keywords: Self-reflection · Sensor-based learning support · Public speaking · Multimodal learning application

1 Introduction

Instead of pledging for mercy after being accused from corrupting the minds of young people, Socrates in his public apology gave one of the most influential speeches of all time with the central message claiming that "the unexamined life is not worth living" [1]. From asking people to examine their life, to influencing a whole country to send a man to the moon [2], public speeches have the power to shape human history. Currently educational researchers, teachers, employers and policy makers consider public speaking as a core competence for educated professionals [3–6] and include it in the list of 21st century skills that help learners to function effectively at work as well as in their leisure time [7–9].

Practice and feedback are key aspects for the development of public speaking skills [10]. Nevertheless, the opportunity for learners to get enough practice and feedback in current public speaking courses is limited, thus graduates often lack the skills to speak in public [11]. Providing learners with the feedback needed through human assistance

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is neither a feasible nor a practical solution. Computerized systems with multimodal sensing capabilities have already been used to provide learners with feedback for numerous types of learning applications when human tutors are not available [12]. These learning applications include the development of basic public speaking skills, where several presentation training applications have been developed and tested showing positive results in laboratory [13–16] and classroom conditions [17]. One of these applications is the *Presentation Trainer* (PT), a multimodal tool that allows learners to practice their presentation skills while receiving basic feedback in real-time regarding their nonverbal communication [16]. One limitation of the PT according to experts in the field of public speaking is that the PT provides learners only with corrective feedback when ultimately there are no strict rules for presenting to the public [17]. Therefore, experts suggested to expand the focus of the PT, making it a tool that allows learners to increase their level of awareness and help them to reflect on their performance [18].

To improve the PT, based on the expert evaluation, we developed a self-reflection module for the PT. The purpose of this paper is to report on the user tests conducted to explore the usage and impact of this self-reflection module.

2 Presentation Trainer

The Presentation Trainer is a multimodal tool designed to support the development of basic public speaking skills. It allows learners to practice their presentations while receiving feedback regarding their nonverbal communication. The PT uses the Microsoft Kinect V2 sensor to capture the nonverbal communication of the learner. The learner can practice her speech while standing in front of the Kinect sensor and receiving immediate feedback from the PT. The reason for providing immediate feedback to the learner is that for aspects that can be corrected immediately such as the nonverbal communication, immediate feedback has proven to be more effective than delayed feedback [19]. Another important aspect of the PT's feedback is that it provides the learner with a maximum of one corrective feedback instruction at a given time (see Fig. 1). This because the display of multiple feedback instructions at a given time has shown to be too overwhelming for the learner [20]. With the addition of the self-reflection module, a practice session with the PT consists of two phases. In phase one, the learner practices her presentation and receives immediate feedback through the real-time module. All data is captured and aggregated for use in the self-reflection module. In phase two, the learner is guided through the self-reflection module.

2.1 Self-reflection Module

The self-reflection module of the PT has the purpose to help learners to increase their awareness regarding their performance while reflecting on it. It consists of six different sub-modules: *Pauses Report, Posture Report, Gesture Report, Overall Performance Report, Future Improvement, and Improvement Text.*

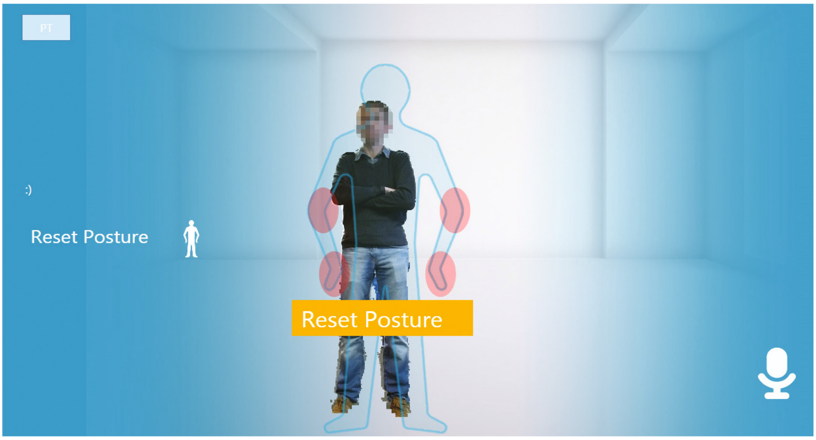

Fig. 1. PT telling the user to correct the posture.

Pauses Report is designed to help the learner to reflect about her use of pauses during the practice session (see Fig. 2). The first item presented in this report is a timeline that shows the learner her speaking and silent moments that were captured during the practice session. This timeline also shows the total number of pauses, the average pausing time and the average speaking time. The second item of this report asks the learner two questions:

- "Are you using your pauses with purpose?"
- "How can you improve your use of pauses?"

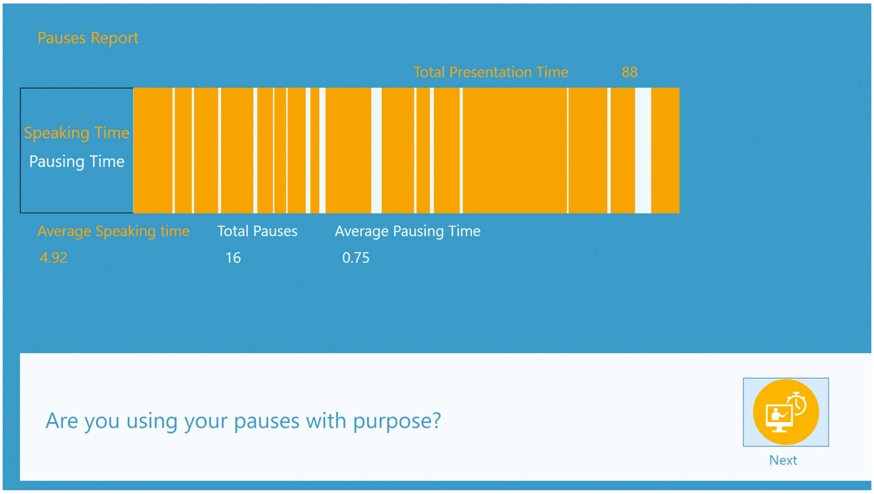

Fig. 2. Pauses Report sub-module.

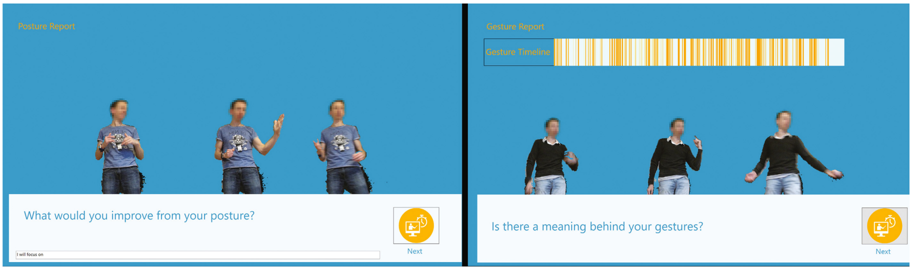

Fig. 3. Left: Posture Report; Right: Gesture Report

The second question comes up with a text-field allowing the learner to type an answer.

Posture Report (Fig. 3. Left) is designed to help the learner to reflect about her posture during the presentation. The first item displayed in this sub-module is a set of three screenshots captured in the moments that the PT captured a "posture mistake" during the practiced presentation. In case that the PT identified less than three "posture mistakes" during the practice it will show the learner screenshots of random moments from the presentation. The second item in this sub-module asks the learner two questions:

- "The attitude reflected in your posture, is the same attitude that you want to convey?"
- "What would you improve from your posture?"

The second question comes with a text-field allowing the learner to provide an answer.

Gesture Report (Fig. 3. Right) is designed to help the learner to reflect about her use of gestures. The first item presented in this module shows a timeline that indicates the moments during the practice presentation where gestures were identified. The second item shows three screenshots taken while the learner was using a gesture during her practice. The third item of this sub-module asks the learner two questions:

- "Is there a meaning behind your gestures?"
- "What gestures can you add to support your communication?"

The second question comes with a text-field allowing the learner to type an answer.

Overall performance Report (Fig. 4) presents the learner with a timeline showing all the identified events captured by the PT during the practiced presentation. It shows in red the moments where a "mistake" was identified, in green the moments where a positive behavior was identified (e.g. smiling). It also shows with small icons the moments where the feedback of the PT was displayed.

Future improvement (Fig. 5. Left) asks the learner "what would you like to improve for your future presentation?". This sub-module allows the user to select one of the aspects that can currently be trained using the PT: Posture, Voice Volume, Gestures, Pauses, and Facial expression. If the learner selects Posture, Gestures or Pauses then during the following training session her *Improvement Text* (Fig. 5. Right)

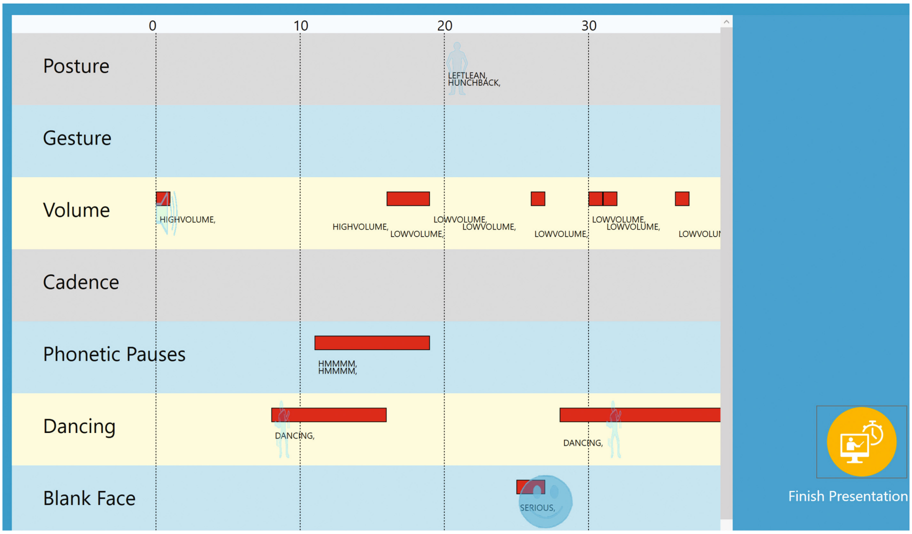

Fig. 4. Overall performance report showing the events capture by the PT during practice (Color figure online)

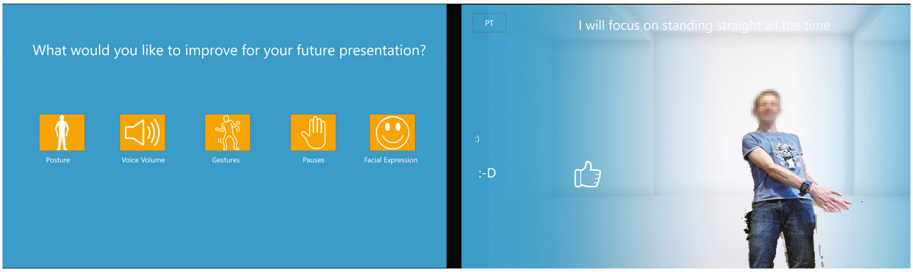

Fig. 5. Left: Future Improvement Screen. Right: Practice session showing Improvement Text on top

will be displayed. The text displayed in the *Improvement Text* corresponds to answer given by the learner to the second question of the corresponding report. For example in the case that the learner selects to improve on her Posture, then the *Improvement Text* displayed during her following training session is the answer she gave to the question "What would you improve from your posture?" from the *Self-reflection Posture Report*.

3 Method

In this study we conducted user-tests [21] in order to evaluate the self-reflection module of the PT. The objectives for conducting these tests were the following:

Objective 1: Identify perceived difficulty for learners to correctly interpret the different items from the self-reflection module.
Objective 2: Identify whether the different items help learners to become aware and reflect about their performance.
Objective 3: Identify the influence of the Self-reflection module on the learners' decision to select what to improve for future practice sessions.
Objective 4: Explore the influence of the Self-reflection module in the learners' performance.

3.1 Study Context

We conducted this study in the setting of a course in entrepreneurship for master students in a university. For this course students are divided in teams. During the course each team is required to develop and present an entrepreneurial product or service. Presenting their project effectively is an important aspect of the course, therefore during the course students receive guidance regarding their presentation skills. This study was conducted five weeks after the students had their first public speaking lecture for the course.

3.2 Study Procedure

Twelve participants, nine males and three females between the age of 24 and 28 years took part in the study. To prepare for the study, students got the homework to prepare a 60 to 120 s long pitch regarding their project. One week later the user-tests were conducted during a two-hour session slot.

For the user-tests participants individually entered into a classroom with the PT. After arriving the experimenter gave the student a brief description of the task and a brief description of the feedback from the PT. Then the student practiced the pitch two times using the PT. After the two practice sessions the student filled in a questionnaire regarding the self-reflection module of the PT.

3.3 Apparatus and Material

The version of the PT that includes the self-reflection module was used as the intervention tool for this study. The log files generated by the PT were used to measure the performance of the participants. The log files included all the events captured during the practice sessions e.g. posture, gesture, volume, phonetic pauses, facial expressions and cadence mistakes. These log files also contained the selections made by the participants for future improvements.

A post-test questionnaire was used to inquire participants about their experience with the PT's self-reflection module. This questionnaire was divided in segments that align with the self-reflection sub-modules of the PT: *Pause report*, *Posture report*, *Gesture report*, *Overall performance report* and *Future improvement*. The items in the questionnaire inquired about the difficulty to interpret the different timelines displayed in the reports, and the perceived usefulness of the elements, i.e. helping learners to become aware of their performance and reflect on how to improve in the future.

During the experimental sessions the experimenter took notes regarding the use of the self-reflection module and performance of the participants.

4 Results

Results from the post-test questionnaire regarding the *Pause report* are displayed in Table 1. The results show that generally the *Pause report* helped participants to reflect about the use of pauses. The element that received the highest rating with a mean score of 4.22 out of 5 turned out to be the question: "Are you using your pauses with purpose?". As an extra remark one participant commented the following: "The timeline make me realize that my usual pauses are too short."

Table 1. Scores from the post-test questionnaire regarding the *Pause report*

Item from the questionnaire	Mean and standard deviation (1 totally disagree–5 totally agree)
The timeline for speaking time and pausing time is easy to interpret	4.11 (0.93)
The timeline helped me to remember what I did during the presentation	3.33 (1.12)
The question: "Are you using your pauses with purpose?" helped me to reflect about my performance	4.22 (0.67)
The question "How can you improve your use of pauses?" helped me to think on how to improve my future performances	3.67 (1.41)
Overall the *Pause report* helped me to reflect about my use of pauses	3.89 (0.78)

Table 2 displays the results from the post-test questionnaire regarding the *Posture report*. Overall the *Posture report* helped participants to reflect about their posture. The item that received the best score with a mean of 4.33 out of 5 was the question: "What would you improve from your posture?".

Table 3 displays the results from the post-test questionnaire regarding the *Gesture report*. Overall according to the participants the *Gesture report* helped them to reflect about their use of gestures. The screenshots captured of the participants while doing a gesture was the element of the Gesture report that received the highest score with a mean of 4.67 out of 5. As an extra comment one participant suggested to also record some videos for the captured gestures.

Results from the post-test questionnaire regarding the *Overall performance report and Future improvements* are displayed in Table 4. In summary the *Overall performance report* was perceived as easy to interpret, helpful in terms of reflecting about the

Table 2. Scores from the post-test questionnaire regarding the *Posture report*

Item from the questionnaire	Mean and standard deviation (1 totally disagree–5 totally agree)
The pictures of me giving the presentation helped me to become aware of how my posture is perceived by the audience	4.22 (0.97)
The question: "The attitude reflected in your posture, is the same attitude that you want to convey?" helped me to reflect about my performance	4.11 (0.93)
The question "What would you improve from your posture?" helped me to think on how to improve my future performances	4.33 (0.71)
Overall the *Posture report* helped me to reflect about my posture	4.11 (0.78)

Table 3. Scores from the post-test questionnaire regarding the *Gesture report*

Item from the questionnaire	Mean and standard deviation (1 totally disagree–5 totally agree)
The gesture timeline is easy to interpret	3.22 (1.09)
The gesture timeline helped me to become aware of how many gestures I used during my presentation	3.89 (0.78)
The pictures of me using gestures helped me to become aware of how my gestures are perceived by the audience	4.67 (0.50)
The question: "Is there a meaning behind your gestures?" helped me to reflect about my performance	4.33 (0.50)
The question "What gestures can you add to support the communication of your message?" helped me to think on how to improve my future performances	3.67 (1.66)
Overall the *Gesture report* helped me to reflect about my use of pauses	4.11 (0.93)

overall performance and helpful on reflecting how to improve future performances. One participant commented that it was difficult to connect the problems shown in the timeline with the things done during training. Generally participants liked the idea to be asked by the PT on what skill they want to focus for the following practice sessions. Most of them also considered it a good feature to display on top of the screen what they want to improve during the next practice session. Only one commented that having this extra information is overwhelming.

We analyzed the performance of the participants for both of the practice sessions using the logged files generated by the PT. In its current version the PT is able to analyze behaviors that are considered mistakes. To evaluate the performance of the participants for each of the practice sessions, we calculated the percentage of time that a mistake was identified during a practice session (pTM). To calculate the pTM we add

Table 4. Scores from the post-test questionnaire regarding the *Overall performance report* and *Future Improvements*

Item from the questionnaire	Mean and standard deviation (1 totally disagree–5 totally agree)
The Overall performance report is easy to interpret	4 (0.71)
The Overall performance report helped me to become aware of my performance	3.89 (1.17)
The Overall performance report helped me to think on how to improve my future performances	3.78 (1.39)
It is a good concept that the PT asks: "What would you like to improve for your future presentation?"	4.33 (1.32)
Seeing my answer on top of the screen of what I want to focus during my presentation is helpful	3.67 (1.22)
My selection regarding what to improve on a following session was based on (Multiple selections were possible)	Pause report – 6 participants Gesture report – 4 participants Practice Feedback – 2 participants Posture report – 1 participant

the duration of all the mistakes captured by the PT during a practice session, and divided this added mistake time by the total duration of the practice session. Table 5 displays the mean and standard deviation pTM values for the first and second practice session in this study. Results show that on average participants during the second practice session improved in all aspects. The aspect that received the worst evaluation for the first session was use of pauses, followed by used of gestures and then voice volume. In the second practice session the use of pauses got the worst assessment, followed by voice volume and use of gestures. The aspect displaying the biggest improvement for both sessions was the use of gestures, followed by the use of pauses.

Table 5. pTM scores captured during the practice sessions (mean and standard deviation).

	Posture pTM	Volume pTM	Pauses pTM	Blank F. pTM	Gestures pTM	Dancing pTM	P. Pauses pTM	Total pTM
1st Session	0.017 (0.05)	0.153 (0.10)	0.290 (0.19)	0.009 (0.21)	0.238 (0.28)	0.000 (0.00)	0.032 (0.02)	**0.739 (0.47)**
2^{nd} Session	0.009 (0.04)	0.133 (0.11)	0.197 (0.22)	0.001 (0.22)	0.082 (0.17)	0.012 (0.02)	0.016 (0.02)	**0.451 (0.33)**
Mean difference	0.008	0.020	0.093	0.008	0.156	0.012	0.016	**0.313**

We examined the possible effects that the selection to improve a specific behavior had on the performance on this behavior in the following practice session. To do that, we measured the improvement between practice sessions. We grouped the participants who made the same selections. Then we measured the improvement that they had for the selected behavior. We obtained this improvement by measuring the difference of the pTM scores between the first and second practice session for the selected behavior. Finally we compared the mean improvement from the group that selected the specific

Table 6. Comparison of the captured improvements grouped by the participants who selected to improve a specific behavior against the whole set of participants.

	Improvement 1st and 2nd practice session for participants who selected to improve the specific behavior	Improvement between 1st and 2nd practice session for all participants
Pauses	0.226	0.093
Posture	−0.021	0.008
Gestures	0.255	0.156
Facial expressions	0.05	0.008

behavior against the mean improvement from the whole set of participants. Table 6 shows the comparison of the improvements from the groups that selected a specific behavior against the whole set of participants. The results on the table show that participants who selected to focus on the use Pauses, Gestures or Facial expressions between the 1st and 2nd practice session displayed on average a bigger improvement for their selected behaviors, than the average improvements for these behaviors taking into account all participants. The exception is Posture, where the performance of the participant who selected to focus on Posture, become worse in terms of Posture during the second practice session.

The experimenter observed that in the first few moments of the second practice session participants did put a lot of effort in improving what they selected to improve. For example usually participants make the first pause once the PT sends the feedback that is time to make a pause, currently this time is set up to 15 s of speaking without pausing. From the logs of the presentation trainer is possible to observe that the six participants who selected to improve their use of pauses, made a deliberate pause before the first 15 s of the second practice session. After that, their following pauses where made after the PT indicated them to do so. Similar behavior was observed with the participants who selected to improve their gestures. During the first moments of their second practice session they introduced some iconic gestures, later they stopped with the iconic gestures and returned to the usual way of moving their hands while speaking. The same was observed with the participant who wanted to display a "more open posture". The participant started the speak with arms open, palms of hands facing to the front and after few seconds, the participant returned to the ordinary posture.

One final observation happened while the participants were interacting with the self-reflection module. During this interaction four participants commented out-loud that in order to improve their performance, it would be necessary to modify their pitch and rewrite it based on the information presented by self-reflection module.

5 Discussion

Results from the post-test questionnaire allowed us identify that the different elements of the self-reflection module of the PT were interpreted correctly by participants without major difficulties. Results also indicate that the different elements of the self-reflection module were perceived as helpful in supporting learners to reflect about their performance. These two outcomes satisfactorily address *Objective* 1 and *Objective* 2 of this study. The post-test questionnaire also positively addresses *Objective* 3 of this study. It shows that the self-reflection module substantially influenced the participants' selections on what to focus on future practice sessions.

Objective 4 of this study deals with exploring the influence of the self-reflection module on the learners' performance. To examine this influence we analyzed the logged data of the PT. The analysis of the logged data shows that the participants that selected a specific behavior to improve, had a slightly bigger improvement in this behavior than the participants who did not select it. However, the number of participants and the difference in improvement are both to small. Therefore, we cannot attribute with certainty that the observed improvements are the result of the interaction with the self-reflection module. Similar results were obtained when looking at the general measured improvements (improvements considering all skills, not only the selected ones to be improved). The general improvements captured in this study are also slightly bigger than the improvements observed in a previous study that used a version of the PT without the self-reflection module (0.313 measured in this study in contrast to 0.284 measured in [17]). Nonetheless, the difference in settings between both studies and the minimal difference in improvements does not allow us to assert that the self-reflection module of the PT influenced the participants' performance. Having said that, observations from this study lead us to consider that the slightly bigger improvements can be attributed to the first few moments of the second practice sessions. During these first few moments it was observed that participants deliberately changed their usual communication practices, and that these deliberate changes quickly fade away. This points out a limitation for this study. The set-up of the study did not provide with the necessary methods to systematically measure the possible subtle differences in performance influenced by the self-reflection module. An important limitation is the constrained amount of practice offered. Just one additional practice session is likely too limited.

One of the most interesting findings in this study is that without being asked, four participants out-loud commented the importance of rewriting their pitch based on the information presented by the self-reflection module. Due to time constrains and study design participants were not allowed to do so. However, these comments are clear indications that the module fulfilled its main purpose. It made participants truly reflect on how to improve their performance. These comments made us reconsider our approach on how to study the influence that self-reflection has in the learners' performance. In this and previous studies with the PT, the learners' performance was measured through the learners' displayed behavior, cognitive changes were not assessed. Therefore the main influence of the self-reflection module might not merely be displayed as machine-measured improvements in behavior. Rather, the main influence of this module relies on the awareness raised on participants to reconsider and adapt their behavior, for further practice sessions with the PT or even better, in real presentations.

6 Conclusion and Future Work

In resent years the use of multimodal public speaking instructors has been researched, in order to support learners with the practice and feedback needed to develop their public speaking skills. So far studies regarding these instructors have presented promising results showing that learners are able to adapt their behavior based on the feedback provided by these systems. Research has also shown that these changes in behavior also translate to better presentations according to human audiences. Following public speaking experts' suggestions on how to improve these technologies, we added a self-reflection module to the PT and conducted a formative evaluation on it. The module added fits well within theories of reflection [22]. With the added module the PT enables now both reflection-in-action (reflection on behavior as it happens, so as to optimize the immediately following action) and reflection-about-action (reflection after the event, to review, analyze, and evaluate the situation, so as to gain insight for improved practice in future) [23]. This evaluation allowed us to draw the following conclusions:

- Learners perceived that the different reports of the self-reflection module helped them to reflect about their performance. These reports confront learners with evidence of events that happened during the practice session (e.g. screen shots, timeline of events), together with questions inquiring whether the presented evidence is aligned with their expectations, and questions asking for means to improve their performance.
- The self-reflection module influences the learners' decision on what they would like to improve on in future practice sessions.
- The self-reflection module does not present a substantial influence in the participants' measured behavior. Likely, only one additional practice is not sufficient.
- The self-reflection module made some participants aware that a new pitch should be rewritten taking in consideration the presented information in order to substantially improve their performance.

To improve the self-reflection module we find it important to continue studying its effect on the learners' performance. This includes systematically exploring the changes in behavior that seem to happen during the first moments of the practice sessions. Closely identifying the changes and timely measuring when they fade. Also provide learners the opportunity to rewrite their pitch or presentation based on their self-reflection, and meticulously study the differences between the old and the newly rewritten pitches. Moreover, equally, important, to investigate the optimal amount of practice sessions. Finally investigate whether the self-reflection module is able to influence the learners' performance, in a way that a human audience is able to recognize.

To finalize, this study instead of providing conclusive evidence on the effects of a self-reflection module for multimodal public speaking coaches, it revealed new paths for future research. Paths that go beyond the exploration of multimodal applications designed to support learners with the automation of their behavior. It revealed paths for investigating how sensor-based public speaking coaches can also support learners with the examination of their performance and making it worth for them.

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The Integration of Augmented Reality and the Concept of Sticker Album Collection for Informal Learning in Museums

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Abstract. Informal learning can have an important role in today's Education but, to be effective, it should be contextualized individually for each learner, and situated to enhance experience. Museums have invaluable collections of assets that are in display and curators use their knowledge to engage the audience. Museums are places where informal learning can be fostered to engage the students and provide opportunities for situated learning. Pervasive systems, that take into account context, from both the learner and the location, have a good potential to promote this effectiveness in a gamified process that transforms the regular museum exploration into an engaging experience that provides learning opportunities at the appropriate time and place.

In this paper, we propose a gamified approach based on the concept of sticker album collection and its integration in an Augmented Reality (AR) mobile application. The concept of sticker album collection is quite familiar to most people, mainly from their youth, and is the main dynamic of the gamification design, engaging the learner to collect more stickers and progress in the exploration of the museum. As a pervasive solution, we do not use physical support, but instead, a mobile application to provide the learning experiences by uncovering the stickers using AR over the museum collection, in order to enhance the knowledge transfer and rewarding. We present a prototype developed for a boat museum where, digital stickers are obtained by overcoming challenges in the context of the exploration of the boats in the museum.

Furthermore, we provide two evaluations fromexperts: a preliminary evaluation of user experienceand a gamification evaluation using the Octalsysframework.

Keywords: Sticker album collection · Gamification · Museums · Augmented reality

1 Introduction

Museums consolidate the heritage of a country and a given region, interlinking history, art, science and the territory, among others. Confirming its importance, there is a gradual increase in the number of visitors, and the literature review points out to an increase in

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projects that try to incorporate recent technological developments to effectively improve the attraction of (mainly) the younger population.

As an inalienable landmark in the history of Portugal, we focused this paper on a case study about Maritime Museums, and most particularly, the exploration of traditional boats. The main research question is: how to integrate museums in a gamified informal learning experience?

So, the basis of our approach is to capitalize the value of museum collections to provide engaging experiences and then to add an AR layer that gamifies the assets of the exhibition to provide the dynamics to foster progressions on informal learning activities. We focus on the concept of the digital sticker album collection as the basic dynamics together with a set of mechanics that require solving challenges using AR.

2 Related Work

Museums are places that materialize and display knowledge, fostering the collection, preservation and sharing of that knowledge with the public [1]. Museums are changing the way they engage the audience, by turning the visitors from passive to active participants [2, 3]. Technological solutions have been fostered to improve the experience of visitors, incorporating multimedia elements and AR [4, 5]. However, the technology should be integrated in the design of the experience and gamification [6] can have a major role to enhance it. Arnab and Clarke propose a holistic model for gamified and pervasive learning design, highlighting the necessity to shift the focus away from current strong overemphasis on technology in the field, and move it toward prioritizing the value of context, pedagogy and basic game design [9]. Pervasive learning can be defined as “learning at the speed of need through formal, informal and social learning modalities” [10] and should be explored to provide learning opportunities, formally or informally in contexts such as museums, that provide an epic context to deploy the learning activities.

Collecting can be defined as the process of acquiring and possessing things in an active, selective and passionate way [7]. The sticker album collection is rooted into many cultures and is intergenerational. Different target audiences have come to eternalize collecting, with football sticker cards and characters from the world of fantasy and comics, to the universe of adults with collectible objects and marketing strategies aimed at them. From these perspectives, previous work has focused on the integration of AR with the concept of the sticker album collection to enhance the visitor experience in a traditional boat museum [8].

In this paper we advance further in the validation of the gamification design to enhance the experience and relevance of AR in the context of museums to provide opportunities for pervasive learning.

3 Gamification Design Based on the Sticker Album Collection

The gamification design was inspired on the concept of the digital sticker album collection. Important in this design is the concept of the “Players’ journey” which divides the players’ experience in four steps: discovery, onboarding, scaffolding and endgame.

The discovery phase is not addressed in this study, but in the case of a museum the entrance lobby is a good place to motivate the user to download the app. Or in the case of a school visit, the teacher or the museum guide can have an essential role.

The onboarding phase is fundamental to provide ownership and identity in the experience and also is a tutorial phase in which the player learns the basic mechanics. As soon as the application is downloaded, and after selecting the language, a video introduces the story/goals. Afterwards, the registration/login menu appears, which can be performed through Google or Facebook, thus making it possible use the social networks in a transmedia perspective and also to access some basic profile information to customize the application to the user. The user can also customize the theme layout (historic or children theme) and the avatar.

After the initial setup, the application shows an empty album. But to complete the onboarding, the user gets automatically the first sticker and the first challenge (Fig. 1) motivating the user to progress.

Fig. 1. The first sticker

Scafolding is the third phase of the Players’ Jorney and, basically, it is a progressive activity that engages the player into small iteration cycles in order to provide mastery. Informal learning can be included in these cycles. In this case, the user will discover thedistinct boats of the museum and will unlock the digital stickers to complete the collection.

Each boat has a predefined number of stickers that, being initially drawn as empty slots, show the number of challenges to solve (this number can vary) in order to collect the boat. Figure 2 shows the typical iteration cycles for a specific boat.

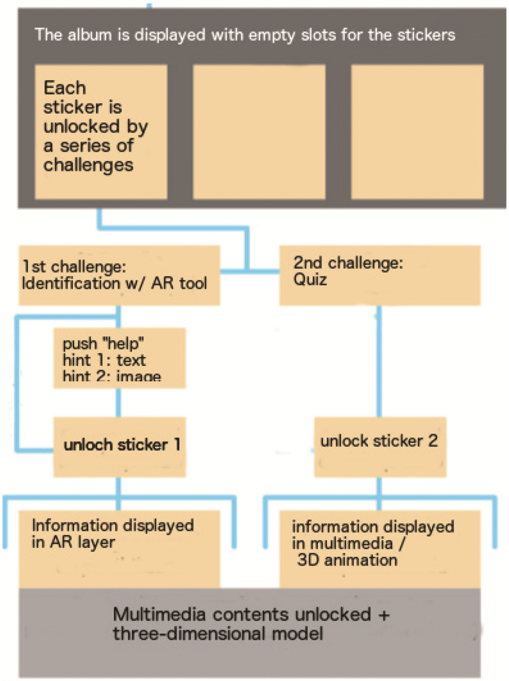

Fig. 2. Iteration cycles designed for each boat's collection of stickers

The first sticker provides a brief description of the boat and challenges the user to identify a specific component of the boat. Using the AR tool the user will need to find it. In the case of difficulty, a "help button" can be pressed and a text hint will be provided (about its location) and if the user is still not able to find it, another more detailed hint (like a drawing of the boat component) will be additionally provided. This provides mastery to proceed.

As the user identifies the boat component, additional information is provided in the AR layer, showing specificities and details on top of the original museum boat. This launches the second challenge, a simple quiz that assesses basic information provided previously in AR or on the site. After collecting this second sticker, the boat image in complete in the album, and a new multimedia content is available as a reward: a three-dimensional model of the boat and a small animation of how the boat is constructed. Thus, the user progresses through each level by surpassing each challenge, gaining access to digital stickers (and associated multimedia content) as a reward, making the exploration of the museum and the real apprehension of knowledge more attractive. The AR layer has the major role to make the connection with the heritage of the museum.

By exploring the museum rooms and completing the sticker album collection, the player reaches the Endgame phase, where (s)he is awarded a captain certificate and a complete collection of three-dimensional models of the boats that (s)he will be able to bring home. This experience could be shared on the social network where the user has registered or continued in other museums, for which a "passport" could be created, and a "travel stamp" would be rewarded also for each museum.

4 Preliminary Evaluation of User Experience

Based on the application developed, still as a prototype, a preliminary evaluation of the user experience was carried out with specialists on the museum area, through a questionnaire applied after an experimentation session. The questionnaire was applied to six key stakeholders, from the Director of the museum to staff members and visitors, as well the author of books on these particular traditional boats.

Figure 3 summarizes the mean and standard deviation of the responses obtained (Likert scale 1 to 5) according to the following key metrics: graphic layout, relevance of content, relevance of the application, interactivity, user feedback, usability, effectiveness, appropriateness of instructions, objectives, learning and the degree of satisfaction with the application.

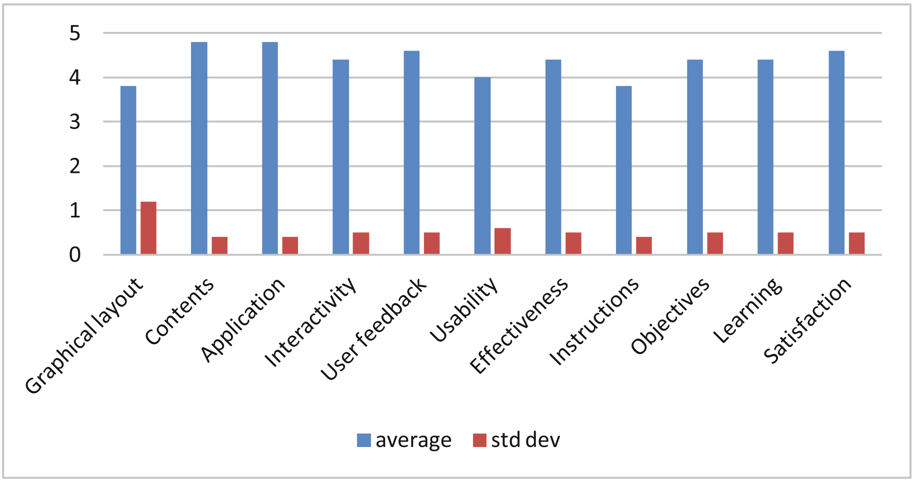

Fig. 3. Results of the preliminary evaluation

The results show that all metrics were scored above four, with the exception of two: graphical layout and appropriateness of instructions. Being a prototype, this is natural as the design and instructions have not been completed. But, overall, this good score shows a large potential to promote the prototype to a final product and to explore it in other applications.

There are also other variables to test, namely the most appropriated number of stickers for each boat and the number of iterations in the museum. In this first prototype we have developed five iterations (each one on a distinct boat) with just two stickers for each boat.

5 Evaluation Using the Octalsys Framework

The Octalsys framework, allows the evaluation of the effectiveness of the gamification design in 8 core drives, assessed on a scale from 0 to 10.

On the basis of the prototype developed we assessed the potential of this approach by involving four experts in the area (three of them with a PhD). In the following paragraphs, we show the resulting score (average/standard deviation) of the distinct contributions, and exposing the main reasoning behind it:

Epic Meaning & Calling (6,5/1,29) is related to the motivation (call to action) of the user. Discovering the history through museums can provide an epic meaning, particularly if the user integrates the learning activities within the museum experience. This could also be enhanced through an interesting narrative but, it is the AR tool that creates the connection of the experience to the real historical artifact, bridging the virtual and physical worlds.

Development & Accomplishment (8,75/0,5) is the internal drive of making progress, and in this case is the core nature of the stickers card collection. The motivation to complete the album provides small iteration cycles that provide progression and learning. Furthermore, the visual feedback on the collected/missing stickers works like a progress bar.

Empowerment of Creativity & Feedback (3,5/1,29) is when users are engaged in a creative process. Although the user can explore the rooms and the stickers collection over an arbitrary order, following a personal narrative, this is not a main drive of the approach. However the three-dimensional models awarded could be used on creative activities after the museum visit and promote feedback from the visitor on additional activities.

Ownership & Possession (9/0) is one of the main drives of the stickers collection as it is the user that constructs the album by collecting each individual sticker. Also the user can configure is own avatar and customize the theme layout, witch will engage them even more. At the endgame phase the user takes possession not only of the album but also of the multimedia/animation contents and the three-dimensional models of the boats.

Social Influence & Relatedness (3,75/2,5) is one of the topics that we did not explore deeply in this work. Nevertheless if the user uses social networks, the "stickers" working similar to achievements, can serve as means to compare experiences between visitors, as well as an incentive to promote cooperation and competition. And, clearly, this is one of the future work directions, as the core concept of the physical stickers collections is the exchange of stickers between people. This could be digitally provided to distinct students in a school visit to the museums or through the social networks.

Scarcity & Impatience (7,75/0,96) is driven by the desire to complete the collection. Having to unlock each sticker in each challenge requires exploration and learning at the museum rooms. However, this can lead the visitor to subvert the visit to the museum, focusing on hastily collecting stickers instead of enjoying the museeum. This is where AR takes another relevant role to focus the visitor attention on the museum collections.

Unpredictability & Curiosity (6,5/1,73) is also something that, although we did not explore deeply, is also natural to the physical counterpart of the album as you open the stickers bags… You do not know in advance which sticker will come out and if they are missing or already have been collected. This is also something that can be pushed forward in future work as the museum collection can provide this unpredictability, tied to the visitor's curiosity and thirst for knowledge.

Loss & Avoidance (7,25/1,5) is a "negative" drive that motivates people to continuing progressing in order to avoid the loss of the previous effort. A collection is only finished when all the stickers are collected. So by missing just one sticker the whole objective is comprimised.

Looking at the eight core drivers individually we can see unanimity and high scores in "Ownership & Possession" and "Development & Accomplishment", which are good leads for learning. On the contrary, it shows low scores in "Empowerment of Creativity & Feedback" and in "Social Influence & Relatedness". Particularly in this last score there was some disagreement on the experts panel, showing that, although not explored in this approach, there is a good potencial.

Looking at Fig. 4 we can observe the resulting diagram of the Octalsys evaluation of the concept of the digital sticker album collection. The diagram has the eight core drives represented in the eight vertexes of a regular octagon. But the order is not random and from the symmetry of the diagram we can observe that the drives on the left side of the octagon are related to the "left side of the brain", associated to logic, calculations,

Fig. 4. Octalsys diagram [9] of the Sticker Album Collection with AR

and ownership, while the ones on the "right side of the brain" are associated to creativity, self-expression, and social aspects.

The resulting diagram of this evaluation shows an ample gamification (large blue area) and also that it is quite balanced, with just a slight shift to the "left side". This means that this concept has a lot of potential to engage the user, and the shift towards the "left-side of the brain" means that this approach is more appealing to the logical reasoning than to motivate the creative skills of the user or social engagement. This result can be interpreted as suggesting the use of this approach for informal learning in STEM rather than in Arts.

6 Conclusions and Future Work

In this paper we propose the concept of the sticker album collection integrated with AR to improve the experience of informal learning. The museum heritage is the anchor point that provides the epic meaning of the experience, and informal learning is fostered on the challenges associated to the locked stickers, while progression is achieved by collecting the missing stickers. The AR layer is the key element that provides the connection between the museum's heritage and the gamified learning experience. Preliminary evaluation of the user experience achieved a good score, showing the potential of this approach to engage the visitors. We also validated in more detail the potential of this approach to gamify experiences in museums using the Octalsys framework. The results obtained with four experts gives a clear view on the balance and amplitude of this approach.

Future work will extend the approach to improve social interaction and unpredictability, as well as to develop pilot studies in informal learning activities on specific STEM areas like programming, for example.

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Immersive Indiana: Constructing an Augmented Reality in Columbus

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Abstract. The Columbus Indiana Augmented Reality Project is a student-driven initiative to research, interpret, and reproduce the historic urban architecture and landscape of Columbus, Indiana. Focusing initially on the 7 Landmark Buildings housed in the city, the project uses primary source information (original archival drawings photographs, letters, and audio material) to create an enhanced digital model, which patrons can use through an application and web platform to navigate the city either on-site or remotely. Employing the Ball State University approach to entrepreneurial learning, as students learn techniques for creating the environment, they then teach their peers and the public about the information, thus introducing and then reinforcing learning objectives and skillsets. The project provides real world experience in cutting-edge heritage preservation issues and methods, giving students an immersive experience, working with professionals in the field, and creating an immersive digital model to help the public engage with important modernist architecture.

Keywords: Augmented reality · Digital heritage · Modernism · Architectural history · Embedded archiving

1 Introduction

In the historical context of heritage interpretation, the historic city has been treated in multiple capacities: as a series of artifacts, which remain individually isolated; as an historic environment, which offers historical hegemony as a collection; and particularly as a palimpsest of historical layers, which meld and intermingle, creating a complicated web of associated time periods and values. In each case, the interpretation of the history is driven by context—the purposeful reconnection of elements to assist in user understanding. As interpretation methods have evolved over the course of the 20th century, site planners have shifted focus from signage and physical reconstruction to less-invasive technologies, providing information without in-place construction. To assist in this technological shift, the development of digital reconstructions and augmented reality applications have recently been applied to heritage sites, suggesting the applicability of user-based immersion and interpretation.

Columbus, Indiana is no exception to the historical city typology, features several periods of major development with resulting architectural artifacts. Yet, understood primarily as the catalyst for mid-20th century international modernism in the American

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Midwest, the city is currently situated at an uncertain point in its continuing history. Developed to be a facilitator of innovation, the city has continued to grow under the influence of experimental design and the conceptualization of inspiring space. While this promotes the narrative of Columbus as a vanguard of design in the Midwest, the original Modernist structures have seen little continuing investment and interpretation as history has marched on without them.

Modernism in the Midwest was developed as a student-led entrepreneurial learning initiative within the Ball State University Department of Architecture, which seeks to create an augmented reality application and web platform for Columbus, Indiana. Seeking to educate students on the practice of heritage interpretation, the project uses application and platform as a way to teach immersive through immersion. When completed, the project is intended to work alongside community partner Columbus Indiana Architectural Archives, to provide an enriched heritage environment for Columbus' local and international tourists. This paper discusses the methodology behind the in-process Columbus Indiana augmented reality project and its impact on teaching emerging technologies in cultural heritage using digital design programs.

2 Columbus as an Historic City

Housing 22 buildings on the US National Register of Historic Places, Columbus Indiana (Fig. 1) has a significant record of historic architecture, but is most known for its seven "Landmark" buildings by European and American modernist masters, including Eliel

Fig. 1. Columbus Indiana entrance by way of Stewart Bridge. Bartholomew Country Courthouse historic building and Saarinen's First Christian Church peek out in the skyline. The image represents three significant periods of development in the urban space. Photo by tpsdave.

and Eero Saarinen, Harry Weese, and John Carl Warnecke among others. Unlike many historical cities, the legacy of Columbus lies not within its hegemony, however, but in the continuing emphasis on driving design forward throughout its relatively short history.

Beginning with the modern settlement of the area in the early 19th century, the town was dependent on new technologies–primarily the railroad early on. Much of the Victorian period domestic architecture survives, as does the Crump Theater, the oldest in Indiana. While this is not uncommon for American Midwestern cities to retain a Victorian architectural identity, Columbus conversely has seen substantial architectural investment since the turn of the 20th century, promoted in the mid-20th century by the Chief Executive Officer and chairman of the Cummins Engine Company and plant, J. Irwin Miller. As a Rust Belt manufacturer and distributer headquartered in Columbus, Cummins, and particularly Miller, were intent on enhancing the local environment to recruit workers for the company, and subsequently invested in architectural innovation and academics. The resulting Cummins Foundation developed its own Architectural Program, which financed up-and-coming signature architects to build new schools focused around pioneering curricula with the expectation that this would drive recruitment. The Mabel McDowell Elementary School (and later Adult Education Center) by John Carl Warnecke was one of the now-Landmark projects to come from this program. The foundation continues to invest in cutting-edge architects, but has expanded the program to include the design and implementation of other public facilities.

Fig. 2. First Christian Church, Columbus, Indiana. Photo by author, 2017.

While the Cummins Foundation provided one avenue of modernization in Columbus, Irwin Miller also drove separate campaigns to bring architectural modernists to the area. Together with several other prominent Columbus families, Miller sponsored the design of a new building and site for the Tabernacle Church of Christ (now First Christian Church) by Eliel Saarinen (Fig. 2), a popular Finnish architect who came to the United States in the 1920s to design and teach as an extension of his well-known design work in Scandinavia. His son, Eero Saarinen, who was also involved in the First Christian project, continued the Modernist legacy in Columbus through the design of the Irwin Union Bank and Trust (now used as a training and conference center by Cummins), J. Irwin and Xenia Miller's home,–a reference to Ludwig Mies van der Rohe's International Style—and eventually North Christian Church, all three of which have been designated National Historic Landmarks. Harry Weese's First Baptist Church followed in the now-established Columbus tradition of redefining ecclesiastical architecture, but under a stricter budget, still resulting in an inventive interior space, known for its sensitivity to natural light and materiality.

These buildings help create a Modernist context for Columbus, but also have served as catalysts in its continued economic development. As they were all built to reference other, historic areas of Columbus, so have the buildings that have been built since. Following the mid-20th century Modernist movement, signature architects and landscape architects continued to build in Columbus, particularly with a reference to its historic past. The Cleo Rogers Memorial Library by I.M. Pei & Partners was situated to axially reference North Christian Church, drawing in the concrete sidewalk of the church to

Fig. 3. Image taken from Cleo Rogers Memorial Library, showing the integration of brick and concrete plaza, tying the urban space together. Large Arch by Henry Moore in foreground. Photo by author, 2017.

recreate a circular plaza outside (Fig. 3). This also facilitated the landscape context for Large Arch, a bronze sculpture by Henry Moore, which frames the church and bell tower from particular pedestrian circulation paths. As an urban space, Columbus is a gestural architectural timeline, but without the hegemony of the traditional historical city. Although it is inherently historic, it does not serve to exhibit only the dominating Modernist buildings, as they are tied into the previous and following architectures of the urban space. In this sense, Columbus is unique as a historical city, but defining itself as a continuing narrative and history, not dependent on a singular epoch of significance, but as an incubator of continuing architectural innovation.

3 Augmented Reality and Modern Heritage

At its earliest stages, interpreting heritage sites for the public began with full physical reconstruction. Projects such as Sir Arthur Evans' redesign of Knossos, Crete and the construction of the Manitou Cliff Dwelling (Manitou Springs, Colorado) are archetypical examples from the early 20th century—dependent on costly or invasive reconstruction and dependent on in-person tourism. This methodology evolved over the course of the 20th century to exhibit partial anastylosis projects alongside informational signage featuring two-dimensional reconstruction drawings. These were much more easily changed with new information and could exhibit multiple theories or phases simultaneously, but were typically directed at adults, and not particularly engaging. By the 1990s, interpretations such as the Ename 974 project in Belgium have consistently introduced the concept of on-site or distance interpretation, in forms that vary from web platform navigation to fully on-site augmented reality using a virtual reality (VR) headset. As a groundbreaking platform in these emerging technologies, the Ename 974 project experienced the same interpretive issues of other world archaeological sites—the creation of an understandable narrative for a site with complicated and poorly-preserved heritage—but has acted as an incubator to consistently develop new technologies to meet these demands [1]. Beginning with the Ename Timescope 1 project, which used a kiosk and computer to digitally reconstruct a monastery over the existing remains, through a second Timescope iteration and a digital Timeline as part of the museum, the museum has innovated as new technologies have become available. Similarly to Ename, other historical sites and companies met the same challenges with technology, resulting in virtual and augmented reality experiences that range from an augmented reality recreation of the last days in Pompeii [2] to the 'Assassin's Creed' video game series, which promotes a simulated historical environment [3].

The focus of many of these heritage adaptations is history beyond living memory, where the projects seeks to provide context through an immersive experience, allowing visitors to imagine the site at the height of its importance or through the entirety of its historical narrative. While these examples provide integral precedents in producing an augmented reality space in a historical city, the focus of the Columbus Indiana digital heritage city space differs from that of its predecessors. As a city that exemplifies the rare mid- to late-20th century Modernist urban space, the project has the opportunity to educate and engage the public in an emerging heritage, thereby beginning the interpretation while the buildings and design documents are still extant, and while the cultural history of the city remains in living memory.

4 Technical Process and Methodology

The Columbus, Indiana on-site augmented reality application and navigable platform presents the opportunity to immerse the public in the available Modernist architectural space, and present the plethora of primary source information as part of the interpretation. These types of opportunities are uncommon, and not yet realized for rare Modernist cities, many of which do not have the incubator attitude of Columbus. As a result of the prospect of using the project as a learning opportunity for design and historic preservation students, the project partnered with an upper level undergraduate and graduate student seminar, with the intention of immersing students in the process of reconstructing and interpreting the architectural space, informed by community partners and digital heritage experts. The course relies on a system of in-depth research presentations and computer skills labs to walk students through the process of researching and writing about the architecture, and then reconstructing it using primary sources and in-person photography and analysis. For the creation of the app, the Department of Architecture partnered with the Ball State Institute for Digital Intermedia Arts (IDIA) Lab, experts in digital heritage interpretation, who previously developed and tested multiple digital heritage spaces, including a unique iOS app to act as a virtual companion for Mounds State Park, Indiana [4]. As well as building the application for the project, the IDIA Lab staff agreed to act as specialty instructors for a number of workshops, teaching students photogrammetry and digital reconstruction through CAD.

The objectives for the course mirror those of the project, but present the course as a teaching opportunity to develop students' interest in heritage as a potential future career. Along with learning the software programs and photogrammetric method, the intention is for students to come away from the course with a heightened understanding of methods of historic preservation, and advanced archival literacy and research skills. The course allows the students to drive the physical product through group collaboration, much like a company start-up, with the instructors introducing methods of research and historical background into the conversation. This two-tiered approach provides students with the context in which to make important decisions about the augmented reality space, but without coming to the project blind.

To introduce the project, students began by researching existing digital heritage spaces and geocached applications for Apple and Android devices to assess functions and capabilities that would be integral and affective when applied to Columbus (Fig. 4). Apps included global history-based or crowd-sourced programs such as HistoryPin, UAR, and Field Trip, available through the App Store or Google Play. As the application is the first outcome of the Columbus project, an analysis of existing history or heritage-based apps provided the best background for necessary functions or framework. While the class did not have access to some publicized, cutting-edge applications like The CHESS Project, common concerns with the available apps were the lack of updating done by administrators, and particularly the frequency of failed functions or complete failure of the application or its viability within the operating system.

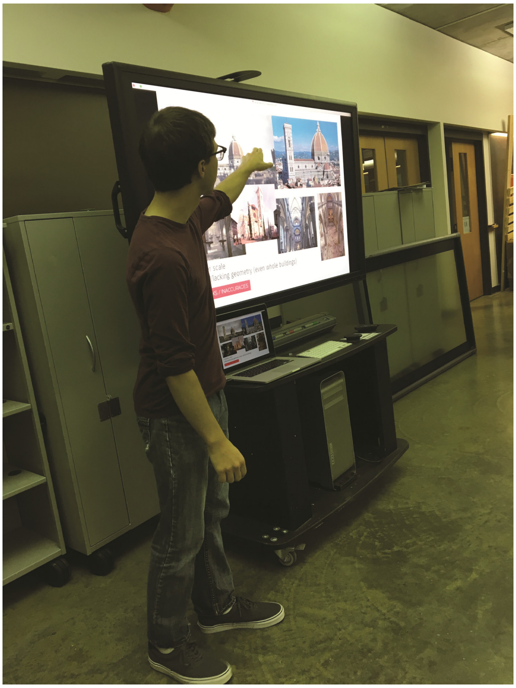

Fig. 4. Zack Lenza, architecture student, analyzing a preexisting navigable digital heritage space for benefits and applications. Photo by author, 2017.

The applications were analyzed alongside digital heritage web spaces, such as the Lascaux Cave navigable space [5] and the Digital Hadrian's Villa Project [6], a joint effort of the Ball State IDIA Lab, and Indiana University Virtual World Heritage Laboratory. These and similar projects were assessed to better understand how to incorporate navigable elements and primary resources into the augmented reality application. While no assessed application offered an ideal framework for the Columbus project, each presented an interesting take on included heritage interpretation, and provided students with an understanding of how digital and heritage spaces are currently conceptualized.

Following the assessment of heritage applications and web platforms, students were asked to research the individual Landmark buildings that they would be digitally reconstructing, creating a database of primary and secondary resources to reference in the application. These included original architectural drawings by the architects of record; audio recordings of architects and primary principals in the history of Columbus, such as Irwin Miller; historical photographs and maps; and historical and contemporary bibliographic sources. While students were asked to seek primary sources through traditional research means, the original architectural plans for the Landmark buildings were provided by the Columbus Indiana Architectural Archives and the Ball State Drawings and Documents Archive, and are discussed later in the paper.

In order to begin modeling the Landmark buildings, and later the entire city, the students were taught two methods of reconstruction as part of the course: photogrammetry using the original structures, and digital modeling through AutoDesk Maya, Revit, and Rhino, using primary archival sources and in-person materials and lighting analysis. The photogrammetry project began with the Large Arch sculpture by well-known Mondernist sculptor Henry Moore in the library plaza. As a whole and accessible object, it provided a relatively simple photogrammetric analysis for students, who had public access to photograph the sculpture. To teach photogrammetric method, Leigh House, a graduate of Ball State University volunteered as an on-site instructor (Fig. 5), relating techniques and applications of photographing a whole object for photogrammetric reconstruction. This was paired with a tutorial by Trevor Danehy (Ball State IDIA Lab), during which students were taught how to use AutoDesk RECAP using the photos taken onsite (Fig. 6). Students were then asked to use photogrammetric method and principles to reconstruct a sculpture on Ball State's campus.

Fig. 5. Leigh House, heritage professional and architectural designer, explaining the principles of photogrammetry to students on-site. Photo by author, 2017.

The photogrammetric skillset was applied in tandem with a workshop on AutoDesk Maya, in which students, most of whom came to the course with some building information modeling (BIM) background, were taught basic procedures for modeling buildings based on site visits and original documents. The Maya project utilized historic archival documents for the Japanese Teahouse, a small building on the Ball State University campus that integrates several material palettes and was small and simple enough in form to provide a practice model as a method for learning the Maya commands and tools. The process of building the Maya model of the Teahouse purposefully

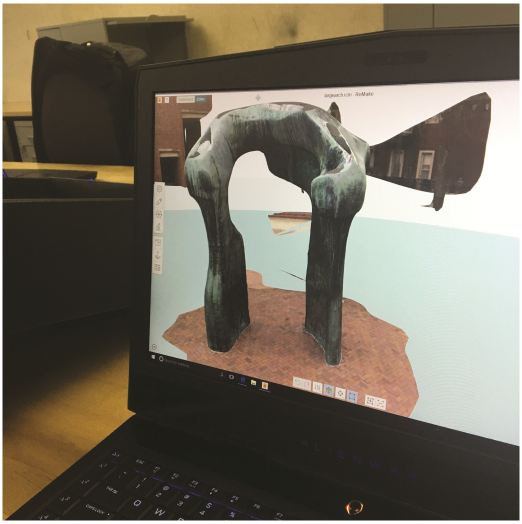

Fig. 6. A completed photogrammetric model of Large Arch by architecture student Kurt Green, based on photographs taken on-site. Photo by author, 2017.

mirrored the process of building the Landmark models, easing the students into the technology and procedures for replicating light and materiality on a building that is easily accessible on a daily basis.

The workshops and on-site experiences exemplify the approach to the immersive project using the principles of "introduce" and "reinforce." Students were introduced to skillsets as part of the classroom instruction and then asked to apply these principles on their own (reinforce). To facilitate a dialogue about the processes, the student-produced projects were then discussed in the seminar to reveal common concerns or impediments to the techniques, further emphasizing methods and reinforcing principles. Students were then asked to apply both techniques together to the digital construction of the Columbus Indiana Landmark buildings and their urban context, focusing on experience of the visitor, material, light, and providing primary resources and history through augmented technologies.

The context for the Landmark buildings was initially wire-framed, with the intention of continuing to fill in the additional historic context as time and funding permits, while still highlighting the Landmark modernist buildings. In addition to the time and funding constraints for this step, the project is complicated by multiple phasing of building in the city, which adds layers to the eventual navigable space, requiring the selection of a particular period in which to begin modeling the city. To accomplish this, the city will first be reconstructed as it exists *in situ*, solely as an augmented reality app to provide access to primary sources of information and explanatory text about the city, buildings, and important architects and patrons. Once established and tested, the project will then explore layers of the digital city that produce an architectural context for particular time periods. This is being developed in part as a reaction to the Exhibit Columbus Project slated for 2017, which will provide an important moment in the development of

Columbus, but will not result in a permanent exhibition. The application can therefore be used to document and interpret this and similar temporary architectural exhibits, in the context in which they were created, producing another primary resource for future generations.

5 Embedded Archiving and Immersive Education

As the process of interpreting heritage objects for the public has evolved, so has the use of integral primary and secondary resources in design and reconstruction. Coinciding with the rise in digital humanities, archival documents are now more available and accessible in digital form, creating an information web in which original or primary sources are readily available for distribution. For the creation of the Columbus augmented reality app, the Department of Architecture partnered with the Ball State University Drawings and Documents Archive [7] and Columbus Indiana Architectural Archives (CIAA) [8] as community partners to produce high quality digital scans of the seven Landmark buildings. Given the longstanding collaboration history between both archives, the process of partnership allowed the class to seamlessly integrate available primary sources into their research. The students were given physical and digital access to all of the Landmark buildings original drawings (Fig. 7) for observation, and then the

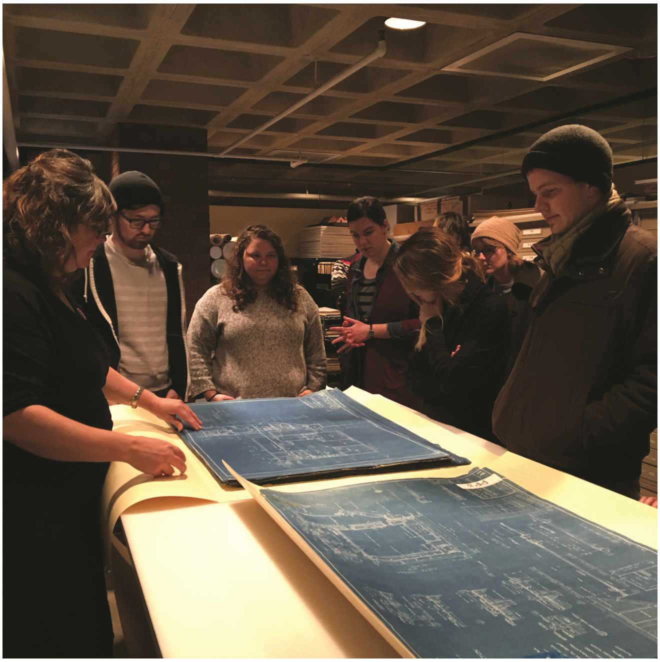

Fig. 7. Tricia Gilson, archivist with the Columbus Indiana Architectural Archives, showing students the primary source archival drawings for First Baptist Church by Harry Weese. Photo by author, 2017.

digital scans were used in the research and digital construction phases of their design. The course is taught by Kristin Barry, an architectural design and history professor, with Carol Street, an embedded archivist from the Drawings and Documents Archive. By utilizing both instructor experiences and skillsets, the course serves to reinforce not only the historical context of Columbus and its continuing historical narrative, but also the importance of archival literacy in the study of architectural city.

Students visited the CIAA on each of the two class field trips to Columbus, and visited the Drawings and Documents Archive once. In addition, some students made repeat visits to CIAA and consulted the archivist at the Drawings and Documents Archive during weekly class time. Instead of typical one-shot instruction where students receive information about the archives and are left to conduct primary source research on their own, their experience was scaffolded to create communication between archivist and researcher, and to build student confidence in conducting archival research.

Immersing students in important primary source material and the methods for acquiring it facilitates research, and provides integral context to the study and digital reconstruction of the buildings. As the diversity of the Columbus architecture is celebrated as an eclectic urban space, the original architectural drawings provide cohesion of information alongside additional evidence of changing design. As students move between vellum, linen, trace paper, half-tone sheets, and blueprints, the educational component of the study is deepened to include the understanding of architectural design and documentation processes throughout history, as opposed simply to how the designs were executed. This information is then passed on to the public audience through the augmented reality application, where patrons will be able to see scans of these different types of drawings.

The Columbus augmented reality project serves the to be an immersive environment for two audiences: the education of students through entrepreneurial/immersive learning, and the interpretation and education of tourism audiences through an immersive environment. The pedagogy and methodology of the education component promotes learning through teaching others. As students are asked to analyze, interpret, and present primary resource information, they are inherently connected to the audience of this information; as they teach each other, they learn how to teach the community. Through the process, students become active members and stakeholders in the Columbus community as part of immersive, service-learning education, which promotes the continued preservation of the historical architectural space as a result of increased community value in it, and perpetuates the idea that Columbus is a city of innovation, suggesting that the next innovation is through augmented reality. In contrast to applying this service and technique after the architecture has fallen into disrepair, as with archaeological sites and demolished urban spaces seeking interpretation, the architecture and city evolves with the project and students, who are then about to become leaders in augmented reality immersion for historic spaces.

6 Dissemination and Application

The purpose of the digital models and eventual fully augmented reality space is to engage a broader audience in the historic past of Columbus and enhance the understanding of heritage therein. In order to facilitate the process, the project will be partnering with the Columbus Visitor's Center to publicize the application, which will be publically available on the Apple App Store and Google Play. As an informational product, it will be free of charge as a public service. The objective of the model, and by extension, application, is to provide an enhanced heritage experience and perspective for an important historic urban space, suggesting that the detail and additional materials will provide greater context for the construction, interpretation, and continued use of the historic buildings and cityscape. Following the completion of the application, the digital model and augmented space will be used as part of a web platform remote navigable space that will allow for audiences to engage with the architecture and urban setting without the need for traveling to the site. Bringing in new, broader audiences through the web platform will drive the dissemination of the information to a larger audience, who will in turn help to enhance the content and usability of the digital models through crowdsourcing feedback. The intention of a release for the public is to encourage a cyclical process, which promotes user engagement while the model continues to develop.

7 Future of the Project

The project is designed as a catalyst to identify processes that students may use in researching, interpreting, and reconstructing historic urban spaces based on primary source archival evidence. These processes are then implemented to encourage a public visualization of heritage in an augmented reality setting, educating not only on the remaining urban space, but also on the processes used to build the digital space and the paper trail of information and history that provides the context for it. Once the Columbus Indiana Augmented Reality Space is established, tested, and working, the processes used in the project can then be applied to other Indiana architectural historic cities, such as Indianapolis and Gary. While the Columbus project remains ongoing, the projected timetable of completion is the end of 2017, leaving time for app development and product testing before a full release in 2018.

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Technology Acceptance of Augmented Reality and Wearable Technologies

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Abstract. Augmented Reality and Wearables are the recent media and computing technologies, similar, but different from established technologies, even mobile computing and virtual reality. Numerous proposals for measuring technology acceptance exist, but have not been applied, nor fine-tuned to such new technology so far. Within this contribution, we enhance these existing instruments with the special needs required for measuring technology acceptance of Augmented Reality and Wearable Technologies and we validate the new instrument with participants from three pilot areas in industry, namely aviation, medicine, and space. Findings of such baseline indicate that respondents in these pilot areas generally enjoy and look forward to using these technologies, for being intuitive and easy to learn to use. The respondents currently do not receive much support, but like working with them without feeling addicted. The technologies are still seen as forerunner tools, with some fear of problems of integration with existing systems or vendor-lock. Privacy and security aspects surprisingly seem not to matter, possibly overshadowed by expected productivity increase, increase in precision, and better feedback on task completion. More participants have experience with AR than not, but only few on a regular basis.

Keywords: Augmented reality · Wearable Technologies · Technology acceptance

1 Introduction

Technological innovations such as brain stimulation, simulations, sense making, augmented reality and virtual reality are making possible major changes in the following: the nature, depth and scope of human experiences; our capacity to re-experience and constructively reflect upon our own experiences; our ability to share actual experiences;

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our capacity to synthesize partly-false memories that combine fragments of our direct experiences and synthesized third-party experiences. One indicator of this trend is recent work about people who lose or gain a core sense (see, for example, 'Notes on Blindness', http://www.notesonblindness.co.uk).

Sensory-focused work like that can be useful in assessing the social context, development and dynamics of changes in science and technology and thus being better able to empathise in some way with the initiators, developers, and prospective users of a given scientific or technological innovation, for example by providing ways to share and to communicate the experiences and feelings of people who are in need of a particular innovatory technology. A consequence of that empathetic approach is being able to extend how we identify and measure the degree of 'fit' between a technology and its users' needs and wants.

Numerous proposals for metrics for technology acceptance and behavioural intention to use were made in the past to help assess success of then-new information and communication technology before committing to and investing into its introduction [1–7]. The metrics and associated Technology Acceptance Models (TAMs) developed at a particular time reflect the insights, experiences and concerns of that time's expert communities, and the development and dynamics of the associated science, technology, society and culture. Technology innovations such as Virtual Reality (VR) and Augmented Reality (AR), can help to benchmark and predict success (and failure), but as acceptance is not independent of usage culture (think 'home office'), fashion trends (think 'themes'), and paradigm shifts (think 'mobile computing'), revisions had to be proposed over time.

The current third generation of AR does not only provide adaptation to location/viewpoint and not only links content with computer vision to physical objects [8], but provides immersive experience where human vision (and other senses) are manipulated in a way that very believable illusions seem to alter reality.

Wearable Technologies (WT), such as smart glasses, watches, or armbands, use embedded systems to fit accessories and garments with computing facilities. They play an important role as delivery devices for such immersive experience.

The combination of AR and WT is currently subjecting computing as we know it to further transformation – quite likely more than just a little disruption in usage culture, with nearly 1 M AR Smart Glasses sold in 2015 and 10 M expected for 2016 and mass markets of > 1B predicted for 2019–2023 [9, 10].

AR/WT solutions are not conventional software systems (like desktop software, web, or mobile application), but have different, non-standardised form factors as well as different user interfaces.

Within this contribution, we first investigate the suitability of the generic models acceptance models for benchmarking acceptance of AR/WT solutions, tending to the particularities of such emerging technologies.

Moreover, we investigate whether from the application context – not for home use for leisure or life, but in a workplace context in aviation, medicine, and space contexts – specific constraints on AR/WT acceptance can be identified. The three application areas are explored within the research project WEKIT. Each application area is represented in the project by an industrial partner company.

We do so, because both, AR and WT as well as their application in these work contexts are emerging fields and remain widely unstudied: Existing studies look either into hardware [11], regardless of the application, or they are validation studies of effectiveness and efficiency of use [12], not acceptance.

The rest of this article is organized as follows. First, we describe the methodology for constructing scales, a two-stage approach of using experts to gather feedback on the scale items to select those that are on scope and that can be included in a questionnaire to be answered by participants to the three pilot areas of the WEKIT project (trials in aviation, medicine, and space). We report the results from the scale construction first to then report the results from the participants of the pilots that validate the applicability of the new scales. We also discuss what this 'baseline' benchmark means with respect to the introduction of AR and WT in an industrial context (and potential required interventions). An outlook on open problems and future plans for iterative measurements using the resulting model concludes the article.

2 Methodology

In order to build a model of what drives acceptance and use of technology in the context of maintenance and repair operations in aviation and space as well as training on operating procedures (of imaging equipment in the health sector), we collected items from existing technology acceptance models.

This included items from UTAUT, TAM-3, UTAUT-2, and TPB (see Sect. 3), as well as additional items from the generic literature on user experience (Ux). We enriched these items in focus groups with experts in technology as well as ergonomics to include also items specific to industry needs.

As Sect. 4 will report, this resulted in a pool of 91 statements, many of which belonging to groups of items, investigating the same construct, but asking for different aspects or using different phrases to express the same statement. The statements are formulated in a way so that they can be rated with a 7-point Likert scale, ranging from strongly disagree to strongly agree, including a neutral 'neither agree or disagree' in the middle. This pool of items to draw from would be too large to enquire with participants in the target groups directly, where a set of 15–20 items would be deemed appropriate.

In order to test reliability and measure internal validity of the constructs and items in the model, we asked 15 subject matter experts from a project consortium partnership to provide ratings for all items of the pool. With that, we measured the correlation (Pearson's r) across the responses with the sum scores of all items to assess that each item is actually measuring what we are interested in, testing for discriminatory power of the item [13]. The general assumption of this is that in total the chance for error is less likely than with a single item [13]. If responses to an item do not correlate with the sum scores of all items' responses, then it is very likely to not measure aspects of acceptance and use of technology, but rather something else. This analysis step allowed sorting out those items not correlating high with the sum score.

Subsequently, we calculated the item-to-item correlations to identify further those items loading onto the same construct. If the correlation between two or more items is high, a single item (or a subset of the correlating items) can be selected.

Then, Cronbach's α was measured to estimate interrater reliability, comparing the reliability for the full pool as well as the final subset selection.

Finally, the resulting questionnaire was validated with responses from 33 participants from the three industrial partner companies Lufttransport (Norway), EBIT (Italy), and ALTEC (Italy) in the areas of aviation, medicine, and space. A split half reliability test and the predictive quality of the items against measured behavioural intent over this pool of responses from end-user participants assess reliability and internal validity of the model. While the findings of technology acceptance of AR and WT of these 33 participants measured with this instrument may not be representative for the whole target group in the three industries, it still can serve as a reference for future investigations. Moreover, the sample size is large enough to assess reliability and internal validity and the results found indicate that this instrument can successfully be used to predict technology acceptance of AR and WT.

3 Existing Models of Acceptance

Venkatesh et al. compare eight models and integrate their constructs into the Unified Theory of Acceptance and Use of Technology (UTAUT), consisting of 31 items in four core determinants of intention and usage, namely Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC), see Fig. 1 [6]. Moreover, they identified four additional moderating variables, i.e., gender, age, experience, and voluntariness of use.

UTAUT thereby integrated constructs from the theory of reasoned action, the technology acceptance model, the motivational model, the theory of planned behaviour, a model of PC utilisation, social cognitive theory, and a combi-model. The model was validated and accounted for 70% of the variance in usage intention, outperforming the models it built on. Even though the results are very promising, the authors demand that "future research should be targeted at more fully developing and validating appropriate scales for each of the constructs" [6], while at the same time asking for "alternative measures of intention and behavior". They particularly stress the importance of further investigating the relation of individual and organisational technology acceptance (p. 470) and propose to further align success factors relevant in these two social spheres.

One of the very established precursor models, is the Theory of Planned Behaviour (TPB) [14]. Key constructs in TPB are Attitude Towards Use (ATU), Subjective Norm (SN), and Perceived Behavioural Control (PBC). The model is still being applied in recent years. For example, Teo and Lee use it to explain about 40% of the variance in intention to use technology among student teachers [2], finding, however, PBC not to have any significant path from PBC to intention (and a rather small effect for Subjective Norm).

Venkatesh et al. propose an extension to UTAUT, adding Hedonic Motivation (HM), Price Value (PV), and Habit (HT) as constructs [1]. Price Value is especially important for consumer contexts, where costs define expectation of experience. Habit is automated, learned behaviour. Hedonic Motivation, also known as the "fun or pleasure derived from using a technology" [1], picks up on research into user experience [4].

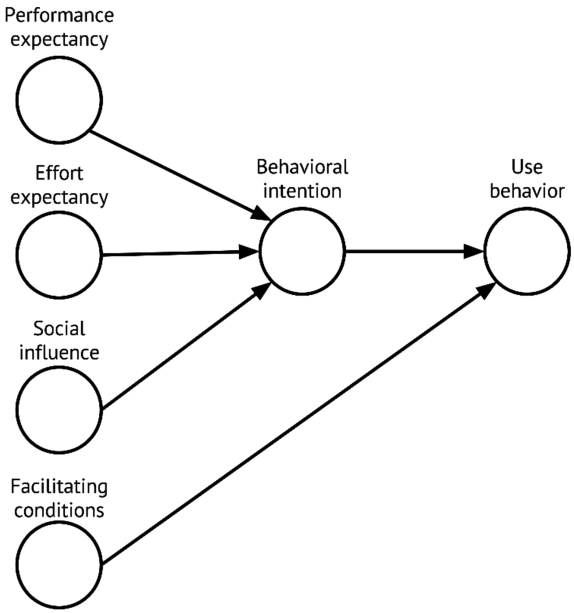

Fig. 1. Direct and indirect determinants of user acceptance and usage behaviour, redrawn from [6]

Beyond the items proposed, various uX authors recommend additional constructs for assessing the experiential quality, in particular usability, utility, affective quality (AF), or aesthetic experience [4, 7, 15].

Finally, Venkatesh and Bala propose the third version of the Technology Acceptance Model (TAM-3), comprising Subjective Norm, Image (IMG), Job Relevance, Output Quality, Result Demonstrability, Computer Self-Efficacy (CSE), Perceptions of External Control, and Computer Anxiety (CANX) to moderate Perceived Usefulness and Perceived Ease of Use that then drive Behavioural Intention (BI) and actual Use Behaviour [5].

4 Item Pool Generation and Reduction

An expert panel was used to select items from the existing models introduced in Sect. 3 that were considered likely to be relevant for studying technology acceptance of AR and WT, casting the net widely. Moreover, the expert panel included additional items, resulting in a pool of 91 Likert statements plus six Use Behaviour (USE) questions, varying the delivery devices.

The pool of 91 statements (and six different types of usage frequencies) were rated by the board of 15 subject matter experts using a 7-point Likert agreement scale each. The data table lists participant responses (rows) against items (columns), containing numeric value from 1 (strongly disagree) to 7 (strongly agree). For the first analysis step, sum scores for each row were calculated and each item vector was correlated with the sum score vector using Pearson's product moment coefficient r.

Results show that there are several items that do not correlate (directly or inversely) with the sum score (Fig. 2). There are 12 items in total correlating with the sum scores on a level higher than 0.7, a total of 36 items on a level higher than 0.6, and 45 items with a correlation value higher than 0.5.

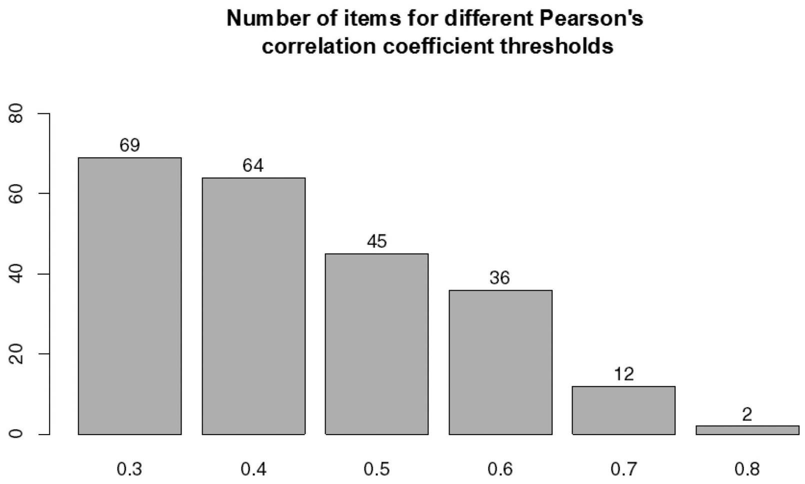

Fig. 2. Number of items for different correlation thresholds.

Since the sum scores are composed of all items, including items that may not directly measure what we intend to investigate, we decided to select a threshold of 0.6 of the absolute correlation as acceptable for identifying whether items are on scope. The sum scores indicate that the other constructs either measure something completely different or are not independent of other influences.

Next, we turned to item-to-item correlations and their groupings. The visual representation in Fig. 3 clearly indicates that there are groups of items that are related, as expected since we adopted several groups of items from the existing technology acceptance models. The figure displays the correlation matrix [16] of the items graphically, indicating the correlation value via the size (area) of the circles and additionally colour shade as well. The order of the items in the plot is determined using a hierarchical cluster analysis (hclust, package: stats) [17], so items close to each other along the diagonal are tend to correlate more highly.

The triangles visible along the diagonal and the rectangles further away from the diagonal of the figure indicate that there are groups of items belonging more closely together. This confirms already visually, that there are indeed groups of questions amongst the 36 items selected that may load on the same aspect. This potentially will allow picking just one of the items in each group (instead of posing all of them).

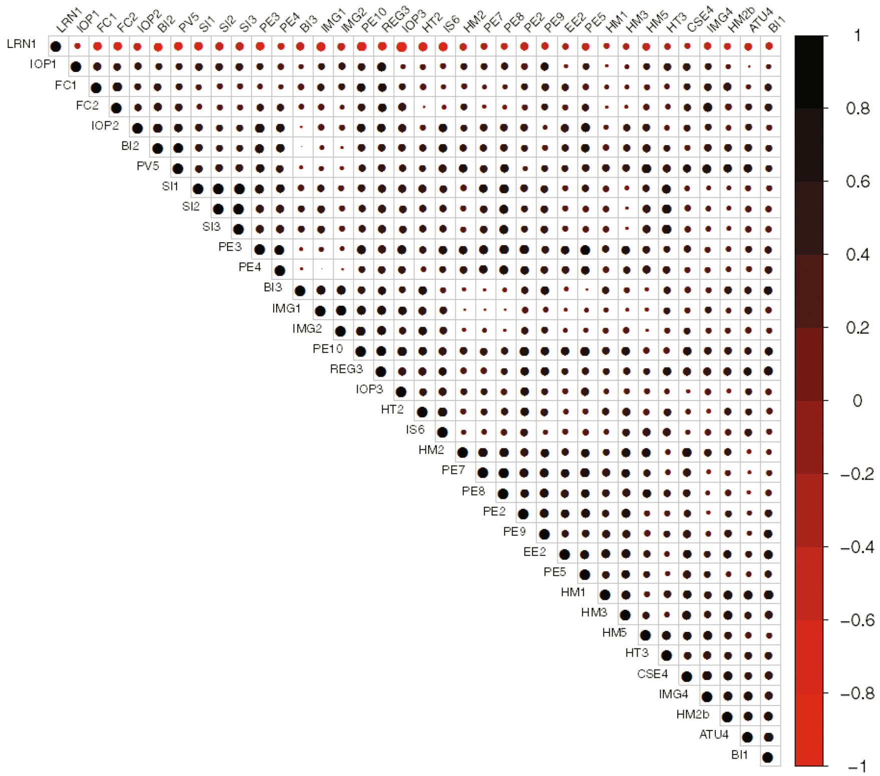

Fig. 3. Item to item correlations (selected 36 items)

5 Selection of Items

Investigating the excluded items, i.e., the ones not in the 36-item selection (with correlations to the sum scores above 0.6), shows the following particularities.

Anxiety (group CANX) does not correlate with the sum scores. This may have to do with the selection of our test participants. This group of items is likely to be more relevant in an everyday use context and it may not be so relevant in a work context. Workers also may prefer management by objectives that are way within their capability. We can't separate whether anxiety would be personal or work related and this is better to explore qualitatively in an interview context, in which we can separate between personal use and work use (and the anxieties connected to it).

Questions about management support (such as DM1) are too early to ask, as in most contexts right now AR/WT are in prototype or exploratory use (if at all) and such question would need real exposure in daily routine.

Questions about integration with legacy systems do not work. This is likely to have to do with competence of people asked, as system integration is not their job, nor within their knowledge. Similarly, the lack of exposure or exploratory use of AR/WT is a problem among this group of questions.

The question about appeal of the workplace to younger people is out of place: respondents may not know this. Questions about content and content experience (in dropped items in IOP) could not be answered. Maybe end-users do not see this separation between content and system as we do.

Table 1. Analysis of itemgroups (selected items shaded in black). Item texts are listed in Table 2 (if selected) and in the references in Sect. 3 (if not selected).

ITEM	COR	ANALYSIS
ATU4	0.63	Better question than alternatives (A1, AF1): future oriented.
BI1	0.71	Expected to group, but inter item correlations (0.4, 0.6, 0.01) is not very strong. Preference for BI2 over BI1/BI3, because it is not dependant on current use of AR/WT.
BI2	0.69	
BI3	0.6	
CSE4	0.71	Covers the other three CSE items.
EE2	0.61	Works best amongst this group of EE items. More technical than the other questions - good in our technology context.
FC1	0.65	FC1 and FC2 work well (they correlate with 0.74, keep FC1 as it is the more broadly formulated one).
FC2	0.62	
HM1	0.63	Expected that we can only ask one of these HM items - they are very similar.
HM2	0.61	
HM2b	0.67	
HM3	0.63	
HM5	0.67	Badly phrased, drop.
HT2	0.7	Two of the four HT items correlate with sum scores. HT2 and HT3 correlate with 0.5, but HT2 is better formulated.
HT3	0.72	
IMG1	0.65	Three of the four IMG items correlate higher with the sum score. Expect two more to drop out with group analysis: IMG1 vs. IMG2: 0.91, so keep IMG1.
IMG2	0.62	
IMG4	0.69	
IOP1	0.66	3/10 IOP items correlate highly with sum scores. Questions on existing integration and on content / content experience cannot be answered. IOP1, 2, 3 do not correlate (0.45, 0.23, 0.57). Drop IOP1, as "interoperability" is a difficult word.
IOP2	0.64	
IOP3	0.68	
IS6	0.69	Only item left in this group.
LRN1	-0.78	Reverse item.
PE2	0.71	Very close, pick PE4 as it is more different from the other PE items.
PE3	0.74	
PE4	0.62	
PE5	0.69	These are novel, AR/WT functionality related questions. The task completion questions can be grouped. Reduce error and increase precision express the same.
PE7	0.6	
PE8	0.65	
PE9	0.73	
PE10	0.87	
PV5	0.74	Out of context: interpretation impossible w/o other PV items.
REG3	0.87	Should have been an inverse item, but isn't, so: drop.
SI1	0.71	Similar, picked one of the three well loading items.
SI2	0.7	
SI3	0.7	

The lack of correlation with sum scores of questions on privacy may be a result of lack of exposure (or infrequent daily use). Questions also do not differentiate by target group of data (and their level of exposure), this would have to be further specified.

The target group cannot answer statements on value for money.

For both the full pool as well as the selected 36 items, the standardized Cronbach's α, as a measure of internal consistency, is similarly high (0.96 for the full pool, 0.97 for the 36 items).

Analysis of the 36 included items and their item groups finds that several items correlate highly within their group and a choice can be made for the phrasing with more clarity or for the aesthetically more pleasing formulation (see Table 1).

6 Final Questionnaire

The final set of statements contained 20 items (Table 2).

Table 2. Final metric scale

CODE	STATEMENT
ATU4	I look forward to those aspects of my job that require me to use AR & WT.
CSE4	I could complete a job, if I had used similar technologies before this one to do the same job.
EE2	My interaction with AR & WT is clear and understandable.
FC1	I have the resources necessary to use AR & WT.
HM2b	I like working with AR & WT.
HT2	I am addicted to using AR & WT.
IMG1	People in my organization who use AR & WT have more prestige than those who do not.
IMG4	I use AR & WT solutions, because I want to be a forerunner in technology exploitation.
IOP1	Interoperability is important for AR & WT.
IOP2	I am worried about vendor lock in with AR & WT.
IOP3	Integration costs of AR & WT with other software systems in use are high.
IS6	I would find it useful if my friends knew where I am and what I am doing.
LRN1	Learning curve for AR & WT is too high compared with the value they would offer.
PE10	With AR & WT, I immediately know when a task is finished.
PE4	Using AR & WT increases my productivity.
PE8	AR & WT increase precision of tasks.
SI1	People who are important to me think that I should use AR & WT.
BI2	I will always try to use AR & WT in my daily life.
UF1	Please choose your usage frequency of AR/WT

7 Current Level of Technology Acceptance

The final resulting questionnaire now allowed us to administer another survey with participants from the pilot companies, which allows validating whether the metric scale successfully predicts technology acceptance. Even though not necessarily representative of the three industries (qua its small and non-representative sample size), it still provides a first reference for what drives technology acceptance, use, and all the other success factors.

We ran the questionnaire with the aim to draw an equal share of participants for each pilot area WEKIT is looking at (about 10 each). Additional people across the project consortium contributed. Most of our participants are male and aged 25–44, with only a few being younger or older. Respondents come mainly from the space industry and the educational field, with additional participants classifying themselves as from transportation, R&D, manufacturing, or medicine. Participants added maintenance, media, IT consulting, and telecommunication service provider to the list of industries offered. Within these organisations participants are mainly end-users or researchers, with some participants being managers, developers, or trainers.

The findings for these 33 are presented below in Fig. 4. The respondents generally look forward to using AR/WT (ATU4) or are neutral about it and plan to use AR/WT in their daily life (BI2). They are rather neutral about learnability of AR/WT for being similar to existing technologies (CSE4), but agree that their interaction with AR/WT is generally clear and understandable (EE2).

Participants do not necessarily have the resources available (FC1) to use AR/WT (some do, some don't), but the majority likes working with AR/WT (HM2b) without

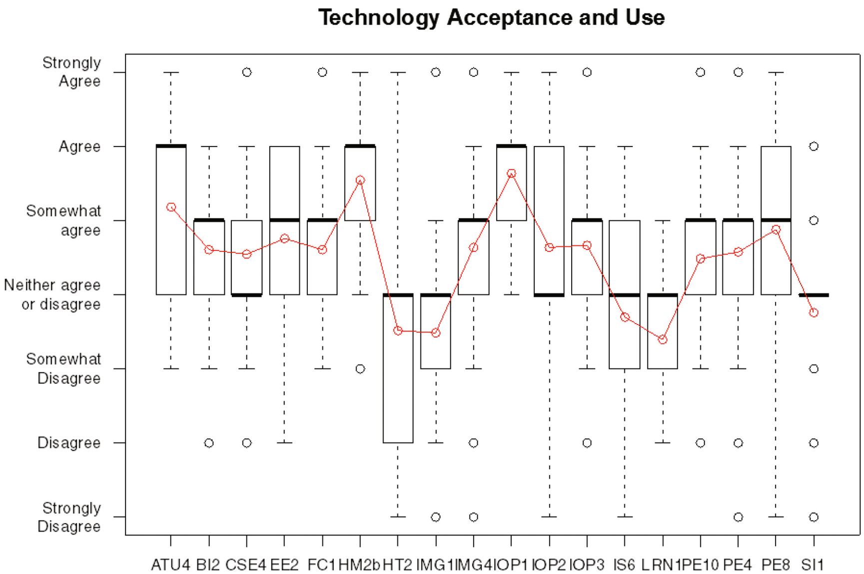

Fig. 4. Variance in the validation sample

feeling addicted to it (HT2). They don't see AR/WT as prestigious tools (IMG1) but rather a tool for forerunners (IMG4). Interoperability is seen as a highly relevant issue (IOP1) and participants are slightly worried about vendor lock-ins (IOP2). They fear high integration costs for AR/WT solutions (IOP3).

Participants are rather neutral about privacy and security aspects, i.e. the use of AR/WT for informing others about current activity or location (IS6). In addition, they are neutral about the learning curve needed to adopt AR/WT (LRN1).

With respect to performance expectancy, participants are slightly inclined to believe in an increase of productivity (PE4), an increase of precision (PE8), and the advantage of feedback on task completion (PE10). Participants are rather neutral about social influence of other people on the use of AR/WT (SI1).

The majority of participants has no experience in the use (UF1) of AR/WT (never: n = 14), some use AR/WT rarely (once/month: n = 7; once/two weeks: n = 6). Only a few people use AR/WT on a regular basis (daily: n = 1; several times a week: n = 5).

We tested the *reliability* of the developed questionnaire with a split half reliability test [13]. This means calculating the correlation between the sum scores of odd-column items versus the sum scores of even-column items, resulting in a Pearson's r value of 0.77. Since 'limiting' the number of items for the halves to half the full set, the underestimation can be corrected with the Spearman and Brown formula: rs = 2*rs1, s2/(1 + rs1, s2). This results in rs of 0.87, which is above the recommended value of 0.80 [13]. The standardised Cronbach's α is 0.86 (same with the raw α).

Testing the *predictive quality* of the sum scores against BI2, the behavioural intention to use shows a correlation effect of 0.6075 (Pearson's r), which is highly significant with a p-value below 0.001. This shows that the developed adapted metric scale can actually be used to predict technology acceptance (measured via the behavioural intent) through the core determinants enquired.

8 Conclusion

Within this contribution, we have extended and applied a metric scale to assess technology acceptance, including key factors determining success. In particular and beyond existing models, we have added constructs and items for interoperability, learnability, and privacy, as these items deserve special attention in this current phase of emergence of an AR/WT market. We have validated the adapted and extended metric scale in two stages, first with experts and then with 33 end-user participants. Results indicate that the adapted and extended metric scale can successfully be used to assess technology acceptance of AR and WT.

In the industries screened, it is clear that specific attention has to be paid to equipping users with the resources needed, in particular with the devices. Device management will be an issue, also for managing update and upgrade procedures. Integration with legacy systems is of big concern, so in the introduction of AR/WT, interfaces have to be created ensuring that any new solution fits seamlessly in into the existing pool of hard- and software.

More than half of the participants in this sample did not have prior exposure to AR and WT. Studying the difference between these users with direct experience to those having none could possibly provide valuable insights about, for example, expectations or potential misconceptions.

It is important to ensure solutions meet expectations with respect to hedonic quality and performance gains. Hopes are high that an increase in productivity, precision, live feedback will be delivered by solutions that are fun to use. If these expectations are not fulfilled, acceptance will suffer. This clearly demands thorough user experience and usability/utility testing. For an overview on the according methodology see [18].

We found a lack of social influence and, at the same time, expectations about AR/WT being used by forerunners. This indicates potential for supporting the introduction with social communities, with key personnel leading by example. We expect that with more widespread use of AR/WT peer pressure will rise.

The lack of concern about privacy is surprising, indicating lack of exposure. To avoid legal consequences to arise ex post, we recommend elaborating individual policies for privacy and data security in joint consultation with providers, management, and employee representatives.

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Community Learning Analytics with Industry 4.0 and Wearable Sensor Data

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Abstract. Learning analytics in formal learning contexts is often restricted to collect and analyze data from students following curricula through a learning management system. In informal learning, however, a deep understanding of learners and entities interacting with each other is needed. The practice of exploring these interactions is known as community learning analytics. Mobile devices, wearables and interconnected *Industry 4.0* production machines equipped with a multitude of sensors collecting vast amounts of data are ideal candidates to capture the goals and activities of informal learning settings. What is missing is a methodological approach to collect, manage, analyze and exploit data coming from such an interconnected network of artifacts. In this paper, we present a concept and prototypical implementation of a framework that is able to gather, transform and visualize data coming from Industry 4.0 and wearable sensors and actuators. Our collaborative Web-based visual analytics platform is highly embeddable and extensible on various levels. Its open source availability fosters research on community learning analytics on a broad level.

Keywords: Community learning analytics · Visual analytics · Industry 4.0 · Internet of Things · Wearables

1 Introduction

Industry 4.0 refers to a paradigm shift currently taking place in industrial production towards the use of a combination of Internet and future-oriented technologies [7]. On the one hand, triggers are social, economic and political changes; on the other hand, a number of technologies like apps, 3D printers and the Internet of Things (IoT) pushes innovation in industry. Beyond the industrial context, the availability of mobile computing devices has also changed our personal lives remarkably over the last years. Smartphones, tablet computers and smart watches have become commodities and are used for various use cases. Both Industry 4.0 appliances and personal smart devices are equipped with a multitude of sensors that produce a lot of data. Wearable computers build the vanguard, with sensors that are tightly integrated with body functions, like heart

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rate sensors and eye trackers. In this context, the term Internet of Things represents the idea that everyday devices become interconnected to form a huge network of artifacts that is closely embedded into social interactions. However, the speed of innovation is currently hampering the adoption of a compatible standard; the challenges lie in the sheer number of devices, protocols, standards and platforms.

For technology enhanced learning researchers, the broad availability of IoT technologies in Industry 4.0 and wearable contexts opens new doors to explore the possibilities and limitations of applying wearables for various workplace learning settings. Research questions include how to leverage body and device sensors and, more generally, contextual information to provide and sustain adequate services to learners. Traditional formal learning analytics often targets the interactions of learners with learning management systems while neglecting the context and environment of learners. In informal learning contexts, goals and activities are not fixed in a curriculum; they may be more short-term [5]. While white-collar knowledge worker communities such as the insurance claims processors described by Wenger [11] leave analyzable traces in the software they are using, the digital footprints of industrial blue-collar machine workers are typically more fragmented and numerous across machines and wearable sensors. We realize that methods known from formal learning analytics are not applicable for the vast amount of heterogeneous data sources available from sensors. With new types of sensors and subsequently new kinds of data available on a regular basis, we need a cross-cutting methodological and sustainable approach for targeting all kinds of possible scenarios. In this paper we therefore present the Social Web-based Environment for Visual Analytics (SWEVA), a conceptual approach and prototypical implementation of services able to retrieve and visualize data from heterogeneous data sources such as machine data or wearable sensors. It is extensible on various levels to handle a wide variety of current and future protocols and standards in the IoT realm. Within the framework, advanced social network analysis tools can be accessed, such as overlapping community detection and expert identification to significantly drive forward community evolution. Due to its Web-based nature, learners are able to open the application in any browser to take part in their communities' analytical undertakings. Ultimately, our platform for analyzing learning services for Industry 4.0 and wearable sensors may help to significantly increase the relevance and applicability of learning services in this domain.

The paper is organized as follows. First, we give the motivation for our research in Sect. 2 and highlight related work in Sect. 3. We then present the concept in Sect. 4. Section 5 describes the prototypical implementation that is evaluated in Sect. 6. The paper is concluded in Sect. 7 with an outlook on future work.

2 Motivation

Learning with Industry 4.0 appliances and wearables is different from traditional classroom based learning in various ways. Mainly, it is not tied to a particular location and time. It may leverage the actual context of the user, spanning from detecting the actual physical location and even tool the user is employing, up to measuring body parameters like the current heart rate. Industry 4.0 appliances and wearables offer an enormous amount of data and are therefore usable by a huge variety of learning services. Examples of such data are inventory trackers and alerts on incorrect operation. In comparison, body-worn wearable sensors may capture the heart rate, arm movements or track the eye gaze. However, the more data is available, the more complex it is to analyze and reason upon it. What is needed is a uniform approach for (real-time) learning analytics. One of the challenges in reasoning and researching on this data lies in the high degree of context sensitivity and interdependency of data coming from machine and human data sources. For example, a higher stress level identified through a significantly increased heart rate may be the cause or effect of machine malfunction. On the technical level, currently different implementations of sensor networks often struggle with a myriad of standards for accessing the data and related inter-compatibility problems. For instance, standards and protocols for IoT include MQTT, XMPP, CoAP, Bluetooth, and Zigbee, amongst many others. However, we are observing a consolidation towards open Web protocols to make the data available on the human-facing side. Specifically, this means that while the actual machine-to-machine communication happens over proprietary protocols, most commercial off-the-shelf solutions come with a gateway that translates device-specific communication channels to the open HTTP Web standard, so that it can be accessed by apps running on smartphones. That is the main point of contact of our framework for getting device data into our analytics pipeline to perform visual analytics tasks.

Visual analytics (VA) is the "science of analytical reasoning facilitated by interactive human-machine interfaces" [4]. It is a multidisciplinary approach covering data science, data management, data analysis, human computer interaction and decision support amongst many others. The VA process is displayed in Fig. 1. It starts with collecting and optionally transforming data. The goal is to gain knowledge through building models and visualize them. Thereby, the visual part remains highly adaptable based on user interaction. Knowledge can be used to adapt and improve the monitored artifacts, or to calibrate the selection of data sources.

In informal learning contexts, there is a lack of institutional rules which induces the negotation of roles in communities based on reputation and expertise [5]. Community learning analytics is therefore concerned with identifying expertise within a community and in comparison with other communities. A learning system able to discover the experts within a community is empowered to transfer knowledge from experienced users to new staff. For instance, wearable sensors may capture the expert fulfilling a certain task by operating a machine. Later, the recordings may be replayed to less experienced users through augmented reality devices. The access to expert identification [12] and expert recommender algorithms [2], along with the visualizations of their outputs, is therefore a crucial requirement for our system. (Overlapping) community detec-

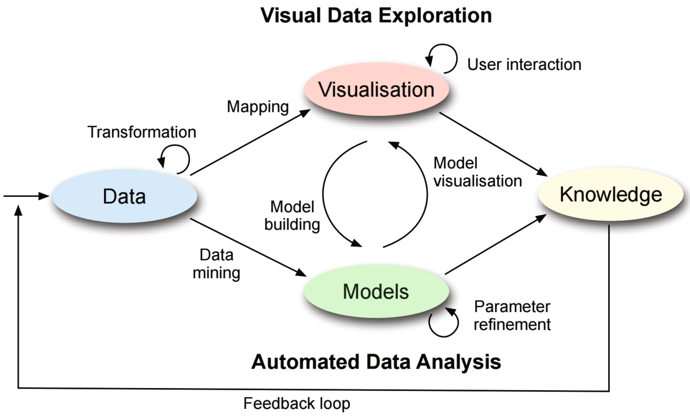

Fig. 1. Visual analytics process [4]

tion algorithms in turn are key to expert identification systems, as they are able to distinguish between the core and the periphery of a community. Moreover, the propositions of visual analytics are twofold. On the one hand, the effectiveness of the measured knowledge transfer may be visualized on a dashboard. On the other hand, visual cues gained through analytics can themselves be embedded right into the performance augmentation process. For instance, augmented reality devices may integrate security alerts coming from self-managed machines in the field of vision.

Our methodology presented in the following reaches from the gathering and transformation of data coming from innovative wearable-based learning services up to the support of its usage via (near) real-time visual analytics.

3 Visual Analytics Platforms for Internet of Things Data

In this section, we reference related research and commercial work for visual analytics of heterogeneous IoT data. In particular, we look at Web-based dashboards to make device-specific data available for evaluation on the Web.

IBM Watson IoT Platform is a commercial visual analytics platform for the Internet of Things [3]. The Web application offers IoT analytics features for device management and analytics applications. Devices can be configured to send data into the cloud using the MQTT protocol. Applications can then interact with the data. Finally, collected data can be visualized in a configurable dashboard that provides location, live property values as well as alerts caused by user-defined rules.

Bosch provides their own IoT solution called the Bosch IoT Suite [1]. Using the provided development toolbox, users can create their own IoT applications. The platform offers an IoT Hub component that transports IoT data from sensors to the applications developed by the customer.

Pheme is a cloud-based service that repurposes Web analytics services for IoT data collection and visualization [8]. Web analytics usually refers to the collection and evaluation of data that users produce when visiting websites. In their work, Mikusz et al. mapped typical Web analytics properties to IoT events. Pheme consists of four different modules: import, preprocessing, visualization and reporting.

We presented three representatives of visual analytics systems that process data coming from heterogeneous data sources. In the area of learning analytics for informal learning, we mainly find approaches displaying data in a preconfigured dashboard. A representative of this research is Social Semantic Server Dashboard by Ruiz-Calleja et al. [10]. It is able to collect and visualize data collected from Social Semantic Server, a semantically-enriched artifact-actor network. What remains unclear, is the applicability of the dashboard to accommodate dynamic real-time data.

What became evident in our research survey is the lack of tools specifically designed for learning analytics for heterogeneous data sources. In particular, we miss approaches integrating social network analysis methods like (overlapping) community detection and expert identification. The existing solutions further do not support the dynamic export and recomposition of the visualization widgets into third-party websites. In the following, we present our conceptual approach to fill these gaps.

4 Data Processing and Analytics Pipeline

The main building block and reasoning behind our approach is to leverage open Web technologies over the whole chain from accessing device data to analyzing it. Our system collects data from heterogeneous sources through Web technologies and makes it available via a browser-based platform that visualizes the data in near real-time. The complete pipeline and its layers are shown in Fig. 2 from top to bottom in chronological order. The platform is extensible in terms of more data sources and visualization options. In the following, we explain the three main additions of our framework in detail, namely the core framework, the model editor and the visualization frontend.

As shown in Fig. 2, the pipeline starts at the data source level. Data sources can be anything from real Industry 4.0 machines, body-worn wearable sensors or input captured on smartphones. Besides, data can also be retrieved from any website, such as open data provided by governmental and non-governmental organizations. The actual data format like JSON or XML is not yet important in this step.

The next level is the data aggregation tier. Here, data that is typically not available over the Internet is made available on repositories. For instance, sensors that are using heterogeneous exchange protocols may upload their capturings to a common IoT database. This step also comprises 3rd party services, such as sentiment detection of discussion forums or map providers.

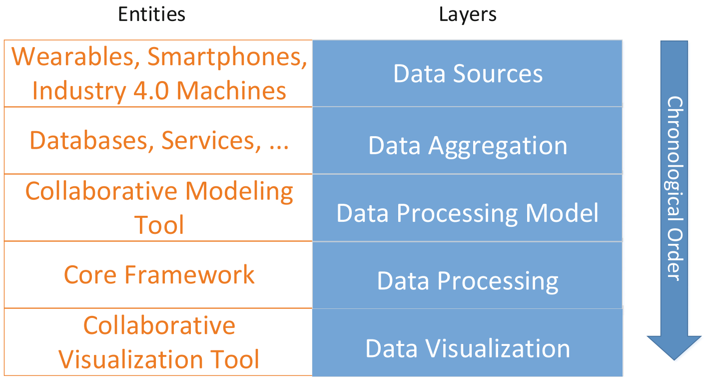

Fig. 2. Data processing pipeline

After the first steps that make the data available on the Web, the collaborative model editor comes into play. It is a tool for creating and editing visualization pipeline models that define the processing steps from raw data to highly interactive visualizations. These models are graphs consisting of nodes and edges connecting the nodes. Per definition, these need to be directed acyclic graphs (DAGs). DAGs consist of a finite number of nodes and edges with each edge directed from one node to another, without any cyclic loops. There are two types of nodes available in the collaborative model editor; first, data processing nodes and second, input nodes. Data processing nodes can either retrieve raw or processed data from a data source, e.g. a REST-based Web interface or a Websocket-based push server, or they perform a calculation, e.g. transforming data. Input nodes represent parameters that influence the data retrieval or visualization options. They represent the screws to be adjusted during the visualization. An example is filtering which data is shown in a visualization.

The data pipeline remains open for continuous refinement during the visual analytics process. Created models can be grouped into compositions and exported for later use. That way, recurring, complex data transformations only need to be modeled once; later, they can be imported into other visualization pipelines.

Once the model is ready, the core framework comes into play. The core framework is responsible for running the pipelines defined in the model. When a model is executed for the first time, the core framework collects the default values of the user input nodes and then runs the code within the data processing nodes. It collects and transforms data using Web services or local computations. Multiple modules within a model can be executed concurrently. At the end, it calculates the final output of the model execution and makes it available to the visualization. The visualization tool is responsible for displaying the results of the model execution. It provides user interface elements for editing the user input variables. Upon changes to the user input, it calls the core framework to recalculate the results, which in turn triggers the recalculation of the visualization. In the next section, we explain the prototypical implementation of the Web-based system for visual analytics.

5 Social Web-Based Environment for Visual Analytics

For the prototype implementation, we use a component-based software architecture. The frontend is developed using the state-of-the-art Web components group of W3C standards. Similar to the efforts of earlier widget-based frontends, Web components allow the definition and encapsulation of user interface widgets into reusable software packages. They can later be embedded into arbitrary websites, keeping their functionality. For executing long-running data retrieval and transformation operations, we set up a microservice-based backend. Like Web components on the frontend, microservices encapsulate well-described functionalities into their own software packages for later reuse in a different context. Figure 3 shows a screenshot of the whole Web application. The instance portrayed in the figure displays the processing model for retrieving development data from an open source repository on GitHub. Specifically, the model first retrieves raw data in JSON format from a public Web service. The dataset contains dates as index and the number of lines added or removed as values. This dataset is then separated into additions and deletions via two processing nodes. Finally, the data is fed into a line chart that can be seen on the right of the figure. In the following, we explain the details of the implementation based on the conceptual parts described in the section above.

Fig. 3. Screenshot of the web-based visual analytics tool

The collaborative model editor is implemented as a standalone Web component, thus it is embeddable into arbitrary websites. The interface consists of a model viewer and editor, which we developed using the open source jsPlumb

Toolkit[1]. The jsPlumb Toolkit enables developing graph-based modeling application for Web browsers. On the left side, we added zoom controls to be able to look into details of the model. On the right side, a toolbar gives access to various model-related functionalities, like adding input nodes or data processing nodes. To simplify reuse, we added a library of pre-defined data processing nodes which can be browsed through in the interface. The visualization types, e.g. line chart, stacked area chart or bar chart, can be selected in the toolbar as well. Finally, the update model button generates the data visualization pipeline as JSON document and hands it over to the core framework.

The core framework is responsible for running the data retrieval and transformation pipeline. It is developed in JavaScript and can thus run in browser or server environments, the latter using a NodeJS instance. We also developed an execution service to be able to run it within our Java-based peer-to-peer microservice framework called las2peer [6]. After the core framework has generated an output JSON file, it is handed over to the visualization tool.

The visualization tool consists of a viewer where various charts can be loaded and displayed. It inherently supports zooming and panning operations; besides, the diagrams it loads may offer further functionalities like expanding or collapsing a tree structure or limit the displayed key space to a certain time period. Similar to the model editor, the right side features a toolbar. It contains the controls defined as user inputs. Currently, we support text, number, numerical slider, toggle, dropdown and fixed value inputs. The inputs are automatically validated according to their type. For instance, user inputs to numerical fields are checked whether they represent numbers; if not, they are not processed. In case of such a validation error or other malfunctions during running the pipeline, an error is displayed in a logging pane at the bottom of the screen.

As stated above, both frontend parts are developed using Web components. One of the main advantages are their reusability. After importing and declaring them in HTML, they can be used as normal elements on the page. We use the Polymer[2] library from Google, as it adds compatibility to various browsers, some syntactical sugar, and most importantly, a consistent set of pre-designed user elements adhering to the Material Design guidelines[3]. This enabled us focussing on functionalities, rather than browser quirks and accessibility issues.

6 Preliminary Evaluation

To validate our results, we performed preliminary technical and usability evaluations of our system. For reproducibility reasons, we used an IoT dataset from hurricane Katrina [9], one of the most severe natural disasters in the history of the United States. The dataset contains multiple thousand measurements of several weather stations. In our scenario, the data was replayed through an XMPP server, and our visual analytics frontend was connected to the XMPP server.

[1] https://jsplumbtoolkit.com/ last accessed in April, 2017.
[2] https://www.polymer-project.org/ last accessed in April, 2017.
[3] https://material.io/ last accessed in April, 2017.

For up to 30 nodes, the near real-time graph widget rendered the graph at a speed of around 55 frames per second. When adding more than 30 nodes, the visualization began to slow down. For around 70 clients, the frame rate dropped to around 30 frames per second. When monitoring a network with 110 clients, we still measured 20 frames per second.

We additionally invited 12 volunteers out of our pool of bachelor and master students of computer science and performed a usability study. In total, we held six evaluation sessions with two participants in each. The participants were asked to collaboratively generate near real-time visualizations using the IoT dataset described above. We provided two laptops running on Windows 10, with recent Chrome browsers. A third laptop hosted the frontend and backend services as well as the evaluation network simulation. After the modeling of the data pipeline, the participants were asked to identify certain nodes in the analytics. For that, they had to interact with the visualization. Finally, the users had to fill in a survey. Although most participants knew about the Internet of Things paradigm, only few were familiar with the details of IoT protocols and visual analytics. All users agreed that for the given analytics tasks, extracting the information via the graphs was efficient and easily comprehensible. Furthermore, the availability of near real-time visualizations was helpful in understanding the inner working of the IoT network. Minor usability issues detected in our tests like finding the right buttons could be solved by changing the icon and offering tooltips. Overall, the preliminary evaluation showed the usefulness particularly in scenarios where a large set of data is available.

7 Conclusion and Future Work

The Internet of Things, Industry 4.0 and in particular wearable computing are currently introducing a new era of ubiquitous computing. For researchers in technology-enhanced learning, this opens the door to a whole new way of analyzing learners' behaviors especially in informal learning settings. By reading and interpreting sensor data in near real-time, learning services can be adapted and continuously improved more precisely. Yet what is missing is a cross-device infrastructure for setting up these kind of community learning analytics services. In this paper, we presented a highly flexible approach to visualize live data coming from IoT sensors in Industry 4.0 contexts. Our simple Web-based visual analytics tool is able to capture and transform data coming from a wide variety of sources and formats. It can be arbitrarily extended both in the execution phase and in the visualization parts. We performed an initial evaluation from the technical and usability perspectives that lead to promising results.

On the practical side, we are working on a library of prepackaged modules to cover a wide variety of data sources. Already, we provide modules for retrieving JSON, XML, MQTT and XMPP protocol data, covering a majority of IoT gateways and learning management system APIs. Current challenges include taking into consideration aspects like data quality, and showing uncertainty in the visualizations. As we developed the concept and implementation, we neglected privacy aspects to a large part, thus ethical and moral issues need to be discussed alongside evaluations. Possible future tasks include machine learning techniques to further automate analytics tasks. The tools are available open source on our GitHub repository[4]. We would like to open the academic discussion to research new use cases in the area of informal learning.

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Customized Games, Off the Shelf Modifications

MythHunter: Gamification in an Educational Location-Based Scavenger Hunt

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Abstract. Location-based applications have great potential to let users explore the environment in an immersive and engaging way. Digital scavenger hunts have a great potential as teaching and instructional guiding tool. However, many tools only guide users but are not designed as meaningful and engaging experiences. Adding more story-based and exploratory playful game design elements such as quests or achievements can make such experiences and the according learning experiences more entertaining and motivating. This paper contributes by introducing concept and development as well as a qualitative evaluation of an location-based scavenger hunt application with focus on a playful and story-based design. It allows users (e.g. teachers) to create multi-staged quests in a web-based editor, which app-users (e.g. students) can then complete in a platform independent mobile application that makes use of game design elements. In a first qualitative study we focus on evaluating the game with regards to fun, learning factors, usability, and engagement. Results indicate that story-based scavenger hunt applications have a high potential as tool to engage users to learn more about their environment. Especially story-based and playful elements are rated as important element for engaging exploratory experiences.

Keywords: Gamification · Educational games · Game-based learning · Location-based learning · Scavenger hunt · Geodata

1 Introduction

In the last decades digital gaming has become a natural part of everyday life and has found its place in the modern culture. A study conducted by Newzoo and GlobalCollect in August 2014 shows that there are 1775 million video gamers worldwide, which are almost 25 percent of the total world population [1]. Computer games can keep people engaged for hours and motivate them to come back to the game again and again. As a natural consequence game elements where introduced in non-gaming contexts to improve the enjoyment of activities that are normally perceived as boring and not very motivating. This introduction of game elements is commonly referred to as "gamification". The positive effects of

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gamification and various game design elements are discussed by multiple authors [2,3].

An important field that profits immensely from gamification is education [4,5]. Studies [6] show that students in game-based learning environments are both more motivated to learn about a new subject and more likely to come back to study the subject after school hours. The introduction of games or game-like elements into classes can also help the students to get a better understanding because they excel in visualizing complex concepts. Thus, it is no wonder that more and more teacher make use of gamification in their lectures and even book publishers issue learning games alongside school books. Educational games have huge potential to create engaging learning scenarios, when designed in a meaningful, interesting, and challenging way [7].

Learning, however, does not necessarily has to take place in the classroom. Mobile applications allow teachers to take classes outside and students to easily take their schoolwork home. This allows the students to more flexibly shape their own learning process according to their own time schedule [8]. A very interesting feature of mobile devices is that they can make use of geodata. Using the "Global Positioning System" (GPS) mobile applications can link information to physical locations on earth. The use of such geo-based features can be a way to create interesting learning games. Playful applications, that make use of geodata are for instance Geocaching[1] and Ingress[2], where Geocaching is already integrated in educational processes (Educaching[3]). In an early prototype, we already demonstrated the potential of location-based applications for learning (blinded for review). However, the application failed to engage the target group - young students in a playful way.

In this paper, we want to create educational and instructional experiences for location-based mobile devices, which integrate game design elements which immerse users in a story and lets them explore the environment to learn about it in an engaging way. Following, we present a mobile location-based scavenger hunt game. The main focus is to make learning about the environment fun and motivating by incorporating gamification based on exploratory and story-based game design strategies such as quests with multiple tasks and achievements. The game consists of a web-based editor for creating new quests and a Unity mobile application that works cross-platform on Android as well as IOS devices. The application improves on the existing applications like geocaching by making the quest creation easier and therefore allows a broader range of people like teachers or tourist guides to develop quests for their students or people interested in learning more about their environment. The mobile application is also developed as user-friendly and simple as possible, to allow also students to easily follow and complete the quests.

[1] https://www.geocaching.com/.
[2] https://www.ingress.com/.
[3] http://www.dotcomblog.de/educaching/.

With this work we aim to discuss the potential of mobile location-based games in educational and exploratory environments and making the following contributions:

1. Design and Implementation of a mobile location-based learning game
2. A first qualitative case-study with focus on measuring fun, learning, usability
3. Discussion of potential risks of location-based mobile applications

2 Background and Related Work

As Prensky states in his article about digital game-based learning [9] "*A sine qua non of successful learning is motivation: a motivated learner can't be stopped*". Digital game-based learning strategies are identified as successful tool to create engaging learning experiences. Gamification can be used to used as tool to extend existing digital applications with playful elements to create game-based learning experiences. In this section we look into the concept of "gamification", how it motivates people to learn and how it is applied in educational contexts. Furthermore, we will have a look at mobile applications that use gamification and analyze which methods they use keep their users interested in the game and motivate them to play and also learn outside.

2.1 Gamification

Deterding et al. describe gamification as "*the use of game design elements in non-game contexts*" [10]. Werbach sees gamification more as a process of making an application more game-like instead of just sticking in some game-like feature [11]. Both authors, however, agree that gamification should make an application more fun to use, encourage users to interact with it voluntarily and repeatedly come back to it. Some popular features that learning applications borrow from games are achievements/badges that encourage students to keep learning to earn the next badge for their collection. Points and leader-boards aim at the competitive nature of children. They enable the students to compare to their colleagues and score higher than them.

2.2 Gamification in Educational Environments

Studies suggest that using gamification in a learning environment has a huge potential if done correctly [12,13]. The biggest chance these studies identify is that most students enjoyed the learning games and perceived them as very motivating. It is, therefore, not surprising that more and more learning platforms make use of gamification to make the often as boring perceived learning content more fun to use for the students [14].

The learning community Scratch[4] founded by the MIT institute teaches children programming skills in a fun and interactive way. The kids can "program"

[4] https://scratch.mit.edu/.

graphic animations by sticking blocks together and can then immediately play the animation and see what effects code-changes have. They can then upload their animations to a Web platform and compare with and learn from the animations of other children. Reiners and Wood [15] see the Gamification of Scratch in the game-like interface on one hand and the freedom of choice the children are given to develop their game. They can build their animations from scratch or take existing animations from the web platform and enhance those. The Information Resources Management Association [16] also highlighted the possibilities of Scratch as a motivating learning application.

2.3 Location-Based Learning

A statistic by Newzoo from 2014 [1] shows that 740 million people in Asia and around 153 million people in Western Europe play games on their mobile devices. Clough [17] elaborates in his paper from 2010 the opportunities of location-based learning applications. It is, therefore, not a surprise that game-like learning applications found their way on these platforms as well. The advantage of such applications is that they can make use of the Global Positioning System (GPS). Using GPS the students do not have to learn about their, for instance, local castle from their classroom, but can be on site and study the castle with their own eyes while being given historical information about it. An added benefit is that learners go outside and exercise, which is beneficial for their health. Their exist many location-based learning games. Three of these applications that incorporate learning are briefly outlined in the remainder of this section:

Geocaching. Geocaching is probably the most well-known location-based application. The goal of the game is to find physical objects in the environment that have been hidden by other users of the application. The possibilities of learning with Geocaching has been explored in multiple publications [18,19]. Under the term "Educaching" the application also found its way into libraries [20].

Ingress. Ingress[5] is also a location-based game where two teams play against each other and try to "capture" distinctive objects, like statues, in the real world using their mobile phone. Ingress recently introduced the possibility to create scavenger hunts that also tell you something about the history of those objects

LMAC. In a previous project, we introduced a location- based mobile application creator [21,22], which allows the creation of scavenger hunts for users that they can complete with their smart phone and learn something about the surroundings using geodata. This app did not include any gamification issues, but simply guided users through the environment. In a first study the educational value of such an application was shown, however, elements such engagement were noted as elements for potential improvement.

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

Additionally, security issues due to a strong focus on the mobile app and losing awareness of the environment (e.g. traffic) was noted. Nasar et al. however show that there are also disadvantages when using smart phones in public [23]. The number of injuries due to distraction by mobile phone use is strictly increasing since 2005. One should be aware of this risks especially when creating a location-based learning application.

In the following section the design and the implementation of a location-based scavenger hunt application, which additionally included gamification features, which gives users more freedom to explore the environment and tell stories, in order to raise engagement and fun. that motivates students to learn using the gamification methods is described. We conclude with a discussion on risks and issues and how these can be minimized.

3 Myth Hunter

Myth Hunter was designed to create an interactive, flexible, and expandable mobile location-based application with focus on enhanced user engagement. Thus, a traditional location-based scavenger hunt principle is combined with playful design and story-based exploration experiences. Users should not only be able to experience such location-based explorations, but should be also able to create own story-based experiences for other users.

The main idea of Myth Hunter is to create playful learning experiences for users: learning and exploring should be perceived as an adventurous quest. This can be used to attract students, to learn more about specific places (e.g. historic parts of a city), for tourists to learn about the city by exploring it, or for users, who are simply engaged by the app to explore the own region. Due to the diversity of the target group in terms of background, motivation, and also age, the design of the apps needs to support flexible and adaptable design and the user interface should be user-friendly and intuitive. This should assure that they can focus on exploring and learning about their surroundings rather than facing usability issues.

Another important goal is to make it easy and attractive to build individual quests for non-programmers while still giving creators the freedom to create quests of their choices. The first prototype of *"Myth Hunter"* prototype was designed to take into account (1) usability, (2) exploratory experience, and (3) flexibility.

It is designed to support all these design requirements by consisting of (1) a web-based editor to create and edit quests and (2) a mobile application for playful mobile learning experience for students. The following sections will introduce the editor and the Android application by focusing on their designs and functionality followed by an overview of the architecture of the whole project.

3.1 The Editor

The software presented in this paper depends on users to create new content for the application. This has the advantage that not all of the quests have to be created by the development team itself, but users can also create their own quests and challenges. However, this decision of relying on externally-created content comes with some challenges. The editor has to be as simple to use as possible so that even users that are not very technically experienced are encouraged to build quests for the application. This section describes the Web-based editor for creating new content for the application and analyses the design decisions for making it as user-friendly and fast as possible.

The quest creation follows some simple steps. First, quest creators name the quest and provide an overall description of the quest. After confirming their input users can use a screen-sized map (illustrated in Fig. 1) providing a search bar. In this search bar, user can look for locations, which should be added to their quest and place a marker on the map by just clicking on it. The newly added marker appears in a menu on the left hand side of the screen. The quest creators can now add additional tasks to the quest, by simply adding additional markers to the map. They can choose from three different types of tasks:

1. **Info-task:** Gives information about the quest to the user (simple task)
2. **Quiz-task:** This tasks challenges the users to answer question such as multiple-choice or fill-in-the-blank questions. This question should involve aspects from the current locations (e.g. using hints hidden at the location)
3. **Invisible-task:** The user has to find a hidden location by following the hints given in the task description

Fig. 1. Map interface of the Web-based editor showing different locations of the quest as markers

Figure 2 illustrated the interface for creating a task (a quiz task in this case). The creator can e.g. add multiple-choice questions by simply selecting the quiz-options. Media elements such as images can be added to tasks as well.

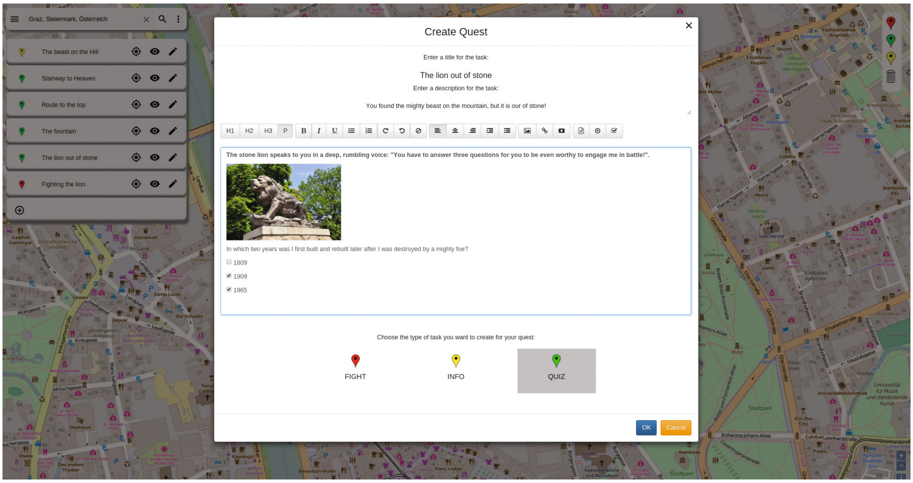

Fig. 2. Interface for creating tasks such as multiple-choice questions, which are triggered at specific locations

3.2 The Mobile App

The Myth Hunter application is the mobile game-application. It is built with the Unity Game Engine[6] which allows to develop the game once and build it for various mobile operating systems like Android, IOS, or Windows Phone 8. The development process is designed ad iterative development approach. So the current version is used as first prototype to get an understanding of the user experience and will be constantly redesigned and updated based on the feedback.

After logging in, the user will see an overview of his/her profile including the number of completed quests and tasks and other motivating statistics as well as information to all his/her active quests (see Fig. 3). It is possible to directly navigate to one of these quests on a map view (Fig. 4) which is the primary screen when executing a quest. A quest in the map view consist of a series of markers of which usually only a few are displayed at once on the map depending on the quest progress. Each of this marker represents a certain task a user has to fulfill by clicking on the marker. This opens a HTML page within the app (Fig. 5) which tells the user what to do next, e.g. reading some information, watching a video, answer questions or find a hidden location. After a Task is completed, the following task becomes visible on the map and an arrow from the users position towards the new marker indicates in which direction the user has to go.

Additionally this screen features a compass to indicate in which cardinal direction the user is heading. The orientation of the map automatically follows the orientation of the user meaning if one looks, e.g. at a street straight ahead the map will also show the street heading upwards on the screen. This makes it easier, especially for kids, to navigate to a given point on the map. However, the

[6] https://unity3d.com.

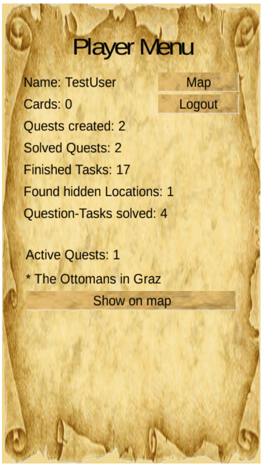

Fig. 3. The profile overview showing statistics and active quests.

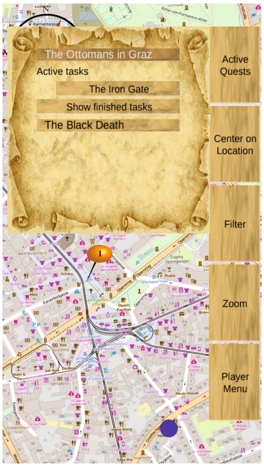

Fig. 4. Map view featuring a compass and several filter options

orientation-following can be stopped at any point by tapping on the compass which allows the user to freely turn the map in any direction. The functionality of the compass itself stays the same in both modes. This gives the user the opportunity to either focus entirely on the quest and easily navigate from one target to the next or discover how to navigate with an ordinary static map and a compass.

On the right-hand side of the map a menu is placed which provides features like centering the map on the users location or filter all the shown quest-markers by various criteria. It also contains an "Active Quests" view which shows a list of all the quests a user has started. Upon a click on one of these quests it expands and lists the next tasks of this quest as shown in Fig. 6. Furthermore, the map automatically shifts and zooms in order to show the position of the tasks relative to the users position. Clicking on a task causes blinking of the corresponding marker on the map to indicate which list entry represents which marker. In this menu it is also possible to make the already finished markers visible again which allows the user to recap what he/she has accomplished so far. In the next chapter the general architecture and the communication between editor and application is explained.

3.3 Architecture

Fig. 7 illustrates the basic architecture of the Myth Hunter prototype. The server-side implementation consists of a Java Webservice Application which is launched on an Apache TomEE Webserver[7]. Via the Java-Hibernate ORM Framework[8] a

[7] http://tomee.apache.org/apache-tomee.html.
[8] http://hibernate.org/orm/.

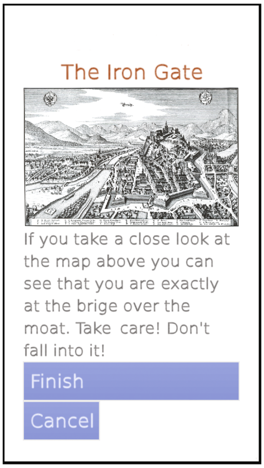

Fig. 5. The HTML page of an Information-Task

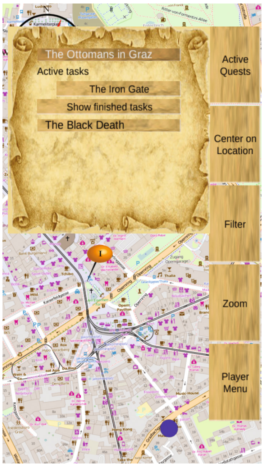

Fig. 6. Map with active-quest overview showing the next task on the map

PostgreSQL[9] database is connected to the Webservice Apllication. Within this Database all the information regarding quests and users are stored.

The Web-Editor Interface is HTML5 based and implemented using the Javascript framework AngularJS[10] in combination with OpenLayers 3[11] for displaying map data from an OpenStreetMap[12]-Tileserver within the web browser.

For the Implementation of the mobile application the GameEngine Unity3D[13] is used. This allows to implement most of the application platform-independent meaning that even though we focus our attention on Android right now the porting to e.g. IOS will not be a big issue. Furthermore the Unity community provides a lot of useful plugins like PowerUI[14] which we use to display the user-generated quest and task description stored in HTML5 format. UnitySlippyMap[15] is another Unity plugin used to display and manipulate OpenStreetMap tiles.

4 Field Study

In order to get first in sights on the prototype for its applicability for students and learning scenarios (e.g. international students learning the abroad location) based on the design and experience goals described earlier we conducted a first qualitative study including eight participant (7 female) between

9 http://www.postgresql.org/.
10 https://angularjs.org/.
11 http://openlayers.org/.
12 https://www.openstreetmap.org.
13 https://unity3d.com/.
14 http://powerui.kulestar.com/.
15 http://jderrough.blogspot.co.at/2012/12/unityslippymap.html.

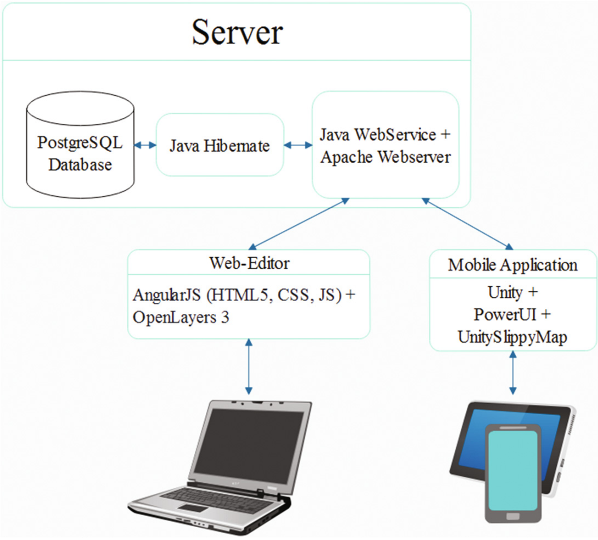

Fig. 7. Myth Hunter architecture

20–35 years old (M = 24.63, SD = 3.46) with different professional backgrounds. They all had only a little experience with mobile games and next to no experience with location-based games. On a Likert scale between 1 (not at all) and 5 (very strong) they rated their experience with mobile games with a mean of 2.88 (SD = 0.83) and their experience with location-based mobile apps (mainly Google Maps) with 2.25 (SD = 0.89). Asking them about their skills to navigate with a map/compass the average mean was 3.5 (SD = 0.93). All participants had to complete the same quest, as described in the next section, and answer a survey afterwards. The questionnaire was designed to assess (1) usability, (2) the exploratory experiences, and (3) engagement with the app (game).

4.1 Scenario

The quest for our field study takes place in the Austrian city Graz and guides the user around parts of the old town up to the peak of the "Schlossberg". To complete the whole quest the users have to walk approximately 1,5 km. The quest consists of seven tasks in total including three Quiz-tasks and one Invisible-task. The answers to the questions of the Quiz-tasks are hidden in the surroundings of the marker's location. Therefore our test-users had to walk around, read information-signs and take a close look at buildings and structures to find the answers. While executing the quest the participants learned facts about the area either by reading the signs or as part of the task descriptions. After completing the quest, each participant had to fill out a survey consisting of two sections:

- **Background:** age, sex, professional and their experience with mobile games and location based apps.
- **Experience with the app:** Experience with elements such as fun, motivation, learning effect, easy use and safety risk.

4.2 Observations

Following, we discuss the results of the study with focus on looking an elements which were noted as engaging, ideas for applications, and flaws and issues.

Engagement. The overall Feedback was very positive: 75% of the participants answered the questions about the fun of the game and the motivation to finish the quest with five out of five points. Especially exploratory and narrative story-based elements were noted as motivating and important aspect they liked: "*[I liked] the funny story. I felt very motivated to finish the task as I wanted to know the story.*"; "*I liked the story a lot and I think that the app - especially if one is not familiar with the city an entertaining way to get to know the city.*"; "*[I liked] the system, the idea I did like how involved I felt and caught by the story.*" Only 12.5% of our testers answered that they would rather read a book about the history of Graz than learning with our app.

Learning with the App. Regarding the learning effect we got very mixed results mostly depending on how familiar the participants already were with the area. 87.5% answered with four or more points out of five when asked how easy it was to navigate with the app and if they always knew where to go next.

Application Scenarios. When asked to estimate how children would react to the application all participants answered that they would expect kids to have fun executing such a quest and preferring it over reading about the same content in a school book. As shown in Fig. 8 they were rather unsure though if pupils would use the application in their free time as well resulting in an arithmetic mean of 3.38 points of five. Additional comments to this question suggested that parents or teachers would need to initiate or propose specific quests to them. For us this is an indicator that the gamification elements implemented so far are not enough to keep players motivated. At the end of this section of the survey we again raised the question about safety risks, but this time especially for children who lead to quite a different result (see Fig. 9): 75% rated this question with three or more points of a total of five indicating that the risk of children forgetting about their surroundings, e.g. traffic is perceived significantly higher than of adults.

Issues, Improvements. Regarding safety risks when using our application we again got quite an unreliable result with an arithmetic mean of three out of five points (Table 1).

Table 1. Your caption here

	AVG	SD
I had fun doing the scavenger hunt	4.75	0.46
I felt motivated to complete the whole quest	4.63	0.74
I learnt something about the history of the Schlossberg	2.50	1.20
I prefer to learn about the history of Graz using the app to reading a book about it	4.38	1.41
I think my ability to use a compass/map increased	1.38	0.83
At any point during the test I knew where I had to go next	4.38	0.74
It was easy for me to navigate with the app	4.24	1.04
I think using the app can bring security risks with it	3.00	1.31
I lost the sense of my surroundings while using the app	2.13	1.36

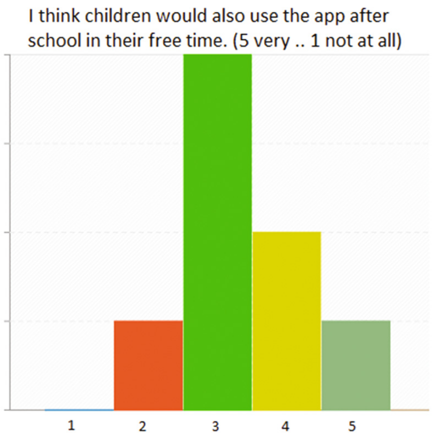

Fig. 8. Question results regarding after school usage of the app.

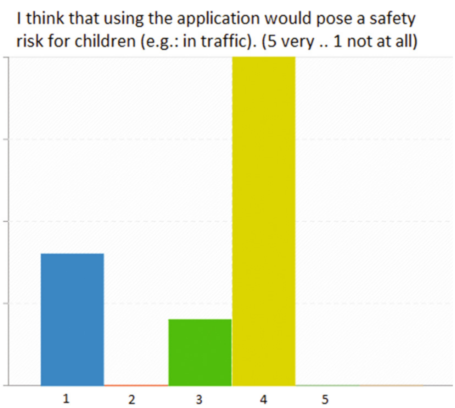

Fig. 9. Result of the question regarding safety risks for children

Following, detailed statistics of this study are listed:

Two of the participants (one with a degree in German studies and one studying to become a teacher) brought up another interesting point regarding our target group of children between seven and fourteen years. They suggested that on one hand the quest they performed with our application had too much text to read for younger children from seven to ten and on the other hand may be not challenging or interesting enough for the older children up to fourteen. We therefore decided to introduce a difficulty rating from easy, over medium to hard quests, where easy quests are more suited for the younger (more graphics, less text, content suited for younger children) and medium and difficult quest the older part of our target audience.

Limitations of the Study. This study is intended and design as first evaluation and proof of concept of the current prototype and game design. The design and development of MythHunter is an iterative process. Therefore, the study design is very limited in terms of trial-size and diversity (age, sex, and background) of participants and application domain. Future studies with a more elaborated prototype will be designed with a stronger focus on measuring engagement, learning progress, and usability.

5 Conclusion and Future Work

Summing up the results of our first study, the users had fun doing the multi-stage quest of the history of Graz and felt motivated to complete the whole quest. They think that children would rather use this application to learn about topics like history than reading the information from a book. The participants presume, however, that it is not very likely that children will use the application outside school. Thus, we will improve the application by adding more gamification elements and therefore make it more fun to use by children, even outside their school environment. Our study also shows that people think such application can pose safety risks especially for children. Therefore, we suggest not to let children use this application alone but, either in pairs or supervised by an adult.

This study was intended to improve the current prototype in an iterative design process. Important planned features are:

- **Fight-task:** We will add a fourth task type where players have to "fight" against, e.g. mythical creatures or historical characters. This "fights" will be decided by playing a trading-card-game where the players have the chance to win a new card representing the opponent for their deck.
- **Card-Editor:** When creating a quest the users will have the possibility to create special cards for this quest by using the new card-editor within the quest editor. They can choose between to types of cards, Magic- and Monstercards, and have a pool of various effects they can add to the card. More and stronger effects make a card more expensive to play in the game itself.

- **Quest-Rewards:** Upon finishing a quest players will receive five random cards (booster) which they can afterwards add to their decks. If this quest included a fight there is a higher chance that the special opponent-card is within this booster. This adds extra motivation for completing a certain quest not only because it sounds interesting but also to collect special cards and strengthen the deck.
- **Quest difficulty rating:** Addressing the point brought up by our survey participants we will introduce a rating system for our quests. Easy quests contain less text and more medial content like pictures or videos. These quests are targeted on younger children between seven and ten. Medium and hard quests contain more mature content, more text and pose more of a challenge to the older children.

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Efficient Software Assets for Fostering Learning in Applied Games

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Abstract. Digital game technologies are a promising way to enable training providers to reach other target groups, namely those who are not interested in traditional learning technologies. Theoretically, through using digital game technologies we are able to foster the acquisition of any competence by specifying competency structures, offering adequate problem solving support while maintaining motivation and taking personality into consideration as part of the tailored game experience. In this paper, we illustrate how this is done within the RAGE project, which aims to develop, transform, and enrich advanced technologies into self-contained gaming assets for the leisure games industry to support game studios in developing applied games easier, faster, and more cost effectively. The software assets discussed here represent a modular approach for fostering learning in applied games. These assets address four main pedagogical functions: competency structures (i.e., logical order for learning), motivation, performance support (i.e., guidance to maintain learning), and adaption to the player's personality.

Keywords: Applied gaming · Learning analytics · CbKST · Motivation maintenance · Performance support · Personality adaption

1 Introduction

Games are not only focusing on children or teenagers. Today's gamer community also include university students (68% of gamers are over 18 years old) and other adults, with an average age of 30 [14]. This potentially grants access to a target group which has left the youth education, by using applied games. As a result, a growing online game-learning trend may emerge, even outside formal learning contexts and not limited by age or distance [7].

Many aspects, such as engagement, challenge, motivation, and achievement need to be considered when dealing with leisure games and applied games. A

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cognitive-behavioral game design model, proposed by Starks [19], incorporates a wide range of psychological constructs and relates them with game elements to meet the demands made to leisure games. He proceeded from the Theory of Multiple Intelligences [10] and the Social Cognitive Theory by Bandura [4] to the factors that make games educational and enjoyable - engagement, challenge, flow, persistence, and mastery.

Besides considering these factors one need to distinct between the game goal and the learning goal [9,21]. Engagement and challenge are the base requirements; on top of that, those factors need to be directed towards the learning content. A clear model of learning is needed, focused on learning activities and problem-solving processes to support and assess the learner. Game developers are facing the difficult task to consider all these aspects of educational game design.

This challenge is acknowledged and addressed by the RAGE (Realising an Applied Gaming Eco-System, http://rageproject.eu/) project and its modular Asset approach. To support the young emerging applied-game industry the RAGE project was started; it makes an interoperable set of advanced technology assets for applied gaming available. These RAGE assets are composed of at least one software component and metadata, such as descriptions, manuals, and demos. We will only talk about the software component, referred to as Asset in this paper.

We have developed seven software components forming four modular assets within the RAGE project, which focus on the educational benefit of applied games. First, the Player Profiling Asset allows a pre-game adaption at the beginning of the game; this enables the game developer to tailor the game to a player's characteristics. Second, the Competence-Based Asset controls the skill or competence development during gameplay; competence assessment and game path adaption based on this assessment are the key features of these assets. Third, the Cognitive Intervention Asset provides learning support based on the in-game activities of the player; this leads to interventions targeting the reflection process based on psycho-pedagogical considerations. Finally, the Motivation-based Asset handles the player's motivation by assessing and modifying it throughout the game. Those four software components represent a modular approach for multi-dimensional learning support in digital educational games. In order to include these assets in an applied game, a technical framework developed in the RAGE project is used (see next section). A demonstration game has been developed that include and demonstrate the assets (Sect. 4).

2 Technical Framework

Within the RAGE project, an asset architecture was developed [22]. The purpose of the architecture is twofold. First is to simplify development of new pedagogical assets by offering an asset template with base features. Second is to maximize reusability of assets across multiple dimensions including programming languages (re-use of architecture), operating systems, game development platforms, and target devices (re-use of code).

Supported programming languages currently include C#, Java, JavaScript/TypeScript and C++. Target operating systems and devices include desktop computers (Windows/OS-X) and mobile phones (iOS, Android). Development platforms include Unity3D and Xamarin game engines. The architecture was verified to be working along these multiple dimensions [23]. Primary focus within the RAGE project is on C# and Unity3D.

The architecture makes use of well-established design patterns from component-based software engineering [3] that facilitate highly reusable pedagogical assets. Apart from reusability, the architecture facilitates development efficiency by providing a core set of functionalities commonly needed for pedagogical assets. For example, the architecture includes an asset manager that enables different assets to automatically register themselves, locate each other and collaborate. The architecture also supports different modes of communication between the assets or with a game. For example, assets can publish events or subscribe for events from the game or other assets. The architecture also provides a convenient interface for data storage. For example, asset's settings can be seamlessly stored in or loaded from a file.

The architecture is also designed to minimize asset's interference with serious game development. To enable smooth integration into games and leave game programmers in control, the architecture imposes restrictions dictating that assets are not allowed to use or make assumptions about the underlying game code and operating system nor have any user-interface. For example, while the asset knows that it can store data in a file, the asset does not care where the file is located and how it is handled. These details are delegated to the game code minimizing potential conflicts between the asset and the game. These two restrictions also result in the easy use of unit test suites for code testing and quality assurance purposes.

To recap, the architecture tries to maximize portability across multiple dimensions and at the same time increase acceptance by asset and game developers and lower the integration efforts into games.

3 Software Assets

This section presents four software assets that support learning in applied games in different ways: Competence development, motivation maintenance, problem-solving support, and personality adaption. We motivate each aspect first and link it to the area of applied gaming.

3.1 Asset for Supporting Competence-Based Learning

What makes an applied game an educational game? The obvious answer seems to be 'the learning effect'. The player has to acquire competences within a given domain during gameplay. A central aspect for this learning effect is considered in the flow concept [6]. The game needs to be balanced and the game should not demand too much or too little from the player. Such a balance requires knowledge about the player's current competences, as well as the next meaningful competences to be acquired. We use the Competence-based Knowledge Space Theory (CbKST) as an underlying theory for this aim.

CbKST is an established theory for structuring learning and competence gain during learning [12]. An approach using CbKST in complex game-based learning situations with respect to microadaptivity was given by Albert et al. [1]; it was elaborated within the ELEKTRA project. Ley et al. [18] applied a CbKST approach within an adaptive informal technology enhanced workplace learning situation. Another approach featuring CbKST was realized from Kopeinik et al. [17] for game adaption in the EC-funded TARGET project.

The CbKST uses competences and relations between them to determine the currently possessed, as well as the next meaningful competences to be learned [12]. We call the relationship between the competences prerequisite relationship; it models the learning process by determining the needed pre-requirement competences to a competence. With knowledge about the set of available competences, the competence state, next meaningful challenges can be determined. The performance during a challenge updates the competence state according to a probabilistic approach [2]. In this approach, each competence is assigned a probability of possession. The competence state consists out of those competences exceeding a given limit.

We adopt the CbKST framework to our needs in the applied gaming context. This is mainly done by defining and structuring competences to be learned with a game. Furthermore, a game is structured into game situations where these competences are taught. Additionally, in-game activities are identified that contribute to the acquisition of such competences. This model is the basis for non-invasive assessment of available competences during game play and for the recommendation of next suitable game situation.

In order to assess the current competence state of a player, the in-game activities are monitored and used to continuously update the current competence state, see Fig. 1. Therefore, three different methods are used to update the competence possession probabilities with so-called evidence. The first method directly updates (increase or decrease) the probability value of a certain competence. The other two methods use this very basic method indirectly. The second method only demands an activity performed in the game. This activity links to one or more basic updates of the first type. The third and last method is targeting games with level structures (game situations). An evidence consists of a game situation and information about the player's success. This information also links to one or more basic updates of the first type.

The basic update method allows different strengths of updates, due to a small adaption to the probabilistic algorithm of Augustin [2]. The strength of an update is determined by two algorithm constants, one for the upgrade strength and one for the downgrade strength. A larger constant yield a larger modification. We introduced three new constants for each of the two old constants; this allows us three different level of update strengths for both, positive and negative evidence. With this algorithm modification, we are able to consider different types of evidence with different power.

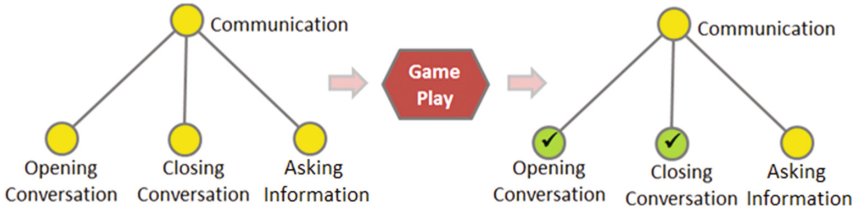

Fig. 1. Schematic representation of the competence update process using a simple communication competence structure. The competence 'Opening Conversation' is one of the three prerequisites of the competence 'Communication'. The outer fringe in the left structure are the competences 'Opening Conversation', 'Closing Conversation' and 'Asking Information'; the outer fringe in the right structure is the competence 'Asking Information'.

Fig. 2. Schematic game situation selection process within a simple communication competence structure. Here, game situation *A* was already mastered; the next game situation would be game situation *B*.

In order to recommend next suitable game situations for the player, the calculated competence state and its outer fringe are used. The outer fringe describes the set of competences a player is ready to learn according to CbKST, see Fig. 1. These are competences, for which the player already mastered all prerequisites. We can exclude game situation containing only already mastered competences since the player cannot learn something new. Furthermore, we can exclude all game situations for which an associated competence is neither in the competence state nor in the outer fringe since the player is not ready to learn this competence. We can now choose a game situation with the minimal number of associated competences in the outer fringe since this reduces the new learning input for the player. A proper game situation in this context is a game situation, with only one competence in the outer fringe and all other competences in the competence state of the player. For this approach, we might want to guarantee always the existence of a proper game situation. A schematic representation of the procedure is shown in Fig. 2.

3.2 Asset for Facilitating Cognitive Interventions

Supplying adaptive interventions during gameplay may be a crucial aspect of an applied game. A significant difference in learning performance was observed between a game version with this kind of interventions and without them in the ELEKTRA and the 80 Days project [16]. As one aspect of adaptive interventions, cognitive and metacognitive interventions aim at enhancing knowledge and competence acquisition. No matter, if an intervention can occur as a hint, suggestion, warning, or feedback, it needs to be both convincingly embedded into the game and tailored to the player's needs.

We use the player's in-game actions to infer about his or her reasoning, that the game can submit to the software asset. This information is then compared to an underlying intervention structure that consists of two application types. First, action combinations representing common misconceptions, which lead to an intervention, if all of them are performed. Second, action combinations leading to success, which provoke an intervention, if such a series is not completed. Out of these two base types, all possible combinations are generated.

An algorithm triggers the interventions based on the cognitive intervention structure and performed actions. The cognitive intervention structure is an a-cyclic directed graph where the edges of the graph correspond to the in-game actions; the vertices, each of which can be active or inactive, correspond to the player's state. Each node is associated with an activation time and may be associated with an intervention type. The activation time describes the timespan for which we assume two actions to be still related; the intervention type describes the type of intervention, which is triggered because of this vertex. Starting with an always-active start node the algorithm handles a new action the following way:

- All active vertices are checked for leaving edges associated with the received action. If such a vertex is found, this vertex is set to inactive (if it is not the start vertex) and the vertex reachable via the received action is set active.
- If the newly activated vertex does not have any leaving edges and is associated with an intervention type, this intervention type is triggered and it is set inactive again. In case it does not have any leaving edges and is not associated with an intervention type, it is also set inactive.
- If during this procedure an active vertex is discovered, which is longer active than its activation time, it gets deactivated and the related intervention is triggered if there is one. Alternatively, the active vertex can be checked repentantly, to avoid a time lag between reaching the minimal time span for a node and the submission of a new action.

Based on the idea that one path in this graph, beginning at the start vertex, represents a series of player actions within the game, we are able to react to observed behavior. As an example, how we use this approach, we discuss our two application types. Although they do not reflect the full potential of this approach, they give an impression of what we can do within this framework.

Tracking Deviations from Wanted Behavior for Solving a Task. For tracking and detecting deviation from wanted behavior, we model a meaningful behavior (in a simple case) as one path, beginning with the start vertex, followed by middle vertices and ended with the final vertex. The middle vertices have one entering and one leaving edge; the final vertex has only one entering edge. By performing the action associated with the edge leading from the start vertex to the first middle vertex, the solving process of the task starts. A player performing all actions associated with the tracks of the path leading to the final vertex in the correct order within the activation time would match the behavior for completing the game situation. If, however, the player struggles to perform such an action within the activation time, the corresponding intervention to the currently activated vertex triggers. This intervention can guide the player towards the desired action or foster reflection about the failure. The final vertex is not associated with an intervention; reaching it would mean a successful mastery of the game situation, and hence, an intervention would be unnecessary. This approach requires only one series of actions to be an expedient one. A graphical representation is given in Fig. 3.

Tracking Misconceptions for Solving a Task. We model a player's misconception as series of actions since it suggests a perceived correct combination of actions in a game situation. Like in the previous case, we model this behavior (in a simple case) as one path, beginning with the start vertex, followed by middle vertices and ended with the final vertex. The middle vertices have one entering and one leaving edge; the final vertex has only one entering edge. In contrary to the above example, only the final vertex is associated with an intervention. Only if the player executes the whole series of actions within the activation time, the player fully performs the misconception behavior, and the intervention of the final vertex is triggered. A graphical representation is given in Fig. 3.

Intervention Types. Interventions, in general, aim at supporting learning and enhancing knowledge acquisition. We defined and used two main categories of different intervention types, which are metacognitive interventions and knowledge

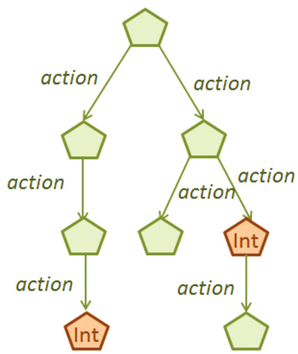

Fig. 3. Graph representing a cognitive intervention structure. The left path representing a misconception; the right path representing deviation from wanted behavior.

interventions. The various individual interventions were elaborated based on previous work described in [15] and related to these main categories. All interventions together constitute the menu of adaptation covered by this software asset.

– Metacognitive Interventions: These interventions address metacognition, i.e. they aim at supporting the player in or prompt the player to think about his or her own learning and thinking processes and on their knowledge. The different types of metacognitive interventions align with the phases of the self-regulated learning process [24]. This type of interventions is generic and may be used across different kinds of games. For example, interventions could be to ask the player to think about the current or reached own goal, to keep track of the own actions, or to consider alternative solutions
– Knowledge Interventions: Knowledge interventions directly target domain knowledge and knowledge acquisition. They are dependent on the individual game and its targeted learning objective and subject matter. For example, in a game about physics, an intervention could be made that reminds on a specific physical law.

3.3 Software Asset for Maintaining Motivation

Another type of adaptive intervention for learning performance enhancement is the class of motivation-based interventions [16]. This type of intervention aims to retain the learner's motivation on a high level, by intervening in case the player's motivation decreases. Such an intervention appears as feedback, praise, incitation, encouragement, or directing attribution of success or failure. It is of crucial importance, that the interventions are triggered in the right situation, otherwise, they may disturb the game flow. In order to trigger interventions to maintain the motivation, the player's actions are monitored and a motivation level is calculated. If this level is low, then an intervention is triggered.

Based on the considerations of the 80 Days project [20] we created a motivation model consisting of three major motivation aspects – attention, satisfaction, and confidence. Thus at the motivation level is a triplet of these three values. The main in-game actions that are taken into account to calculate the motivation level are:

– Number of help requests,
– Number of attempts to solve the task without success (called error guess),
– Reaction time (timespan between task start and first player reaction),
– Solving time (timespan between task start and successful attempt to solve the task).

In order to align the in-game actions with their effect on the motivation level, the following considerations are used. The motivation aspect satisfaction is updated based on the in-game achievements, i.e. it is upgraded every time the player reaches a new level. Reverse, when such an achievement is not reached in a given time period the satisfaction downgrades. The aspects attention and confidence are evaluated together. If the player answers too fast, i.e. the reaction time is shorter than the time to understand the given task, the attention downgrades. The player is most likely guessing; all other information about the motivation quantities is ignored. An appropriate reaction time leads to an evaluation adapting both motivation aspects – attention and satisfaction. First, the solving time is compared to a maximal solving time. If it is fine, the motivation aspect attention upgrades. A too long solving time leads to a higher attention value. Second, the help requests and error guesses are compared against their upper restraints. If one of them is too high, the motivation aspect confidence downgrades. If both values are fine the confidence upgrades.

For updating the individual motivation values, the following formula is used:

$$v_{i+1} = \mathbf{I}_{upgrade} \cdot \left(1 - \frac{1 - v_i}{2}\right) + (1 - \mathbf{I}_{upgrade})\frac{v_i}{2} = \frac{\mathbf{I}_{upgrade}}{2} + \frac{v_i}{2}. \qquad (1)$$

In this formula, v_{i+1} describes the new motivation aspect value, v_i describes the old motivation aspect value and $\mathbf{I}_{upgrade}$ is the Indicator function yielding one in the case of an upgrade and zero in the case of a downgrade. This choice raises or reduces the current value by exactly the half of the possible maximum value.

We use critical low motivation aspect values to identify game situations with a need to intervene. Of course, these critical low values depend upon the update procedure applied to the motivation aspects. For example, when starting with an initial aspect value of 0.5 and the above-mentioned update formula we can reach an aspect value of 0.25 after the first downgrade. Even with an initial value of one, we reach this value after two downgrades. Depended on the game, the game designer needs to answer the question – after how many downgrades do I want an intervention based on the player's status?

3.4 Software Asset for Player Profiling

Recent research indicates that different personality types are attracted by different game design. For example, there is a significant difference on how extroverts and introverts react to leaderboards [5]. In a gamified educational setting, leaderboards generate a different effect on the received playfulness; for extroverts, the leaderboards had a negative effect. For introverts, this relation was opposite in direction. As another example, the connection between player types and personality types are gaining more and more attention [8]. In this context, a table linking different player types, personality types, game elements and game mechanics among themselves was elaborated.

Proven ways to determine the personality type and characteristics are by using psychological questionnaires. There is a wide variety of such questionnaires available to categorize players. For example, we can use the short measure of Big Five personality traits [11] or the Brief Sensation Seeking Scale [13].

The Player Profiling Asset provides an easy way of including a questionnaire into a game. Questionnaires can be loaded, modified and created with an authoring tool into an XML file. The software component uses this file to supply the questionnaire data to the game developer via a well-defined interface. With the supplied data, the graphical representation of the questionnaire is up to the game developer who can tailor it to the individual need of the specific game. The software component then calculates the personality scores after receiving the player's answers.

4 Technical Evaluation

We embedded the assets in a simple showcase game to demonstrate functionality and integration as a first technical evaluation. Due to the technical demonstrating function of this showcase, we did not create an appropriate story. The game consists of a human controlled agent trapped in a dungeon. This dungeon is represented by a series of rooms. The player searches for an exit by solving a riddle in each room to get to the next one. Each dungeon room represents a game situation in the game design. There are two room types a player is facing, see Fig. 4. The first type offers three different doors to leave the room, each marked with an answer. The second type offers four switches marked with numbers; the player has to select two of them to unlock the only door in the room. A help is available for all six different game situations. A NPC standing in each room prompts Interventions.

The Competence-based software asset models the domain of basic mathematic operations. It selects a basic mathematic operation every time the player enters a new room. The room type alternates between type one and type two. Based on the selected mathematic operation, a random task is created and random answers are generated. If the player solves the task correctly at first try, the game situation is considered as successfully solved, or unsuccessfully otherwise.

The Motivation-based software component monitors the behavior within each game situation. It counts the help requests and measures time until the first and last player action. In the case of room type two, it also counts the number of

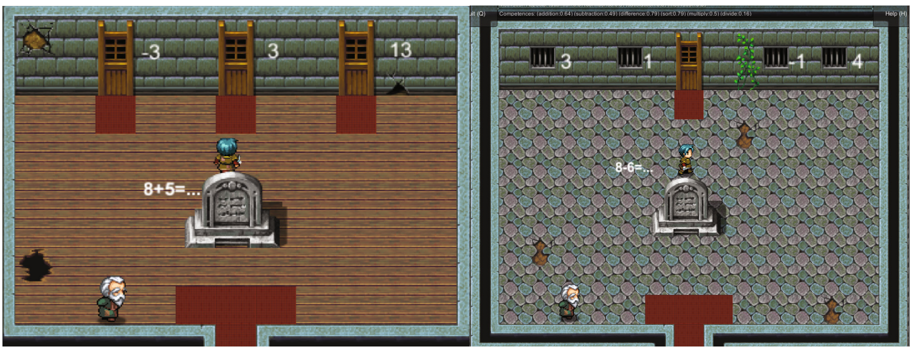

Fig. 4. These are the two types of rooms in the showcase.

Fig. 5. This is one of the intervention prompted to the player in the showcase.

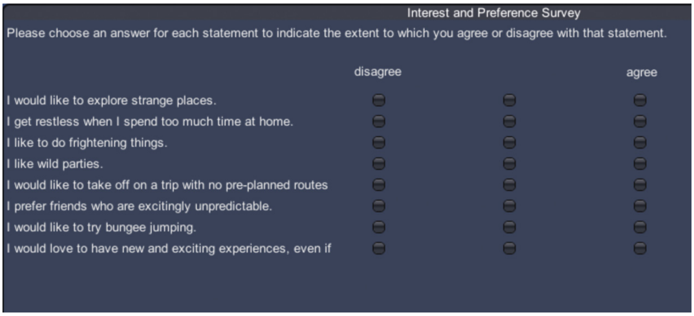

Fig. 6. This is the questionnaire presented to the player at the beginning of our showcase.

false attempts to open the door. In case we reach the critical low value of 0.4 for the motivation aspect attention, we trigger an intervention; to demonstrate an alternative intervention we decided us to shake the room in this case.

With the help of the Cognitive Intervention software component, we identify misconceptions and deviation from desired behavior. As an example for misconception, we prompt a message after the player selects a wrong first switch in room type two, see Fig. 5. An example for deviation from desired behavior can be observed, if the player chooses the correct first switch, but waits too long to select a second switch.

A questionnaire to determine the player's sensation-seeking tendency is presented with help of the Player Profiling software component, see Fig. 6. The player is then categorized either to have a high sensation-seeking tendency or to not have a high sensation-seeking tendency. When first entering the dungeon the NPC prompts the player, in the case of a high sensation-seeking tendency.

This showcase game is available online, tested with windows 10 (http://css-ti.tugraz.at/projects/rage/assets/dummygame/DummyGame-Application.zip).

5 Conclusion and Outlook

The presented assets enable game developers to easily incorporate different models of learning support in their games. We realized each learning model as independent software asset, composed of one or more components. These assets serve four dimensions of learning support, which are competence development, motivation maintenance, problem-solving support, and adaption to the player's personality within a game. Each asset builds up upon a XML data model; it adjusts the corresponding assets to a specific game. This separation of the general learning model and the game specific data model ensures a minimal effort when including the software component into a game. We presented a showcase game to demonstrate functionality and integration as a first technical evaluation.

Future work will focus on the evaluation in terms of learning. We will evaluate games developed within the RAGE project using several assets; the assets cannot be evaluated without a game. The evaluation approach will include three perspectives: the asset, the underlying data model, and the game implementation. Each of these elements is essential for an evaluation in terms of learning.

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Immersive Experiences for Children with Special Needs and Older Adults

A Prototype Immersive, Multi-user 3D Virtual Learning Environment for Individuals with Autism to Learn Social and Life Skills: A Virtuoso DBR Update

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Abstract. The specific aim of this session is to discuss the early design of a collaborative, immersive learning intervention for youth with Autism Spectrum Disorders (ASD), named Virtuoso. Building on our presentation at AECT 2016, this session will describe design and development progress to date, share our design narrative, explicate underlying theoretical and design principles, provide session participants an overview of the Virtuoso system, and present a timeline of ongoing research and development.

Keywords: Immersive · Virtual worlds · Autism

1 Project Description

Virtuoso is an immersive 3D learning intervention for youth with Autism Spectrum Disorders (ASD). This immersive learning intervention adopts a multidimensional approach for providing learners with ASD the ability to acquire both social competencies and life skills in a safe environment that can be manipulated so as to reduce input stimuli and adapt to learner needs. ASD is a pervasive developmental disorder characterized by a triad of impairments, including deficits in social interaction, verbal and nonverbal communication, and repetitive behaviors [1] which greatly influences an individual's independent functioning and quality of life. ASD affects one in 68 individuals [2], or nearly 2% of the U.S. population [3]. Given this high prevalence and the significant impact of the disorder, effective interventions are imperative to address the difficulties in social interaction and communication that individuals with ASD experience.

The aims of Virtuoso include (1) reducing barriers and promoting independence and self-efficacy; (2) providing explicit, direct instruction related to social competencies; and (3) creating an immersive virtual space that is safe, controllable, and highly accessible. To this end, Virtuoso is being developed using a participatory design approach. Researchers, intervention specialists, and graduate students are working together with

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individuals with ASD in an young adult day program to design an intervention program of curricular and technological supports.

This work contributes to and extends extant research on immersive learning for individuals with ASD, including that of the iSocial project, which delivered a 5-unit social competence curriculum to youth with ASD in a 3D collaborative virtual learning environment [3D CVLE; 4, 5] and of the AS Interactive project, which had a focus on using public transportation in a 3D single-user virtual environment [6]. This work differentiates itself from prior research in that, to date, the majority of work in this area has focused on providing interventions and supports for individuals with high-functioning autism. Individuals with ASD are regularly categorized on a spectrum that spans from severely affected to high functioning. Individuals with an IQ lower than 70 and with other cognitive impairments are considered to be cognitively lower functioning. Our work focuses on individuals with more severe manifestations of ASD.

For example, like the AS Interactive project, one of the training foci of Virtuoso is on using public transportation in a safe and socially appropriate manner. The adult day program provides internship and employment opportunities for individuals with ASD; however, employment settings are often geographically distant from where the day program is housed. Day program associates (individuals with ASD who are involved with the day program's services) need transportation to these settings. However, transportation is one of the most cited barriers for individuals with disabilities to be included in community settings. The Virtuoso public transportation training combines curriculum, technological supports, and behavior interventions to help associates become more independent users of public transportation. Specific details and a brief demonstration will be provided at the presentation.

We are currently developing a rapid prototype of Virtuoso using High Fidelity [7]. High Fidelity is a next-generation virtual worlds toolkit that supports collaborative, avatar-based virtual world interaction using desktop displays as well as emerging virtual reality hardware such as Oculus Rift and HTC Vive. High Fidelity is designed to easily scale and to reduce latency problems that have long plagued virtual worlds platforms. This platform allows us to quickly and easily create rapid prototypes that can be used for evaluation and analysis, while at the same time providing a platform that can scale as our project continues to grow.

2 Research Methods

Virtuoso uses a design-based research (DBR) methodological approach. This methodology is a technique that integrates rigorous research with meaningful and relevant solutions to problems often involving educational technology. DBR relies on multiple iterations of analysis and exploration, design and construction, and evaluation and reflection to establish the impact of educational interventions over time [8]. Using this iterative approach over phases of design, implementation, and evaluation, Virtuoso is steadily evolving into a highly refined intervention that is sensitive to the local context and needs.

For the presentation, we will discuss the simulation we are currently developing for using public transportation and results of our usability evaluation with 10 participants. We are using a multidimensional approach to assess usability that was developed in the context of e-Health for serious games by systematically observing patients and families under controlled conditions [9–11]. This approach considers functionality, layout, flow, and content (system) and learning, reflection, and satisfaction (user). Participants with ASD undergo a 1–2 hour-long testing session. Think alouds will also be used to enable the evaluation of the thought processes or decision making of someone performing a specific task. Participants' gaze behavior will be captured using an eye-tracking device. Eye-tracking allows for analysis of eye fixations and movements, thus enabling additional insights into errors, how participants interact with Virtuoso, and expectations.

The Morae usability software suite will be used to record sessions, including screen, webcam, and audio recordings, and eye-tracking data capture. Individuals with ASD may have difficulty thinking aloud due to increased cognitive load and ASD effects. Hence, we will couple the think-aloud methodology with an approach developed for conducting usability evaluations with individuals with cognitive impairments, All-Views Empirical Analysis [12]. This approach utilizes simultaneous analysis of screen capture, webcam and audio recordings, eye-tracking, and trace data (usage analytics) to establish a holistic snapshot of human-computer interaction. This allows researchers to infer usability issues in the absence of think-aloud narrative. Difficulties using the system as a result of ASD will be analyzed and used to refine the 3D CVLE. Upon completion of each usability session, participants will complete the 10-item System Usability Survey to quantitatively assess usability [13]. Our goal will be to make appropriate modifications to our program to attain a usability score >65, indicating high usability.

3 Conclusion

Our current work centers on the development of a rapid prototype 3D CVLE for providing training on life skills for individuals with low-functioning ASD. We are exploring the use of logged trace data to represent user behavior in the environment and how we might incorporate those data into our research analyses. We are also exploring how to develop supports in the 3D CVLE that are sensitive to the unique needs of the participants. For example, we are interested in providing individualized feedback mechanisms that respond to user behavior. The question of generalization and transfer of skills from within the 3D CVLE to the real world is an issue that has been noted in the literature. Our future work will focus on this problem in particular. To this end, we are developing a family of diverse strategies. Examples include a fading of prompts approach, job aids delivered via virtual and real-world mobile devices, and incorporation of multi-modal supports within our broader curricular approach.

Due to the high prevalence of ASD, and the significant impact of the disorder, effective interventions are imperative to address the difficulties in social interaction and communication that individuals with ASD experience. The Virtuoso immersive learning intervention adopts a multidimensional approach for providing learners with ASD the ability to acquire both social competencies and life skills in a safe environment that can be manipulated so as to reduce input stimuli and adapt to learner needs. Research and development is ongoing. We will present an overview of work to date and a projection of future work (approximately one year).

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DISCOVER-ing Beyond OpenSim; Immersive Learning for Carers of the Elderly in the VR/AR era.

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Abstract. Elderly carer training either formal or informal, imposes a long term healthcare and economical cost. Age, work patterns and overall demographic realities make ordinary approaches of teaching cumbersome and at times, even counterproductive. Scenario based learning has already been proven a reliable modality for self-directed education both in formal and informal context. Within this context, virtual environments have also been established as immersive experiential platforms for delivering such educational scenarios to learners. Additionally, with the advent of emerging technologies like Augmented and Virtual Reality (AR/VR) immersion and overlap between the real and the digital become ever increasing. This work describes the evolution of design and implementation innovations that originated in the EU funded DISCOVER project. Specifically, after a brief overview of design guidelines and previous implementation endeavors in virtual environments, the transition of this kind of educational content into the realm of mixed reality is described. Then, an evaluation strategy for such an approach is explored. Finally, the place of such a work in the roadmap of an educational living lab design and implementation is discussed.

Keywords: Scenario based learning · Virtual environments · Elderly care · Augmented reality · Mixed reality · Living labs

1 Introduction

Digital technologies have shaped interventions for healthcare and well-being from their inception. Reduced costs and increased capacities due to innovations in technology have addressed social inequalities as well as fostered economic growth, diagnostic efficacy and intervention effectiveness in the sensitive healthcare sector. This is especially true in the elderly care and wellness sector for chronic diseases [1].

In this specific subfield there are specific challenges that obstruct optimal healthcare delivery to the elderly from carers as well as maintenance of quality of life for the carers themselves. Such obstacles are care cost, the seniors' limited ability for self-sufficiency, as well as the psychological implications of such dependences on both the elderly and the carers [2]. These obstacles many times skew the perceptions of the carers about the effort required for their duties with corresponding care inadequacies. For example Hospital informal caregivers (relatives of hospitalized elderly) confronted firsthand with

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the realities of their role as caregiver, were confronted with the lack of both experience and knowledge to deal with the needs of their charge (patients care, disease, treatment, nutrition, insurance funds, etc.). Formal carers (Nursing staff) on the other hand could not maintain a consistent level of care in chronic disease care for the elderly due to varying degrees of experience as well as the diverse educational background of such stuffs in the healthcare institutions [3].

To address this disparity of needs a learner centric, experiential approach was used. This was Scenario Based Learning. This consists of activities such as simulations, scenario narratives and other organized task-based learning experiences. This approach has been used in various fields for experiential training [2, 4] with many academic and vocational training curricula benefitting from such interactive virtual scenarios, in the healthcare sector aptly named 'virtual patients'. This kind of content and supported learning episodes are designed to be custom and aligned with both the behaviors and experiences of students providing a game–informed, media-saturated learning environment. In that way students can negotiate a case with multiple different options, hone and exercise decision making skills and explore the consequences of their decisions in a safe but engagingly impactful manner [5, 6].

In order to increase immersiveness and immediacy this scenario based approach has utilized as a deployment platform the Multi-User Virtual Environment. This modality, evolved from the mass proliferation of computer games, specifically massively multiplayer online role-playing games (MMORPGs), evolved into a less goal and more activity oriented interactive software, the multi-user virtual environment (MUVE). This is defined as a synchronous, persistent network of people, represented as avatars, facilitated by networked computers [7]. From this definition emerge the inherent advantages of the platform for educational purposes. Multiple users with the immediacy and persistency of synchronous communication, provides collaboration opportunities for both serious and non-serious goals. Furthermore the graphical representation of the user in human likeness implicitly reinforces the users presence and immersion in the virtual environment. These attributes permit the user to partake in the online events with an invaluable experiential intensity [8].

Another medium of increasing experiential intensity, Virtual labs leverage the strengths of computerized models and simulations along with other instructional technologies (video etc.). The goal in this immersive modality is to replicate real life laboratory interactions. For example, a simple virtual lab, would include a series of digital simulations supported by video demonstrations, while a more technologically intensive implementation would incorporate complex virtual reality simulations [9]. These immersive interactive environments facilitate a self-directed, self-paced learning process. By repeating content at will, accessing it at off hours and overall maintaining the initiative in their learning process the user becomes an active participant in the learning endeavor.

Beyond that, the experiential intensity and the capacity for manual simulations in virtual laboratories can cover core weaknesses in training of a manual oriented practice as encountered in the overall healthcare sector. For example, with the current state of the art in genome analysis it is imperative that physicians have a strong scientific background [10]. However the manual laboratory techniques for such procedures cannot be taught through a handbook, neither can institutions provide equipment and personnel to safely and effectively train students on them [11, 12]. This previously limited medical education to theoretical understanding leaving new physicians with significant gaps in their practical lab and clinical skills [12].

To cater for such needs there is an approach, used so far in science training, which brings real world skills to education through the incorporation of virtual and augmented reality (VR/AR) technologies. There are strong evidence that AR technology can increase educational impact of various learning episodes and in that capacity greatly affect the educational outcome [13]. Examples include world exploration at a very experiential level [14], experiencing and visualizing physics and chemistry [15–17]. This immersive immediacy can also be used for the engagement and motivation of students to explore the curriculum on their own and even internalize it intrinsically, thus avoiding conceptual errors [18].

This work presents the effort to coalesce the immediacy of a mixed real/virtual space laboratory with the interactivity of the gamified virtual patient to create a novel but accessible clinical skills training environment utilizing low cost and low development overhead hardware and techniques.

The use of these educational means in the context of elderly carer education was explored in the context of the DISCOVER (Digital Inclusion Skills for Carers, bringing Opportunities, Value and Excellence) the education of carers (informal and formal) project. In this work we explore the innovations in design and implementation of the deployment of a virtual case for elderly care support. Furthermore we explore the technical necessities and implementation of a mixed reality application that incorporates all these principles away from the screen and into the context of a real educational living lab. The rest of the paper is organized as follows. In Sect. 2 we explore the scope of the DISCOVER project and how the deployment of a virtual case falls within this scope. In Sect. 3 the design and implementation details of the virtual case are explored both for the MUVE as well as for the mixed reality living lab implementation. In Sect. 4 a discussion of these technical details is presented along with the position of this research in the wider context of both carer life-long learning, game based learning and educational living labs evolution.

2 Approach and Guidelines

2.1 Elderly Carer Training Through Contemporary e-Learning Paradigms; the DISCOVER Approach

During the EU funded DISCOVER project a mixed experiential training approach was adhered to for lifelong training of the carers for the elderly. The overarching aim was to build an integrated tutoring environment that would provide information and knowledge for a variety of topics that are related to decision making as well as knowledge acquisition on the subject of elderly care.

Thus the learners were constantly motivated to record and classify the content of their learning experience with tags to be used both as content verification, but also as ad-hoc content descriptive annotation [19]. For that reason, several taxonomies have been developed within the project to facilitate accessibility, reusability and ease of communication for and of the learning objects utilizing these metadata regarding both content and e-learning facilitation in general [20–22]. One such example includes the Digital Skills, Dementia and Assistive Technologies taxonomies, developed as thematic, content relevant ontological entities, and which were direct research results of the project. On the other hand, an infrastructural e-learning data model intervention consisted of the enchancement in the SCORM model for online courses through the use of metadata was included in the Discover4Carers moodle platform, evolved from an e-learning system supporting the goals of the project. In the vein of experiential learning, the DISCOVER project utilized the Open Labyrinth Virtual Patient creation and deployment platform [26]. This specific axis of the project was evolved first to the MUVE space and then (as shall be described here) in the AR/VR space.

2.2 Scope Alignment for MUVE-Deployed Scenarios in the Context of DISCOVER

The DISCOVER platform with its delivery model addressed the lack of (formal or informal) carer digital skills. It also aimed to address the lack of topical training in this area. Proper carer training is a contributing factor for both their and their charges'. In that context, the DISCOVER project's guidelines aim at better care provision through socially and technically innovative elements as well as through revisiting and amending existing practices towards novel technically supported solutions for better care provision. What follows is these main guidelines as they are pitted against the attributes and capacities of mixed reality immersive learning content in order to demonstrate the rationale for following through this implementation. For a more extended discourse about the scope of DISCOVER please check the project's website [23, 24]

- Guideline: Iterative user-driven methodology to ensure proactive and continuous involvement of users. Rationale: Mixed reality exploratory learning experiences offer to the user the experiential motivation for interaction and learning.
- Guideline: Real Living Lab (LL) test environments to ensure the best opportunities/ conditions for business success. Rationale: Mixed reality learning experiences in the space of an actual living lab combine both the experiential intensity of digital content as well as the actual LL benefits towards the aforementioned opportunities and conditions.
- Guideline: Training available through a variety of channels including web, mobile, iPTV and gaming consoles provides for significant levels of synergy in terms of enhancing inclusion goals for individuals at risk of long-term social and financial exclusion. Rationale: Simple, inexpensive AR/VR headsets based on the Google cardboard principle (mobile device as digital content deployment platform) adhere to a great degree to this specific goal.
- Guideline: Digital skills embedded into existing content of care, training providers to change perceptions and raise awareness of digital solutions to support high quality care as well as addressing sustainability. Rationale: A digitally augmented physical

space is the ideal place where digital skills can be embedded and internalized, especially for groups whose demographics are not part of the digital era.

- Guideline: Personalized learning pathways fit with time constraints and pressures of the carer role. Rationale: An augmented reality application that enriches an existing space and can be experienced at the learner's pace and order of encounter inherently adheres to this guideline.
- Guideline: Platform independent content including diverse resources, guides, and online simulations designed to promote more engaging learning experiences. Rationale: While true platform independence is very difficult to achieve in the mobile device realm, the proliferation of Android and iOS systems, both of which are supported platforms for the developed application provide adherence to this guideline.
- Guideline: Localization Flexibility including integration of training modules in a growing number of languages over the course of the platform's deployment into new markets. Rationale: Given that the narrative content of the mixed reality application is audio based with clips being customizable by the developer/facilitator, localization is easily supported through both automated means (text to speech supported by translators) and manually (the overhead to record audio-clips even from a simple smartphone is trivial).
- Guideline: Capacity building for carers to become trainer mentors and pass on skills to patients for mutual benefit. Rationale: The internalization that occurs through the immersiveness of an mixed reality delivery method allows the rapid consumption of content and the capacity of the learner to become immediately able to convey to others the new knowledge.

3 Methods

3.1 Application Design

Through the previous discourse it becomes clear that the MUVE deployed virtual case aligns completely with DISCOVER's operational goals for delivering effective training for carers of the elderly. Designing, however, a game-based experience for this specific group of learners needs to take into account its cultural and demographic make-up. The target group of DISCOVER's MUVE deployed Virtual Scenario consisted of old adults (over 50 years of age on average) of varying educational background. All of them are expected to have low to medium computer literacy skills as well as low to none gaming experience. From Game design literature there are several key aspects that have to be taken into account when designing a game [25].

- Reading ability: it is usually better to narrate through imagery and not through readable text. That is why the whole of the narration was conducted through audio (voice narration).
- Learning Curve: The application, as it was developed, has zero learning curve. The user needs only to start the application on her smartphone, attach the device to the inexpensive headset and then begin her learning exploration.

- Cognitive abilities: Given the straightforward user interface and the exploratory type of the learning episode that was aimed for, the cognitive overhead, even for people of some age is minimal.
- Learning style: Learning style does differ according to demographic. E.g. men on average learn better by doing, while women, on average, learn better by instruction [25]. While it is impossible to have an overall generic procedure, the exploratory, experiential way in which the content is presented was considered to be as close as possible to the natural inquiring mind's way of discovering things.
- Physical Abilities: Both the subject matter and the target group's composition dictate against intense physical interaction in the game design. Adhering to that, a deliberate pace of exploration is supported both by the environment, as well as by the narrative platform. Audio narrative in a natural non-urgent tone facilitates this requirement.

Based on these rationale the educational scenario that was designed consisted, as already hinted at, of a mixed reality application that enriched a physical space with image recognition triggered audio narratives which outlined risks and possible pitfalls that can occur in a natural home environment for an elderly person.

3.2 From MUVE Implementation to a Mixed Reality Implementation

The virtual scenario implemented involved an informal carer's (son or daughter) adventure as his/her father moves in to live in the same house due to deteriorating mental health. Details of the implementation were discussed elsewhere [27]. In brief, a node architecture was implemented through invisible, non-interacable in-world objects that contained the logic of the scenario as well as the narrative content [27]. The user moved in the environment and interacted with the in-world items, receiving feedback and navigating the scenario to its successful or not completion.

Implementing experiential content into a mixed reality paradigm, towards a similar goal, the aim was (a) to utilize real physical environments, and (b) augment it with digital content relevant to carer education and training.

The implementation consists of an educational laboratory decorated with AR targets. These shall present, through an inexpensive digital eyewear headset, (Fig. 1) the augmented digital content. In this case, the content consists of audio information, utilizing the mobile device's speaker for narration. To that end a number of AR targets with non-visual content, carrying the audio recordings were implemented. These were put in a real environment (The Lab of Medical Physics' Living Lab) in order to offer educational audio content when the user wears the mixed reality headset and meets such a target in the environment. This kind of educational content has relatively low asset complexity overhead. Thus, custom game engines or standalone 3D solutions are not warranted for effectively translating the educational narrative to the envisioned gamefied mixed reality environment. Given these development attributes, the application was developed using Unity 3D and the Vuforia AR/digital eyewear platform. This development environment provided the ease of use necessary for rapid development, while maintaining a sufficient level of versatility for the kind of content expected to be used within this work.

Fig. 1. Inexpensive Digital Eyewear Headset using the mobile device as application deployment platform

At this stage the application is fully developed. The evaluation of this application will take place in the Living Lab of the medical physics laboratory. Formal and informal carers shall take place custom exploratory learning pilot episodes. In such episodes, each learner shall be exposed to the educational mixed reality environment and explore it, learning about possible pitfalls in elderly care at several points of interest (e.g. fall risk from a folded carpet, hazard risks from kitchen operations, etc.) Educational value shall be assessed through topic specific questionnaires. In addition to that standard engagement and user perceptions evaluation questionnaires shall be filled out by the participants to formulate a concrete picture of the efficacy, usability and impact of this mixed reality virtual environment.

4 Discussion

4.1 Context

System and resource interoperability are significant aspects of open education research [28]. In that context, streamlining of content creation (be that a MUVE based virtual scenario, or an exploratory immersive mixed reality experience) is a necessary first step for utilizing versatile schemes for case authoring tools and other similar repurposing efforts. Taking cues from established educational modalities such as VPs and Problem Based Learning (PBL) approaches [6], efforts are already directed at the overall repurposing/semantic annotation of such content [29].

In the same context, medical education in a gamified context, moves to exploratory freedom for the learner with increased likeness to reality. For example, the dynamic patient simulator [30] and the virtual standardized patient [31] are approaches that extend the research on game based educational episodes. Given, also, that computer games offer a that can seamlessly and unobtrusively integrate analytics support, it is not odd that there are already attempts at stealth assessment [32] in game based learning.

Regarding the rationale for moving such educational endeavors in the AR/VR space, it has been demonstrated that the use of AR technology has a positive effect in learners' retention of knowledge through immersion into the subject matter. [17, 33–36]. Currently, straightforward AR applications are becoming ubiquitous through inexpensive headsets that utilize mobile devices. That way, educators are provided with a widespread platform for immediate access to mixed reality learning content. It has been supported, that it is better for learners to interact in a non-entirely-virtual laboratory, making the mixed reality learning environment an optimal solution [37] Furthermore, it has been postulated that mixed reality learning laboratories have had a positive effect in the time it takes to finalize lab experiments if compared against non-digitally enhanced ones [33]. The rationale that was offered for this difference was the ability of the learner to establish a mental paradigm that integrated science mechanisms easier through immersion. That same process was reported to be a factor, also, in assisting the learner to achieve a positive outlook towards such non-straightforward subject matters, through both increased comprehension but also through increased engagement to it [33]. Transferring such experiential immersion in the healthcare domain, the incorporation of digital content in the real world appears to provide the same kind of impact as conventional Living Labs offer in other sectors of research and business.

A Living Lab (LL) is an environment simulating or actually housing people and supported by technology (facilitators and sensors/actuators), in an unobtrusive, semi experimental setting with the explicit purpose of fostering symbiotic research, development and innovation [38]. A key aspect of a LL is that it morphs the users, from observed subjects, into members of a co-creative ecosystem. Living Labs have been defined formally as "a user-centric innovation milieu built on every-day practice and research, with an approach that facilitates user influence in open and distributed innovation processes engaging all relevant partners in real-life contexts, aiming to create sustainable values" [39]. From the definition it becomes clear that LLs are enablers for businesses, authorities, researchers, and customers towards collaborative innovation, research, co-creation, and marketing, that is applicable in many real-life environments [39]. Existing literature offers rather diligent conceptual discussions about co-creation in LLs. Results from focus groups, interviews and observations, combined with the systematic literature reviews coalesce to six critical factors for fostering co-creation in living labs environments [40]: Engagement, Relationship Management, Operating Principle, Design Layout and Data collection Approach.

In this conceptual discussion, the very first factor, Engagement, is the main focus, also, for the development and deployment of a mixed reality educational environment in a real world setting. The second factor, Relationship Management reflects the functional inter- and intra- institutional relationship between the living lab management and the end user of it [41]. In this relationship, there is direct analogy to be drawn from that to the relationship of the educational environment and facilitator personnel with the learners which are "end users" of the educational process. The third factor, Atmosphere, refers exactly to the immersive facilitation that a mixed reality environment is aiming for. Operating principles, in Living Labs, are a set of overarching guidelines for optimal use of the facility in its context. In the educational context this is directly relevant to the specific educational paradigms (PBL, curriculum optimization) that support the mixed reality educational environment. Furthermore, Design Layout as an aspect that fosters co-creation in living labs is a direct outcome and specific requirement upon which a mixed reality educational environment is devised. The creation of (or the verisimilitude of) specific and each time differentiated educational environments is the very reason for which the real educational environment is enriched through mixed reality technologies. Finally the Data Collection Approach of a living lab environment involves both the sensors' configuration and the data collection strategy. In that comparison a mixed reality educational environment moves in parallel with ready provisions for in app analytics augmenting the physical space's data collection capacities.

4.2 Concluding Remarks

Multiuser Virtual Environments offer great graphical richness and immersion in scenario based learning episodes [42, 43]. This attribute [42] points to a clear direction for creating emergent, experiential, dynamically created content. This work's guidelines and implementation can easily incorporate repurposable content with real-time analytics allowing the carers performance to be assessed and used for various carer learning needs and preferences.

This work evolving along the axes of the DISCOVER project demonstrates ambitious uses of simple methodologies and implementations. Through effective practices and considerations of context these guidelines can contribute to significantly innovative results even beyond SBL within and outside the context of elderly carer support.

Given the previous brief discourse, evolving this effort into a mixed reality virtual environment is a natural next step in immersive experiential educational modalities as instruments for immersive engaging and collaborative vocational training. This instrument, combined with the aforementioned ubiquity of AR development, makes this work a step toward the creation of low technological intensity, financially viable and versatile educational living lab environments.

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Demystifying Ageing Bias Through Learning

Co-designing an Online Course About 'Ageing Well'

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Abstract. Ageing bias is still one of the major concerns in current society that is likely to lead to misunderstandings about the ageing process, denials and stereotypes that tend to have an impact on both illness prevention and health-behaviour changes. Although many technology-based learning solutions addressed to learners aged 50 and over have been proposed, there has been little discussion about the development of these solutions for prevention and health-behaviour changes in later adulthood. In addition, these solutions rarely take both participatory design techniques and the definition of active ageing into account. Thus, this paper describes the conceptualization process of a video-based online course about 'Ageing well' addressed to learners aged 50 and over of the Universities of Third Age. Perspectives on both strategies and elements for developing an online video-based course to encourage health-behaviour changes and a positive attitude towards the ageing process were sought. Thirty-three learners aged 50 and over were involved in the co-design process and the field research deployed an array of longitudinal methods, including participant observation, surveys and group discussions. This study suggests that the main strategies for developing an online course that takes these learners' context into account should: (a) develop an audio-visual strategy that both triggers narrative immersion and at the same time make the learner familiar with the source of information (mentor's credibility); (b) foster self-knowledge ("know thyself"); (c) reward task-management; and (d) build a community of practice.

Keywords: Ageing bias · Ageing well · Online course · Learning experience

1 Introduction

Recently, a considerable amount of literature has been published about technology-based learning addressed to an older public (*e.g.* [1, 2]). However, there has been little discussion about the use of digitally-mediated approaches to demystifying ageing bias and fostering positive expectations and attitudes towards the ageing process [3].

In addition, the majority of studies in technologies and active ageing (*e.g.* [4]) tend to focus on its application to such contexts as healthcare, sports, occupational therapies and rehabilitation and seem to overlook their potential to encourage health-behaviour changes in learners aged 50 and over and positive attitudes towards the ageing process.

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Ageing bias or *ageism* tends to be unconscious and influenced by media portrayal and fear of the proximity to death [5]. The social identity theory [5, 6] suggests that individuals tend to form groups and look at the ones that they belong to in a positive manner, when compared with other groups.

Nevertheless, when there are stereotypes associated with a group as the case in learners aged 50 and over (i.e. association between ageing and ill health or incapability of learning and change; belief that genetic predispositions are the solely aspect responsible for longevity…), three scenarios are likely to occur [6]: (a) social mobility – when individuals act in accordance with younger groups (e.g. plastic surgery, changing dress style…); (b) social creativity – when individuals emphasize the positive aspects of ageing (e.g. association between ageing and wisdom, leisure time, comparisons between themselves and older groups); and (c) social competition – when individuals challenge others' view of the age group and demonstrate their own value. Technologies may lie a potential agent of change by involving the individuals in the process of learning about 'Ageing well' and thus, demystify ageing bias and encourage active ageing and healthy lifestyles.

The aim of this study is twofold: (a) describe the process of involving a group of learners aged 50 and over from a Portuguese University of Third Age in the design process of the online video-based course; and (b) design a prototype of an online course that demystifies ageing bias and encourages a positive attitude towards the ageing process (i.e. accept ageing as a part of life with its own changes).

Given the definition of 'active ageing' suggested by the World Health Organization [7][1], this course is divided in three modules: Health, Security and Participation in society. The paper is structured as follows: Sect. 2 describes related work on online courses addressed to an older public. Section 3 covers the participatory design process, data collection, analysis procedures and ethical issues. Section 4 presents the prototype of the online course about 'Ageing Well', the learning objectives, main strategies and components adopted.

2 Background and Related Work

The first serious discussions and analyses of adult learning ('andragogy' - proposed by Alexander Kapp) have emerged during the 70s with Malcom Knowles and later such terms as 'Gerontagogy', 'geragogy' and 'educational gerontology' are used to define a relevant field that addresses the aging adult learner [8].

The process of ageing involves changes in physiological, cognitive and psychological as well as social domains. Thus, the educational gerontology field follows the assumption that individuals learn differently, when compared to younger age groups [8].

In general, a number studies and reports (*e.g.* [8, 9]) have proposed a set of recommendations for overcoming the challenges posed by learning in later adulthood. Among these recommendations, the following is proposed: (a) transform ageist

[1] According to the World Health Organization [7:12], active ageing is "[…] the process of optimizing opportunities for health, participation and security in order to enhance the older adults' quality of life as people age.".

attitudes towards learning and ageing; (b) provide mechanisms of self-help; (c) encourage participation in society through learning; (d) foster the use of information and communication technologies in learning and adjust them to age-related difficulties; (e) adapt adult learning to the environment, health and population; (f) create collaborative and safe learning environment based on learners' pace and confidentiality; and (g) match the knowledge transmitted to the learners' previous experiences. It is worth to notice, however, that the learning process is not homogeneous, different learning styles should be considered and in the specific case of adult learners, prior experiences and motivations for knowledge should also be brought to the learning environment [8].

In terms of the distance learning in later adulthood, much of the published research has focused on identifying accessibility issues (e.g. [10, 11]) and its potential (barriers and benefits) [12]. There is, however, a general lack of research (*e.g.* [13]) in the development of these digital platforms that address learning and changes in behaviours in later adulthood. The following (Table 1) is an account of some examples of these platforms and courses used that took into account, either, usability and accessibility issues or the needs, context and motivations of the older adult learner. The search was performed using either academic databases (i.e. Scopus and Web of Science) from January 7, 2017 to February 7, 2017 for publications in English. The search terms used were: ((e-learning) AND (ageing OR aging OR elder OR (older AND adults) OR (senior AND citizens))). This search yielded 854 potentially eligible articles. We excluded those not related with the use or development of a prototype or product (57), those that do not cover either the target group or the process of learning (763), repeated documents (11) or not described with a minimum detail (1) and without full access (15) – leaving 7 (Table 1). Due to the lack of reported cases in the development of e-learning platforms to adult learners aged 50 and over (1–7), we extended our search to solutions presented by the industry (8–12).

As can be seen from the Table 1, there is a lack of reported cases in the development of online courses addressed to adult learners aged 50 and over. In addition, the majority seem to: (a) not involve the target group in the design process; and (b) focus on providing computer skills.

Furthermore, there are a number of theoretical models that aim to explain changes in behaviour [20] (e.g. Health belief model, Transtheoretical model, Relapse prevention, Information processing, Social cognitive theory, Theory of reasoned action, Social support, Community organization model, Ecological models, Organizational change, Diffusion innovation) that also have implications for designing learning environments with impact on health-behaviour changes. As can be seen in Table 2, there are sets of implications for designing learning environments that meet the main behavioural change theories [20–22].

Age-related changes also determine the way learning environments should be designed. For example, such changes in information processing, memory and declines in speech, language comprehension or numerical skills lead to the recommendations for designing learning environments presented in Table 3.

It is worth to notice that although these recommendations seem to be transversal for every learner regardless of their age, relating new knowledge with previous experiences and stimulating the learners to build and exchange their experiences are crucial.

Table 1. Examples of the use of e-learning platforms in later adulthood

Designation	Description
1. Virtual-reality to encourage older pedestrians' safety	This virtual-reality programme is designed to train older pedestrians in how to make safer decisions in situations of two-way traffic. This experiment involved both a full-scale and a small-scale simulation device [14]
2. BusinessThinking	This e-learning platform aims to teach adult learners aged 50 and over to develop technology and career development skills by including such modules as: Internet search engines, Excel, PowerPoint, Word Revision function and Career Development [11]
3. Simulated driving in older adults	Driving Simulator that trains such different skills as 'divided attention, visual-spatial working memory and manual control' [15:2044]. The tasks were: 'car-following single task, memory single task, monitoring single task, car-following/memory dual-task, car following/monitoring dual-task' [15:2045]
4. E-learning for tribal elders	A cooperative e-learning management system that incorporates discussion forums, shared content, assignments, learning calendars, assessment and quizzes. Older adults are encouraged to upload their oral history and the platform fosters interaction between young and old members of a tribal community [16]
5. E-learning literacy tutorials	An interactive-based tutorial to deliver eHealth literacy content [17]
6. TAFCITY	An online course that presents a number of open-educational resources, communication and social networking tools. The learning content is divided into the following topics: 'outdoor spaces and buildings, transportation and housing; Respect, social inclusion and participation; Community and health services, employment, communication and information' [18:68]
7. Unibook	A real-time training application with the following functionalities: Raise Hand, Public and Private Chat, Audio and video conferencing, Desktop sharing and shared whiteboard [19]
8. eLSe-Academy	The eLSe-Academy (eLearning for Seniors Academy) is an e-learning platform that aims to provide older adult learners with skills related with the use of Information and Communication Technologies (http://www.lernhaus.net/)
9. U3A online	The U3A Online is an International University of Third Age that distributes a set of online courses in the following modalities: independent study and study with a tutor. The courses divide into the following categories: History and International Affairs, Nature, Writing and Creativity; Lifestyles and Science (http://www.u3aonline.org.au)

(*continued*)

Table 1. (*continued*)

Designation	Description
10. AARP driver	This online course is related with driving strategies and road safety in later age (e.g. safe driving strategies, information on the effects of medication on driving) (http://www.aarp.safety.org/)
11. Colgate	This online course aims to create awareness about oral healthcare in later age (http://goo.gl/HSaMLz)
12. PlotProject.net	This online course covers the topic of healthy ageing and is divided into the following modules: physical activity, falls, alcohol and tobacco, diet and weight, chronic conditions and medical care, sleep & mind, social connections, optimism and adaptability (http://www.plotproject.net/)

Table 2. Implications for designing learning environments with impact on health-behaviours changes [20–22]

Overview of the main behavioural change theories	Implications for designing learning environments
1. *Health belief model* – health behaviours are influenced by the perceived seriousness of a problem and the potential benefits of a change when compared to the barriers	a. Inform the target group about the potential benefits of changes in behaviour b. Simulate scenarios in which the seriousness of the problem is presented
2. *Transtheoretical model* – the individual goes into different phases of change: pre-contemplation, contemplation, preparation, action and maintenance	a. Reduce the perceived cost of taking an action ('progression to mastery' strategy) b. Present 'step-by-step' challenges
3. *Relapse prevention* – minimize lapses in changes in behaviours by promoting cognitive and behavioural coping strategies	a. Reward the target group when they achieve a goal b. Provide alternative coping strategies as exercises
4. *Information processing* – the information is transformed based on the previous knowledge, coded and can be retrieved in response to different types of cues	a. Provide different types of cues (*e.g.* visual, auditory) to be associated to actions and daily habits/routines b. Provide easy-to-remember information
5. *Social cognitive theory* – As individuals believe that they are capable of changing their behaviours (self-efficacy), they are more willing to perform them	a. Link the information with previous knowledge/past experiences/routines b. Remind of prior successes ("small wins")
6. *Theory of reasoned action* – Changes in behaviours are a result of individual's intentions that is both affected by attitudes towards the behaviour and the 'social pressure' to engage in the behaviour or not	a. Turn the challenges/actions socially rewarding (e.g. invitations from friends, group tasks, events…) b. Promote social accountability

(*continued*)

Table 2. (*continued*)

Overview of the main behavioural change theories	Implications for designing learning environments
7. *Social support* – Social relationships can have an impact on health, well-being and changes in behaviours	a. Provide an example for the target group to imitate (social modelling)
8. *Community organization model* – Social communities can have an important role in improving perceived health behaviours.	a. Build a trust network b. Build a social status towards changes in behaviours (e.g. *ranking*)
9. *Ecological models* – Environments and policies that support healthful choices can positively affect changes in behaviour	a. Inform about current policies and initiatives regarding that change in behaviour b. Provide context-aware information
10. *Organizational change* – Institutions can create awareness and encourage changes in health behaviours.	a. Build a long-term relationship with the institutions that can create awareness and encourage changes in health behaviours
11. *Diffusion innovation* – the dissemination of programmes and innovative ideas in health promotion can also encourage changes in behaviours.	a. Spread the message using media

Table 3. Implications for designing learning environments based on age-related changes [9]

Age-related changes	Implications for designing learning environments
1. Information processing is not as fast as in youth	a. Provide instructional design for different learning paces b. Lessen cognitive load c. Divide information into simple words and pictures
2. Loss of working memory (short-term)	a. Avoid large amounts of information b. Link new knowledge with previous experiences c. Stimulate episodic memory
3. Declines in semantic memory (e.g. historical/cultural facts) and spatial cognition	a. Connect new learning to real-life events b. Familiarize learners with the learning content c. Activate memories and emotions through learning objects
4. Declines in procedural memory (know how to perform certain tasks)	a. Encourage "learn-it-yourself" and "do-it yourself" philosophies b. Stimulate the learners to build and exchange their experiences by bringing moments of their lives into the learning environment

(*continued*)

Table 3. (*continued*)

Age-related changes	Implications for designing learning environments
5. Decrements in sensor capacities (e.g. auditory, visual, tactile)	a. Train visual selective attention skills and decision-making b. Incorporate multimodal feedback and interfaces that can activate auditory, somatic, visceral, gustatory and visual senses c. Follow a set of usability and accessibility guidelines
6. Declines in speech, language comprehension or numerical skills	a. Encourage reading comprehension and spelling through narratives and reading materials b. Create decision-making scenarios that encourage interpretation and abstract reasoning

That way, it is possible to provide an "on-demand" learning experience that is much ambitioned by adult learners.

Overall, these studies outline both the importance and design implications that should be taken into account when designing learning environments, which address prevention and health-behaviour changes in later adulthood.

3 Method

3.1 Co-design Techniques: A Qualitative Design Approach

The co-design technique 'Strategic Visioning and Future Workshops' was used in order to understand the learning context and facilitate the adult learners' expression of their ideas and dreams, trough collaboration activities, visual cues or discussions. This technique followed the phases: 1. Critique in which several themes and learning practices were introduced and discussed; 2. Role-play fantasy in which participants had the freedom to explore new ideas and concepts through brainstorming techniques and categorization of the main ideas into headings and themes; and 3. During the implementation, the raised ideas were converted into goals and adjusted to the existing resources and time. The participatory action research occurred in the participants' natural context (University of Third Age) and included participant observation and group interviewing.

3.2 The Participants

The initial convenience sample consisted of 37 participants. The criteria for selecting the subjects were: (i) being 50 or older; (ii) know how to read and write; (iii) voluntary participation; and (iv) interest in learning. Four participants did not satisfy the selection criteria. One did not fit within the age bracket whereas three did not complete all sessions. Therefore, the final convenience sample consisted of 33 participants.

Considering the gender of the participants involved in the study, sixteen were male (48.5%) and seventeen were female (51.5%). The average age of the sample was 67 years old (SD = 7.06, minimum = 55; maximum = 82) and the majority of respondents in both groups had between 10 and 14 years of schooling. Only four (12.1%) has enrolled a course delivered at distance and the main reasons highlighted were: flexibility in schedules; and personalization of the learning programmes to the learner context.

3.3 Data Collection and Analysis Procedures

Data was collected from March 2015 to December 2016 and the participants received a 2-hour session per week. In ensuring internal validity, the following strategies were used: triangulation of multiple sources of data collected (i.e. field notes, questionnaires and document analysis) and repeated observations at the research site.

The participants' information was categorized into the following codes: (a) participants' learning context; and (b) participants' learning strategies for developing an online video-based course.

3.4 Ethical Issues

This study is part of the research project SeriousGiggle (SFRH/BD/101042/2014), which has been approved by the Ethics Committee of the University of Aveiro (Resolution n. 3/2015) that safeguards, among other things: (a) The informed consent of the participants aged 50 and over; (b) voluntary participation; (c) involvement of the research team in the process; and (d) that the risks of participating in the study do not outweigh the risks associated with the participants' daily lives.

4 An Online Course About 'Ageing Well'

The participants were surveyed about the following topics: participation in learning events, learning challenges, mentoring, video-based content, learning exercises, share of knowledge, mentor's skills, self-contribution to the learning process, division of the content per modules, use of social media in learning, linking the learning content to daily life, learning plan, learning progression and learning profile, notifications about learning content, self-assessment, rewards and certification.

The participants found the following topics to be important and relevant to their motivations and needs: the possibility to go to face-to-face learning events (*e.g.* round tables…) (Table 2 – 6a, 6b, 7a, 10a, 11a; Table 3 – 3a); solve problems related with the learning content (Table 3 – 5a, 6b); share the learning content with friends (Table 2 – 6a, 6b, 7a, 8a, 8b, Table 3 – 4b); get challenges that are linked with daily lives (Table 2 – 4a; Table 3 – 2b, 2c, 3a, 3b, 4b); and contribute with own content to the course (Table 3 – 4a). Furthermore, the *curriculum vitae/*information about the tutor and the reliability of the source of information are considered to be one of the most important elements in the learning process. Although the certification of the course is not seen as a fundamental factor, checking and monitoring the competences achieved with a course

(Table 2 – 2a, 2b, 3a, 3b, 5b) is one of the leading factors that affect their adherence to the course. The following is a brief overview of some exemplar quotes from the participants:

> *"I am ready to receive all provided information because, even in the simple things, there will always be something to learn. Solving problems related with the content is the key to learn."* – P31

> *"There is so much to learn in field trips. What do you think professor? That field trip to 'Casa de Camilo Castelo Branco' was worth it, fun and we learned together. Being in the field is what it is… We should have another field trip"* – P11

> *"As long as the learning content is suitable for our daily lives, it is fine. By the way, you could build a learning space where we could share photos and information"* - P7

> *"As I do not need this [learning course] to a career or get a job, surveying about certification of the course or the competences achieved does not make sense. Now, stating the competences that was achieved and the progress made is very important."* – P30

> "*It is very important that the professor says whether I am doing is right or wrong […]*" – P21

In addition, these participants follow the 'bring your device' philosophy. All participants bring their own devices to the classes and when asked about it, the participants pointed out their difficulty to reproduce the exercises or the solutions to their doubts at home.

> *"One thing is to show in a computer that is not my own and then I come home and nothing seems to work. That is why I bring my computer and mobile phone […]"* – P19

Another aspect that these participants are very suspicious about is downloading content (even if they trust the source) and therefore it would be better to do thing in alternative ways in order to deliver learning content for this target group instead of offering the downloading option.

Considering the participants' learning needs, the recommendations previously presented to meet age-related changes and behavioural change theories, the following areas were considered to design the online course about 'Ageing well': *identity* – adult learners express themselves in the profile area (Table 2 – 7a, 9a); *on-demanding delivery of video-based content and in-time doubts* – adult learners mark their own doubts at a specific time of the video-based content (Table 2 – 1a, 1b, 2b, 4a, 4b, 9b; Table 3 –1a, 1b, 1c, 2a, 2b, 2c, 3c, 5a, 5b); *learning events* – adult learners can manage their own time for learning and interact with others towards specific events about learning (Table 2 – 5a, 9b; Table 3 – 3a); *progress monitoring and rewards* – adult learners can check their own progress and be rewarded by some task management (Table 2 – 2a, 2b, 3a, 3b, 5b); and *communication and shareable information* – adult learners share information and communicate about the content of each module from the learning course (Table 2 – 6a, 6b, 7a, 8a, 8b; Table 3 – 3c, 4b). The course (Table 2 – 11a) covers the essential components previously mentioned by the World Health Organization: Health, Security and Participation in Society (Table 2 – 9a).

4.1 Learning Objectives

The course content and objectives were drawn on the definitions presented by the World Health Organization and the materials and the surveys delivered to the participants were validated by a group of four experts in the fields of: gerontology; psychology; education and; social work.

4.2 Developing an Audio-Visual Strategy and Narrative Immersion

In order to identify the best audio-visual strategy for an online course, participants were asked to express their own opinions. They were given a set of options that were explained and examples were provided, in which participants had to choose the best and explain the reason. The options were: Whiteboard animation (telling a story by drawing on a white board), Picture in Picture (displaying two simultaneous videos), video-recorded lessons (classes are recorded and distributed in video format) and audible slides (static images and text narrated by the instructor). Although the 'Whiteboard animation' seems to be both the most appellative, and the one that grabs attention to the story being told (Table 2 – 4a, 4b; Table 3 – 5b, 6a), when presenting the course objectives and what the course is about, a video-recorded lesson should be used as the whiteboard animation misses the visual cue and "first impression" with the mentor of the course (the source of information presented earlier in Sect. 4).

In addition, when trying YouTube, many participants pointed out that videos should stop when they had a doubt about what was being referred. Therefore, the online platform (Fig. 1) was designed to stop the video when the participants clicked on the button 'I have a doubt' and send not only the doubt to the instructor but also the timing of the video relative to the doubt of the learner (Table 3 – 1a, 2c).

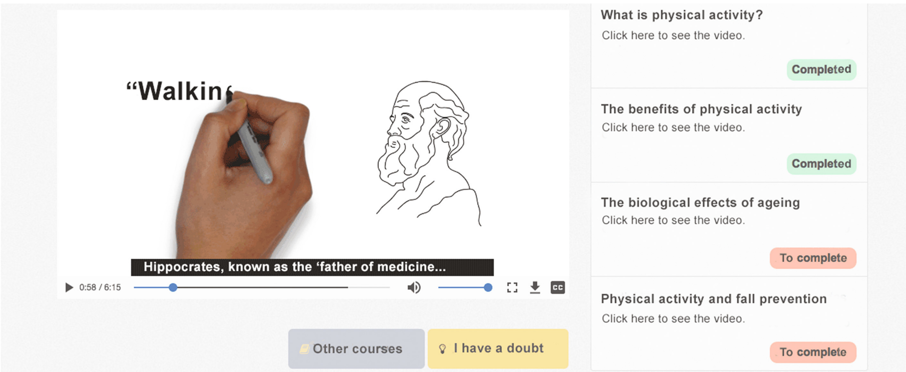

Fig. 1. Classes of the online course

4.3 "Know Thyself": Fostering Self-knowledge in the Online Course

There is a need to engage learners and involve them into role-playing (Table 2 – 6a, 6b, 7a, 8b; Table 3 – 4b, 6a, 6b), aimed at fostering changes in behaviours. Therefore, a profile area was created to enable learners to create their own identity (profile image, description, general progress, enrolled modules, learning team ordered by their progression in the course). This area aims to 'mirror' the current context of the University of Third Age ("myself and my own interests", "the tutor/learning colleagues and their interest", "my progression and others' progression", "the subjects that I have been enrolled") (Table 2 – 10a).

4.4 Rewarding Task Management and Building a Community of Practice

Each module has a set of tasks to be accomplished by learners and as soon as the participants complete them, the number of tasks decreases, badges can be achieved and the percentage of progression is increased (Table 2 – 2a, 2b, 3a, 3b, 5b, 6a, 6b; Table 3 – 4a). Furthermore, there is also an area in which learners can create learning events and a communication area in which learners discuss the learning content with their colleagues (Table 2 – 6a, 6b, 7a, 8a, Table 3 – 4b).

5 Conclusions and Further Work

The course developed aimed to alleviate the negative stereotypes towards ageing and encourage health behaviours and a positive attitude towards the ageing process. In this paper, we described the elements adopted to design an online course to encourage active ageing. These elements are: *identity* – adult learners express themselves in the profile area; *on-demanding delivery of video-based content and in-time doubts* – adult learners mark their own doubts at a specific time of the video-based content; *learning events* – adult learners can manage their own time for learning and interact with others towards specific events about learning; *progress monitoring and rewards* – adult learners can check their own progress and be rewarded by some task management and; *communication and shareable information* – adult learners share information and communicate about the content of each module from the learning course. The literature review on the main implications for designing learning experiences in later adulthood and address changes in behaviours corroborate the results obtained with our co-design experiment. Further work needs to be done in order to test the use of the platform and attitudes of participants towards the ageing process prior and post-course, and possibly involve discouraged learners in the process.

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Immersive Education to Teach Specific Academic Content

Learning Languages and Complex Subjects with Memory Palaces

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Abstract. A memory palace is an ancient technique of using space as a way of organizing memories. It's a powerful tool for learning, retaining, and recalling large amounts of complex information quickly and effectively. In the middle ages, these techniques were widely used to learn and compose large texts and works of literature. In this paper, we present the fundamental theory behind memory palaces as the foundation for the project Macunx - a VR platform for building memory palaces to learn huge amounts in short time and with full retention - as well as the initial stages of its development. The paper concludes with a discussion of the future stages over the testing of the package with end-users for its final refinement.

Keywords: Memory palaces · Cognitive learning · Dyslexia · Spatial memory · Educational games · Heuristics · Interactive learning environments · Virtual environment · Head Up Display (H.U.D.)

1 Introduction

Spatial memory techniques as they can be broadly described – including the use of memory palaces, memory journeys, and the method of loci – systematically apply spatial learning to mastering knowledge-based material typically presented and learned through purely verbal, textual, and numerical formats. These techniques employ innate human ability to process, store, and recall large amounts of spatial information quickly and effectively with relatively little effort. By converting textual and numerical information into visual, experiential, and spatial information, we can learn, retain, and use that information faster than through other methods, including rote memorization, and pure drilling.

Spatial memory techniques have been attested for approximately 2500 years. They were used widely in ancient Greece and Rome for learning and composing works of literature and oration, often of great complexity. We have significant evidence from the Middle Ages of these techniques being used as a primary means of instruction in monastic education. Numerous descriptions of spatial memory techniques exist from the ancient and medieval world, including by such widely known intellectual giants as

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Cicero, Thomas Aquinas, and Hugh of St. Victor. We have yet more evidence of the intellectual feats performed through use of these techniques. In the Middle Ages, for example, it was standard for young pupils to learn all 150 Psalms of the Bible by both Psalm number and line number [1].

In modern times, spatial memory techniques have seen a resurgence in use. Memory competitions have become popular in recent decades, and memory artists have been known to perform incredible feats, including learning long strings of numbers, decks of cards, and other lists of facts [2]. The use of these modern memory systems, however, is extremely limited when compared with their ancient and medieval counterparts. Modern memory systems are used almost exclusively for simple data sets: in other words, information that can be presented in single, sequential lists. In ancient and medieval times, however, spatial memory techniques were used for learning and composing incredibly complex material.

Recent scientific studies [3] have shown the efficacy of the underlying principles of memory as a trainable skill, demonstrating that these principles can be learned and applied by anyone [4, 5]. Successful application of memory techniques requires special training, but not any special innate ability other than that already possessed.

Most educators agree that the interactive nature of e-learning and mobile technologies increase the teacher and student communication. But to date, learning on social media and other e-learning platforms has been a poor substitute for classroom learning. To address this issue, several academic institutions have introduced *blended* [10] and *flipped* [11] learning strategies. In the former classroom strategy, students learn through a “blended” model of in-person (with a teacher) and technology-based instruction with some student control over time, place, path and/or pace of the curriculum.

Virtual reality can be used to support the purposes behind gamified learning since VR alters a person’s perception of reality by tricking the senses and providing artificial computer-generated stimuli [12]. However, tricking human senses can be much harder than tricking the mind. By using multimodality interactivity in relation to spatial domain for creating a believable experience, we can provide the sort of artificial stimuli that are good enough to prompt the mind to create and believe in its own illusion.

In this paper, we present the concept of using spatial memory palaces as a pedagogy toolkit. The paper focuses on techniques used to design the VR memory palaces, user experimentation and the initial development of the Macunx VR prototype [9] currently under the final development stages as part of an EU KEEP+ fund. The study concludes with a set of future steps and possible directions.

2 Memory Palaces: Challenges and Applications

As a skill, spatial memory poses a number of challenges when it comes to wide-scale adoption as a modern pedagogy. In order for memory techniques to be used widely, they need to be applicable to more than just lists of information. The majority of practical subjects – from science, to medicine, to languages – cannot be reduced to simple lists. The information is complex, and requires complex spatial structures for the successful application of memory techniques. This creates several challenges:

- For large-scale systems, there can be an enormous burden on the learner to keep track of and maintain large numbers of mnemonic images. If one of these images is forgotten, it is lost forever and the student must replace that image with a new one. This can cause frustration and can slow the learning process down.
- A common concern is running out of 'space.' It is recommended that students use spaces they know as memory palaces for specific subjects. The same space should not be used multiple times for multiple subjects. In other words, if you have used your house for one subject, you cannot use it again for another subject. This creates a burden of needing to identify and learn a large number of spaces even before being able to apply memory techniques.
- Memory systems for complex subjects require complex spaces, and these are difficult and time-consuming to describe and transfer orally. Training in memory techniques, therefore, can be a very hands-on, time-consuming, and un-scalable process. Learning to apply spatial memory techniques may actually involve walking students through a real physical space while creating imaginative mnemonics and reviewing them periodically.
- In transferring complex spatial structures for the purpose of learning complex subjects, it can be difficult to know whether a student has properly understood an oral description of the spatial layout. With imagined spaces, teacher and student could be thinking of two completely different layouts, but the differences might not be apparent in their dialogue.
- The structure of a memory palace for a complex subject is based on the subject itself. This means a subject matter expert who is also familiar with memory techniques must set up the structure of the space before a student can fill that structure with his or her own mnemonic images.

Owing to these challenges in training and using spatial memory techniques, it is no wonder that they are used almost exclusively today for learning simple sets of data. Wide-scale use of spatial memory techniques for learning complex practical subjects requires a specialized set of tools.

Virtual reality provides the perfect medium for spatial memory training. Students can generate their own mnemonic images using their imagination, but then actually see representations of these images in the form of 3-D models. The software can save both the models themselves, as well as their locations within the spatial structure. This removes a tremendous mental burden for the user, making it possible to create and remember memory palaces of a larger scale and greater complexity. Furthermore, users remember not merely something imagined, but something they have actually seen with their own eyes (Fig. 1).

In virtual reality, an infinite number of new spaces can also be created, so users will never run out of space. Most importantly, however, spatial structures can be created and transferred between users. In other words, multiple users can step inside the same memory palace to understand how the space is set up for specific subject. This makes memory training and its application much faster, more effective, and easier to scale. This has been borne out both by Linguisticator's own first-hand experience, as well as academic studies [6].

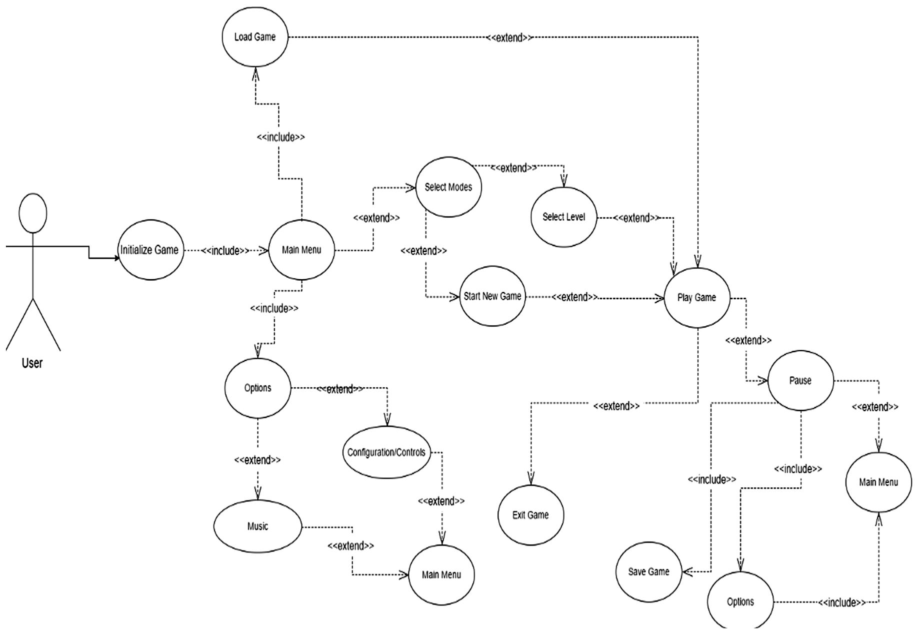

Fig. 1. Use case diagram of interactivity for Macunx VR

3 Memory Palaces for Dyslexia – Concept Testing

Throughout the spring and summer of 2016, Linguisticator Limited performed a number of trials with approximately 20 dyslexic children in Cambridge. Experimenting with both numbers and spellings, spatial memory techniques were used to circumvent and overcome many of the challenges posed by dyslexia.

The majority of students were between the ages of 10 and 14. Most did not know their own phone numbers, so this provided a good starting point for introducing spatial and visual memory techniques. Within 20 min to an hour, all children were able to recite their own phone number not only forwards, but also backwards without error. These results were achieved using purely imaginative memory palaces – no software or visual images were involved. Follow-up visits between one and three weeks later showed that the majority of children had retained 90 to 100% of the material learned in the first session [7, 8].

The same techniques were applied to spelling with comparable success and retention. Children were taught to spell challenging words, such as ‘beautiful.’ By using images placed in space and connecting these images with some kind of narrative – all of which were generated by the students themselves – students transformed spellings of words into vivid and playful stories, each letter of which had a defined character with a specific location.

Preliminary results showed that these techniques unquestionably provided a viable way for dyslexic children to circumvent their learning challenges and use a different methodology to learn the same curriculum as non-dyslexic children. More importantly, however, it was observed that repeated use of spatial memory techniques for learning word spellings actually changed students' perception of text itself. Difficult spellings – once stored using a memory palace – no longer presented the same challenges in either reading or writing, even in entirely new contexts. A word that may have elicited hesitation, and phonetic sounding out each and every time that word was encountered, was subsequently read aloud without hesitation even in entirely new texts. More research is needed to confirm this change in perception, but the preliminary observations have been extremely encouraging.

Further work with dyslexic children has continued to yield impressive results. One 12-year-old boy, for example, has created a mnemonic system for numbers, and has learned Pi to 160 places. The student could repeat the digits both forwards and backwards, and was also using memory techniques to improve his spelling and written composition. In this particular case, the child has been using 3-D modeling software to aid his retention of his numeric systems. Improved results through the use of virtual spaces and mnemonics can readily be observed and have been reported as preferable and more effective by the student himself.

4 Macunx VR Prototype

The word Macunx is short for Magical Quincunx, and is a 2D design developed by Dr Aaron Ralby (Fig. 2). This geometric pattern uses the quincunx (the shape of the 5 side

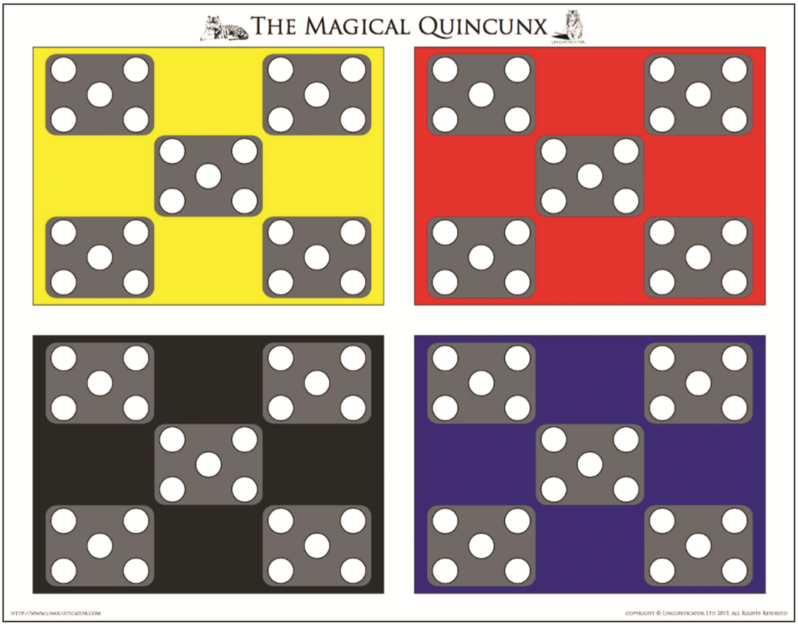

Fig. 2. As a 2D structure, the Macunx can be hung on a wall in your memory palace like a painting. This multiplies the amount of information you can store at each location by a factor of 100!

of dice) to create a memory structure that allows you to learn 100 pieces of information in sequence and by number. The inspiration for the structure came from a 12th century treatise by Hugh of St. Victor on how to memorize all 150 Psalms by number and line number.

The proposed project will consist of three production stages:

- Stage 1: This includes the development of the Macunx VR prototype using Unity. The prototype will have the capability for the users to select objects from a database (create also their own database from loading models/images from local folders or the internet), deploy selective ones (a mechanism to include the most frequent used can be enabled on the User Interface - UI) on the panel – UI and then adjust them on relative locations within the VR Game-mode plane to establish VR memory concepts/ palaces.
- Stage 2: Stage two will be based in stage one production. Memory palaces that will be used to simulate and test the stage 1 will be introduced with the method of tutorials to simulate step-by-step guide to the users of how to create their own Memory Palaces. This stage will include a menu system for the users to select category of building, for example: building walls, modifying the UI interactive menu, toping up libraries with new materials, selecting active libraries, loading previous Memory palaces and saving current ones, and finally other functionalities that the environment will integrate as part of the UI from the VR controllers.
- Stage 3: The third stage will include the integration of an online library for any user to save their own developed Memory Palaces lining them from their own space to the web space of Linguisticator Ltd. This will create a memory palace marketplace, helping other users to be able to download pre-built spaces and us them/the subjects.
- Final mode for this project will include the availability of the user to export the current walkthrough of the Memory Palace on a mobile version and use it with the support of VR cardboard set- this will help potential lecturers integrate memory palaces in larger groups (classes) and produce a “Flip” learning classroom approach (Fig. 3).

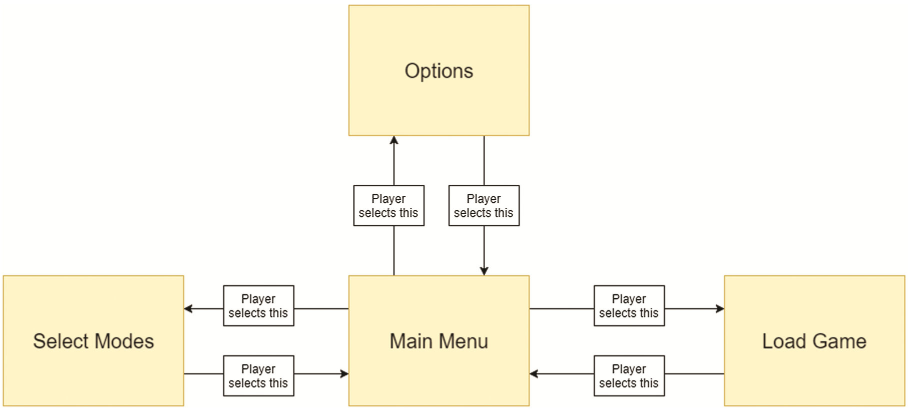

Fig. 3. User system modes and menu interactivity

5 Macunx Implementation

The prototype has been developed using Unity 3D game platform and at this stage is using the HTC VR Headset as the main interactive platform. Future development will include the deployment on Oculus Rift SDK3 as well for SAMSUNG Gear VR and Google Cardboard for final interactive lectures. The design of the framework is following the key-heuristics based on Koefeel et.al [13] research and some of them are summarized in Table 1 below:

Table 1. Heuristics summary for MACUNX VR

No	Heuristic	Reference source
1	***The player finds the application enjoyable and fun with no repetitive or boring tasks***	[14]
	This is a very important heuristic because the objective of the game is to utilize VR in educational applications. The game will strive to be an alternative way of learning without it being overly repetitive that could cause more harm than good	
2	***The program goals are clear. They should provide clear goals for the user as well as short term goals throughout game play***	[14]
	In the prototype, there will be clear goals to give the player as an indication of what they must do next without giving too much away. For example, in the tutorial level there will be instructions on how to use the VR controllers, headset and how to add objects into the game world.	
3	***Controls are intuitive, and mapped in a natural way; they are customizable and default to industry standard settings***	[14, 15]
	This heuristic is another important one as the controls are the key element to any game. Using the VR controllers are a new experience and the player's feedback will impact on the practicality of using VR in games. The controls will be relatively simple to pick up and play	
4	***User is given controls that are basic enough to learn quickly, yet expandable for advanced options for advanced players***	[14, 16]
	The controls mapped on the VR controllers will be simple to understand and pick up. Later on, different modes would require more precise actions and speed to get the correct mnemonic in time.	
5	***Screen layout is efficient, integrated, and visually pleasing***	[14]
	The game will mainly use 3D objects, which means the interfaces, game world and VR integration are key to the overall appearance of the game	
6	***Navigation is consistent, logical and minimalist***	[15, 16]
	The game flow will be seamless as it does not require a lot of going through multiple options just to select an object or command	

5.1 Tutorial Level Designs

For the tutorial level there will be 4 pedestals on which the player must place the correct mnemonic on. Voice narration on this level instructs the player on how to use the VR controls and explains any configurations if needed (Fig. 4). The mnemonics for this tutorial are simple so the topic could be numbers from one to four. The player would have to navigate through the asset browser menu to find the correct mnemonic. Once they have completed it, the player could either remain on this tutorial level and play with the mechanics or go to the next level.

Fig. 4. Tutorial Levels Design- Level 1 (top right), Level 2 (bottom left) and Level 3 (bottom right)

For level 1, there will be 6 pedestals on which the player must place the correct mnemonic on. This is will be treated as the easy level because it uses the player's knowledge from the tutorial level. They will be given hints on what mnemonic each pedestal needs so for this level the hints are formed as the beginning letters. For example "O" would stand for a mnemonic that starts with that letter. Just like the tutorial level, the player has to navigate through the asset browser menu to find the correct mnemonic. Once they have completed the level, they can progress to the next level. For level 2, there will be 8 pedestals for the player this time. The hints are descriptions that are specific to the mnemonic.

For example "______________ is often used to refer to someone selling goods". As with the previous levels, the user has to navigate through the asset browser menu to find the correct mnemonic. Once the user has completed the level, they can progress to the next level. For level 3, there will be 12 pedestals and the player must use their growing knowledge to find the correct mnemonic for each of them. The hints are mnemonics being used in the sentence so for example "Rubbish goes in the ______________ not on the floor". Similar with the previous levels, the player has to navigate through the asset browser menu to find the correct mnemonic and once they have completed the level, they can progress to the next level.

5.2 Object Interactivity

Using the VR HMD's can give the player motion sickness which is a risk that needs to be avoided for safety reasons. To counter this risk, a teleportation feature has been integrated that allows the user to travel safely within the game world without causing nausea. By setting up a camera rig, it will create a play area that uses the room scale of the room to use when interacting in the virtual world. Setting up the dimensions is dependent on the room scale but for now we will scale it to 300 × 225. Using the controller mappings, the user can assign a specific function to each button. For instance, teleportation requires the player to press down on the touchpad in order for a laser pointer to appear with an indicator showing where the player can travel. To confirm their destination, the player will then have to press the trigger button and they will be teleported to their area of choice (Fig. 5).

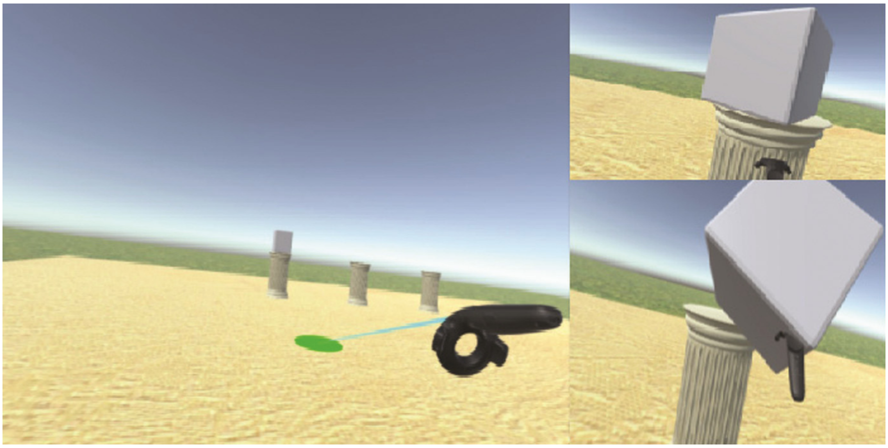

Fig. 5. Laser pointer to show how the user can move in the game world – User teleportation

As of right now, using the trigger button you can pick up an object and drop it by releasing the trigger button. In addition to during the interaction, this feature can also be used during teleportation while the user carries the object – this way, they don't have to keep teleporting to their destination to spawn the object.

5.3 Menu Libraries

The library system is once of the most important features of Macunx VR: users can select their own mnemonics to attach to the game world as part of an integrated menu in the HTC controller (Fig. 6). The final project version will give the user the option to the user to top-up mnemonics via a menu interface library through local directory or the internet.

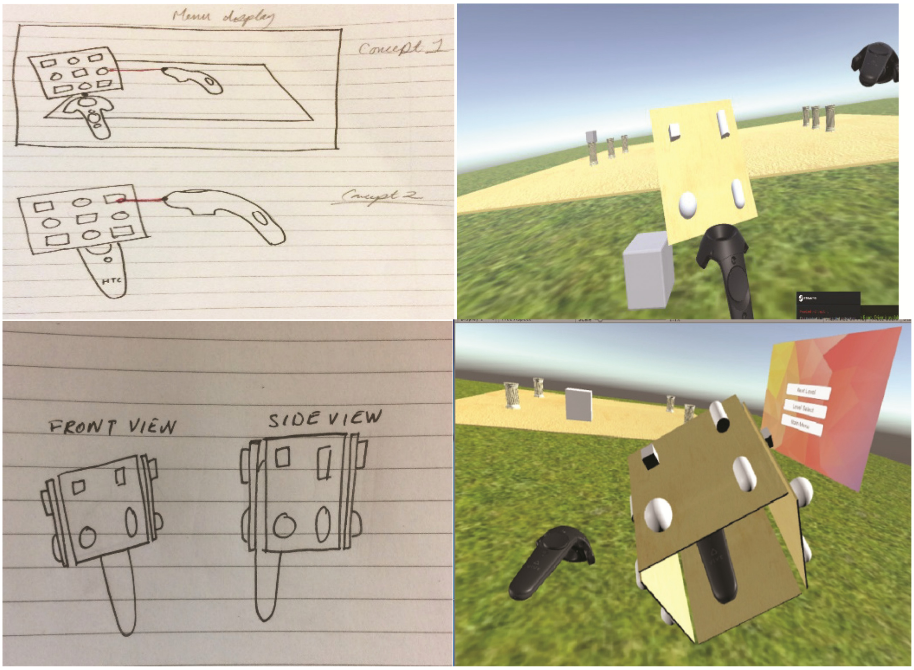

Fig. 6. User interface for selecting mnemonics

6 Conclusion and Future Experimentation

Based on Linguisticator's preliminary results with dyslexic children, as well as continued work with adult learners working on mastering foreign languages through memory techniques, there are a number of simple experiments that can be run with the virtual reality software in order to quantify its efficacy. In particular, spelling and literacy exercises for dyslexic children would be particularly illustrative.

Volunteer children between the ages of 8 and 14 with a confirmed diagnosis of dyslexia would be recruited via local schools. Baseline tests would be taken to determine children's ability to spell a series of 10 to 20 words. Children would also be observed reading aloud texts that contain these words, which would be specifically chosen because of their difficulty to spell. Children would then be randomly split into a control and experimental group.

The control group would receive standard spelling remediation, involving repeated drilling of the same words. The experimental group would receive spatial memory training in virtual reality, learning to spell the same words. Both groups would be tested after the same amount of time in training, immediately after the training session has been completed. They would then be retested after a period of one week to determine rates of retention. Testing would involve active spelling of the specific words, as well as reading new texts with the same vocabulary. Testers would observe any difference in levels of hesitation or in children's need to sound words out as compared to the baseline tests before training.

Such a simple experiment would demonstrate the foundational principles of spatial memory as a viable option for circumventing challenges related to dyslexia. Further testing and observation could be conducted to monitor the long-term effect of such spatial memory training and how it can be used comprehensively to master more than just individual words, but rather entire subjects.

A prototype alpha version of Macunx VR will be available for testing with users by the middle of Autumn 2017. User experience feedback from both students and instructors who would like to work with the toolkit to create their own memory palaces as part of their teaching will provide further feedback for the final tuning of the platform by the end of April 2018. For the final package the intention is to release supplementary video tutorials to support beginner learners and instructors.

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Learning Principles of Electricity Through Experiencing in Virtual Worlds

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Abstract. This paper describes an approach for to make available different experiences for learning using a 3D immersive world called AVATAR. It is based on a case study aimed to create virtual laboratories to assist in science learning and teaching. AVATAR has been designed for following the experiential learning and other relevant educational theories, initially focused on electricity basic principles. In order to validate this approach, a group of 32 users experienced the laboratories and answered a questionnaire aimed at assessing the affordances of these immersive environments. The analysis of the questionnaire answers has provided consistent results that will assist in the improvement and development of new experiments in the virtual world.

Keywords: 3D immersive world · Virtual laboratory · Conversational agent · Experiential learning · OpenSimulator

1 Introduction

Several researches have converged to promote learning through practices, with the aim of building knowledge through realization, thinking, testing and exploration. In a broader sense, the active learning has been seen as a relevant teaching method for learners to develop critical skills and knowledge. This is especially relevant to engineering courses that have to prepare future professionals for solving problems that could not be anticipated, what requires experiments to bring a proper solution. Particularly, experiential learning emerges as an important element for the approach discussed in this article, because learning occurs through the understanding of experience and its transformation into knowledge.

This paper describes an approach to make available different experiences for learning using a 3D immersive world. It is based on a case study aimed to create a virtual laboratory to help science learning and teaching. It is part of a research project named AVATAR, the acronym of "virtual learning environment for remote work" in the local language. The goal of this effort is to build a virtual laboratory for teaching and learning Physics and was initially focused on electricity. The chosen platform for AVATAR project was the OpenSimulator.

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As a result one expect promote learning by doing, thinking, exploring, through quality interaction, interventions and relationships without the impairments that real world experiments may impose like high costs, safety risks, environmental harm and others.

2 Virtual Laboratory Advantages

Virtual laboratories in education are starting to receive great deal of attention especially with the dissemination of computers and tablets in class. The organization and possibilities of inherent to a virtual laboratory will be discussed in more depth in Sect. 4. Some aspects that make virtual laboratories a better approach are:

2.1 Low Cost

In a virtual laboratory there is no need for buying components that may be expensive or even not available in a certain area. Other related items in a real life experiments are tools, vests and protective arrangements like chimneys or exhausting systems as well as special power or illumination condition. As mentioned in Achumba, Azzi and Dunn [1] the typical high costs of traditional engineering laboratories have motivated the incorporation of virtual laboratories in engineering education. On the other hand, the design and building of a virtual experiment will impose costs deriving from manpower for environment visual design, relevant functions definition, learning object to build, behaviors to be elicited in the experiment and learning activities to be allowed.

2.2 No Safety Risk

There are innumerous situations where real experiments may cause life risk due to toxic gas, radiation, intensive light exposure, etc. In the special case of the experiments with electricity, the risk of electric shock is not negligible and consequences may vary in intensity, from small sparks to electrical discharges that can cause serious injury or even be fatal.

2.3 No Environmental Harm

Conducting a real lab experiment can result in solid or gaseous waste whose disposal harms the environment. University research laboratories, for example, produce significative amounts of hazardous waste, use massive amounts of energy, and are currently not operating in sustainable ways [2].

3 Learning Through Experiencing

Experiential learning is the process of learning through experience. However, hands-on learning does not necessarily involve students reflecting on what is being done. For the result of an experiential learning activity to be successful, it is necessary that basic requirements to be met:

3.1 Active Learning

Just observing the completion of an experiment by the teacher, by a monitor or colleagues is not sufficient to promote a good level of learning. The student himself must take ownership of the process and analyze the appropriate action strategies, try them and use some alternative approach when the achieved outcome does not meet expectations. This process can derive what Piaget [3] called reflective abstraction that is the process by which the essential properties of the object are understood allowing infer possible reactions in other contexts. This is also an expected result of experiential learning as it was proposed by Kolb [4]. In this proposal, the experiential learning is the trigger element of the learning process and to be followed by reflexive observation which promotes analysis of the facts and behaviors observed, a summary of their relevant and significant aspects and gives rise to a value judgment that will anticipate behaviors and reactions phenomena observed in other contexts.

In addressing the active and experiential learning, it is possible to realize a degree of similarity between them. However, active learning is not restricted to only experimental aspects, but the student is posture as a builder agent of their knowledge, elaborating and implementing strategies to test their knowledge in a particular field of study. Thus, active learning appears to be broader than experiential learning, serving as a substrate for the second to occurs. In turn, the experiential learning is closely linked to its own experiment, whether real or virtual, it can be characterized by the phases of the cycle Kolb [5]. Thus, both seem to seek a common goal, the development of reflective abstraction of Piaget [3] and, one might add, meaningful learning of Ausubel [6], since both address the conceptual appropriation by the student, excelling both the recognition as the use of such concepts in many contexts.

3.2 Experiential Learning

David A. Kolb [4] proposed experience as the source of learning and development. His work exposed the principle that a person would learn through discovery and experience. His learning theory became widely used and it is known as Kolb's experiential learning cycle. Kolb's learning cycle suggests that there are four stages in learning which follows from each other: Concrete Experience is followed by Reflection on that experience on a personal basis.

This may then be followed by the derivation of general rules describing the experience, or the application of known theories to it (Abstract Conceptualisation), and hence to the construction of ways of modifying the next occurrence of the experience (Active Experimentation), leading in turn to the next Concrete Experience. All this may happen in a short period of time, or over days, weeks or months.

3.3 Experiencing in Virtual Worlds

Virtual worlds are characterized by their use of navigable 3D space, its representation of their users within then through the use of movable 3D characters, known as avatars (Childs and Peachey [7]). The presence of the learner in an immersive virtual world is operationalized through the avatar that it represents and it is a vicarious for its presence in the virtual world and carries out the actions that are possible in the outlined context: jogging, walking, running or even fly, interact with objects in the virtual world by mere approach or intentionally touching so getting responses and reactions.

A question made was if these actions taken in immersive virtual world affects the student. Will they be able to motivate and engage the learner user promoting learning or impact as predicted by theories of constructivist or experiential learning even as a vicarious experience? Marsh, Yang and Shahabi [8] studied vicarious and empathic experience in three-dimensional interactive mediated environments and Piaget [3] states that learning is an active process through which the learner handles the object of knowledge drawing his/her reactions and responses that allow not only to become aware of what is visible and apparent at a first glance but discover elicited hidden behavior when certain actions are performed on the object. In terms of handling the object of the experience, Occhioni [9] shows a virtual world named Techland and the Mathland island, where student can touch, move, rotate, and select the objects to complete and organize the geometric forms in geometry experiments. Each experiment has different settings and degrees of interactivity between students and objects, requiring more knowledge of a pupil.

Virtual worlds, like OpenSim used to support AVATAR laboratory, allows some handling of objects. 3D viewing with zooming, for instance, is a basic possibility in this environment. The avatar may move around the object becoming more or less closer. But when it turns to draw reactions and responses from the objects it will depends on the behaviors previously defined for any object and related script associated to the object. If an object has no script that allow its movement when touched, for instance, it will not move! That is the intensive labor demanding a task in building a virtual laboratory.

From the moment in which the avatar can be considered an extension in the virtual environment of its creator in the real world, it is reasonable to accept that the situations in which the same pass are felt some way by its user. Thus, even if not the fact that world, the virtual can contribute to the development of skills that approximate the real through a surrogate experience or vicarious, i.e., do not need to be subjected to a high-voltage shock to imagine their consequences.

Therefore it is possible to use devices of virtual worlds to expand and qualify some cognitive aspects of students. For example, an experiment in the virtual laboratory explores the basic concepts of electrical circuits can help the student to develop the perception on the effects of incorrectly specifying an electrical component. The student will see the lamp of the circuit burn out in case the current is above a certain limit (Fig. 1).

Thus, the virtual worlds can fill the role that once was occupied by films and other audio-visual artifacts in the development of skills for which the imagination is able to minimize the absence of an effectively real practice.

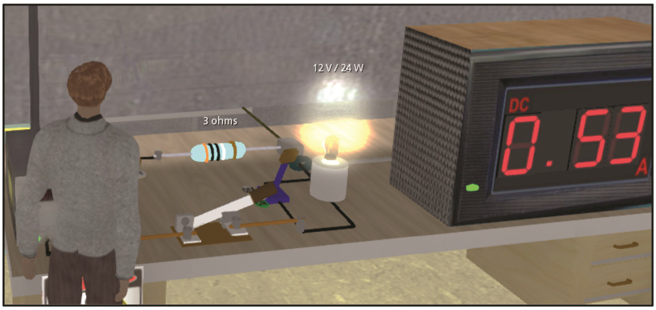

Fig. 1. Example of an experiment with electrical circuits.

There are differences between doing in the real world and the virtual, which can be considered efficient and/or effective or not, depending on the goals to be achieved. While virtual environment has lower realism than real world, by other hand provides benefits in terms of cost reduction, risk of accidents. Furthermore, it is possible to modify the degree of freedom of the student in a virtual experiment (including in real time), which is not always possible in a physical experiment.

It is worth it instead of trying to see what is better but what are the quirks of each and how they can complement each other. Often the effort and investment in a physical experiment to develop certain skills can be reduced offering the same experiment in the virtual environment, approaching sufficient of the required competence.

4 Methodological Procedures

The research design used in this research describes a case study conducted to demonstrate the virtual elements constructed to enable learning through experiments and simulations of electricity in a virtual laboratory.

In order to evaluate the efficiency of the virtual laboratories and their virtual experiments in order to assist learning in electricity related contents, an evaluation was carried out among participants from different study areas. The research subjects were undergraduate and graduate students, making a total of 32 subjects, who interacted with the virtual laboratories in a time between 30 and 40 min.

The previous knowledge about the subject presented in the virtual laboratory was evaluated and categorized as: (1) none; (2) basic theoretical knowledge; (3) regular theoretical knowledge; (4) theoretical knowledge and practical experience. Given that, through the information recorded on the previous knowledge, it was sought the evidence if there is a relation between the level of prior knowledge of the participants and the way they evaluated the virtual laboratory and its experiments.

Participants also answered a questionnaire composed of 14 questions that were constructed based on the authors' knowledge in virtual worlds applied in education (detailed in Sect. 5). In this sense it was investigated participants' opinions on virtual resources and other elements that compose the virtual laboratory and that were experienced by the participants, e.g. 3D objects, experiments and simulations, and conversational agents.

Regarding the research questions that guided this research:

- What were the participants' perceptions regarding the use of virtual laboratories to aid in the learning of electricity?
- What is the relation between the participants' previous knowledge and the way they evaluated the virtual laboratories and their experiments?

5 Learning in Virtual Worlds

Virtual worlds have the potential of embodying abstract concepts in concrete experiences. Different nature of experience using a virtual world derives from sense of presence, contextualization and openness of possibilities in terms of activities selection and sequencing as well as intensity of active participation.

Given that economic restrictions, time, safety among others restrain the realization of the spectrum of experiences that will be desirable for the teaching of science, virtual labs offer a replacement solution. However it is necessary to analyze the differences between the realization of a real experiment and a virtual experiment that involves a simulation of the real experiment. Studies show the importance of the fidelity of the simulation as a factor capable of promoting learning (Thomas [10]), but this is not a linear dependence. From a certain level of realism gains in learning no longer are achieved proportionally to the efforts and costs of producing the simulation. Herrington, Reeves and Herrington, Reeves and Oliver [11] proposes that physical verisimilitude to real situations is of less importance in learning than "cognitive realism", provided by immersing students in engaging and complex tasks.

Situated learning occurs when a student experiences and applies the learning in a specific environment or setting that has its own social, physical and cultural contexts. Immersive technologies provide alternative environments for situated learning, because an almost endless variety of virtual contexts are available, or can be created, that give users a sense of "being there" [12]. But we have to recognize and analyze the limits of the virtual world. Of course there is a dependency between investment in design and development of learning objects included in the virtual world and the realism and its impact as a resource capable of promoting learning. It should be seen that learning is an internal apprentice process and can only be promoted but not forced as motivation and student engagement in the learning process, their desire to build knowledge are affected by factors that go beyond what is possible influence in the context of the learning situation itself. Personal factors, internal conditions and external predetermining influence the learning outcomes without being possible to eliminate them from the context.

5.1 Sense of Being There

To navigate in a virtual world, students are graphically represented by an avatar, through which they can relate to other users and artificial agents, create and interact with 3D objects, as well as to verify images, audios and videos. This virtual representation, causes these users have the feeling of being immersed in the environment, and this perspective entails a greater involvement of the same towards with the objectives presented in the environment, and according to Petrakou [13], these interactions may function as a context for online education, and it can facilitate teacher-student as well as student-student interaction.

According to Berger [14], unique properties distinguishing 3D virtual environments from other learning resources are summarized into two groups, namely representational fidelity and learner interaction. These properties lead to a construction of identity by the user and a sense of presence within the environment. The graphical representation is one of the aspects that involve the students in the virtual world, so it should be used for the benefit of engaging users with educational activities proposed. However, this aspect is not quite sufficient to keep user engaged for long period of time in the environment, because when this lose the perspective of novelty, there must be some other element for the re-engagement of that user in the virtual world. Regarding this, it is necessary to exploit the potential available in the virtual worlds, trying to combine them with external technologies that are part of the student's daily life, e.g. smartphones, social networks, among others.

5.2 Freedom in the Lab

A virtual environment offers typically no boundary for the user that may choose a path to follow when visiting. The fact that the student has many degrees of freedom has positive and negative aspects. Among the positive aspects can be highlighted that students with different levels of prior knowledge can go through different learning trajectories, according to motivation, abilities and characteristics. But it may also happen that a less prepared student to feel disoriented in the environment, which may result in demotivation in any given activity and even his/her disengagement.

5.3 Interaction

In the virtual world, the user has at his/her disposal a wide range of possibilities for navigation and interaction with the environment and their contents. Some prospects that the authors of this work has deepened their investigations, is the use of videos and animations for experiential practice issues related to physical area, as well as the use of images, NPC (Non-Player Characters) agents and the construction of three-dimensional objects, empowered scripts in OSSL (OpenSimulator Scripting Language) and LSL (Linden Scripting Language) languages, to expand student interaction possibilities.

In addition to these possibilities, the immersive environments also provides interactions through e.g. the exchange of messages via chat between users and users with NPCs agents, voice communication, the use of audio and textures. These aspects, that when well-designed, entails student involvement with the scheduled activities. However, it is necessary to reflect about the use and relevance of these elements, it is not sufficient to provide a range of tools for interaction, it is necessary that these interactions promote reflection of the students, because if users identify that there were gains during their interactions, they will commit to the challenges and activities presented in the environment.

However, when it comes to interaction in virtual worlds, it is also necessary to discuss the problems caused by the use of some of the elements mentioned above, e.g. slowness when using video capabilities - which on a large scale can cause delay to perform the streaming. In this sense, Petrakou [13] discusses how problematic might be the users of navigation in these environments, due to be something new in the context of these students, and these “newbies” have no certain rules of etiquette, e.g. knowing when to speak and hear (corroborated by the aspect of intonation and the distance between users), understanding about the manipulation of objects and their avatar, avoiding creating useless objects and also that their avatars collide with other colleagues.

5.4 Learning Support and Scaffolding

Downes [15] examined the intersection of learning, performance support, and mobile virtual worlds and simulations highlighting the background and infrastructure needed to support such a system. He also identified the need for institutions to provide learning support and scaffolding to draw out the benefits of what might be called virtual worlds on the go.

Aiming to assure the best support possible for the user in the AVATAR virtual laboratory some strategies were outlined:

- Adding multimedia (animation and video) to explain scaffolding concepts. These multimedia resources can be added as texture of any prime (basic object used to build complex forms) in the virtual world or can be displayed on portable external devices. In the latter case, panels with QR-CODE are shown in the virtual world and these features can be added as texture of any object in the virtual world or can be displayed on portable external devices. In the latter case, panels with QR-CODE are shown in the virtual world and scanning the code brings direct access the multimedia content and display it student cellphone or other mobile device.
- Offer self-test opportunities using material presented in panels containing small tests built with authoring tools like Hot Potatoes or apps for mobile devices.
- Conversational agents are available in the environment. These agents are NPC (Non Player Characters) activated by sensors that detect the proximity of the user’s avatar and establish a dialogue. Two conversational agents classes have been designed and implemented: (a) agents aimed to present laboratory resources and clarify doubts about the resources or about related pre-existing knowledge that are supposed to be known and needed for the experiment understanding; (b) agents that provide guidance in the use of experiments and present questions that promote reflection on the experiment and its results. These agents work as proxies for a professor or lab monitor and has great acceptance by its users as also found [16]. The implementation of the conversational agent uses chatbot technology and the Alicebot software [17] was the approach selected to expand the agent dialogue capacity.

6 Virtual World AVATAR Evaluation

The AVATAR design was carried out aiming to cope with principles presented in previous session. A virtual lab focused on experiments related to study of electricity was the initial focus.

The virtual world was organized in regions being the first designed as an introductory environment where anchor concepts were presented through videos, animations and tutorials. From there, the visitors could make teletransport to other regions where experiments were available to use, for example, electromagnetism, resistive electrical circuits and voltaic arcs (Figs. 2 and 3). In Fig. 3 it is possible to see one experiment of the resistive electrical circuits laboratory. In this experiment, the user needs to find out the configuration of the circuit that allows the water to reach the highest temperature through heating by the Joule effect.

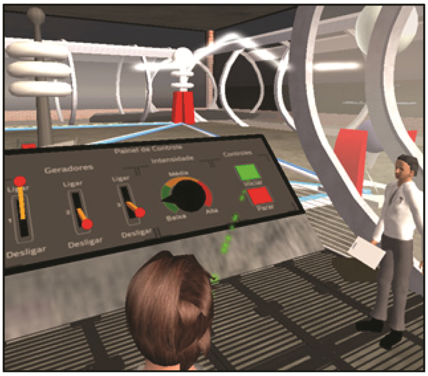

Fig. 2. User interaction with the Voltaic Arcs Experiment.

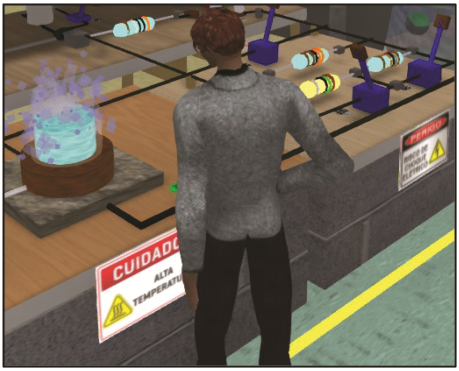

Fig. 3. User interaction with an experiment of resistive electric circuits.

All participants have answered to an online questionnaire after visiting AVATAR virtual world, using a Likert scale for a set of 14 questions as shown in Table 1. In the Likert scale of this questionnaire, 1 meant totally disagree and 5 totally agree with the presented sentence. All the sentences were defined in such a way an agreement (levels 4 or 5) it means a positive aspect of the experience.

An initial analysis of the questionnaire answers lead to the conclusion that generally speaking the impression of the users with the AVATAR Virtual World was very positive, since the median of all answers was 4.0 and 79.2% of all answers were on “4” or “5” levels, which means a high degree of agreement with positive aspects of the experienced virtual world.

By sectioning the data into the four subgroups related to the level of previous knowledge of the respondents it was also observed a high average in all subgroups, with a clear trend of higher averages on subgroups with higher level of previous knowledge. The Mann-Whitney U test was used to check whether the observed differences were statistically significant. The null hypothesis (H_0) of medians equality was rejected, with p-value of 0.000, for two combined subgroups - students with no (1) or basic (2) previous

Table 1. Basic Statistics on Answered Questionnaire (n = 32)

Question	Median	% Responses on “4” or “5”
Q1. The virtual lab is a pleasant environment	5,0	93,7%
Q2. I feel a sense of being in the lab	5,0	96,8%
Q3. Navigating the virtual laboratory is intuitive	4,5	78,1%
Q4. The resources available in the laboratory are interesting	5,0	90,6%
Q5. Laboratory resources are useful for my learning	5,0	100%
Q6. My knowledge was expanded after the activity in the virtual world	5,0	87,5%
Q7. The video shown in the virtual world contributed to learning	5,0	84,3%
Q8. The images contributed to learning	5,0	84,3%
Q9. The environment helped create a sense of immersion	5,0	96,8%
Q10. The experiments were interesting	4,5	78,1%
Q11. The experiments contributed to learning	4,5	78,1%
Q12. The agents provided useful guidance	3,5	50%
Q13. The agents answered my questions	3,0	46,8%
Q14. The agents were useful to promote reflective observation	3,0	43,7%

knowledge and students with regular (3) and more advanced (4) previous knowledge on the subject matter. The confidence breaks for the two combined subgroups can be seen on Fig. 4. In order to identify the main contributors for the observed difference, the responses of each combined subgroup were also submitted to a Mann-Whitney U test, but comparing separately the responses to each question. The difference of medians between subgroups based on previous knowledge was considered statistically significant ($p\text{-value} < 0.05$) for questions related to the conversational agents (Q12 to Q14), Q10 and Q8.

The difference of responses related to conversational agents can be explained by the fact that newest users may have felt more need for support than individuals with more background in the subject matter and this need was not fulfilled once in its actual stage of development AVATAR agents do not have the knowledge base completely filled. It points to the need of special attention to basic difficulties faced by newest users when filling agent knowledge base.

Following an analysis of the answers to each individual question, it was observed the confidence interval for 95% of the mean of each individual question (Fig. 5). It can be seen that for 8 questions the minimum value of the confidence interval was higher than 4. Additionally to the questions related to agents, as previously discussed, it was also observed a lower score on questions Q3, Q10 and Q11. Question Q3 asked about intuitiveness of the navigation in the virtual world and despite being highly scored there was space for improvements. Questions Q10 and Q11 were specifical to the experiments and it was observed more variation in learning value perceived. It was also observed that newest users scored lower to these questions. It may indicate that newest users that

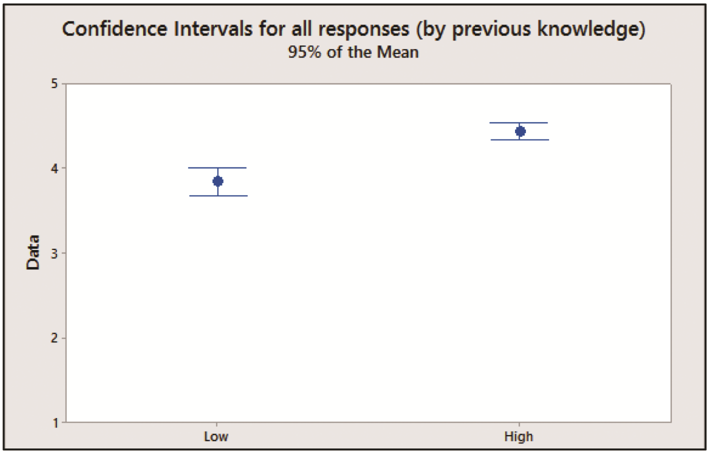

Fig. 4. Confidence Intervals of responses for combined subgroups based on previous knowledge.

had no background on the suggested experiments, may not see the value of them due to a lack of basic understanding. It may indicate the need of either finding ways to stimulate newest users on the value of the experiments or improving the experiments themselves.

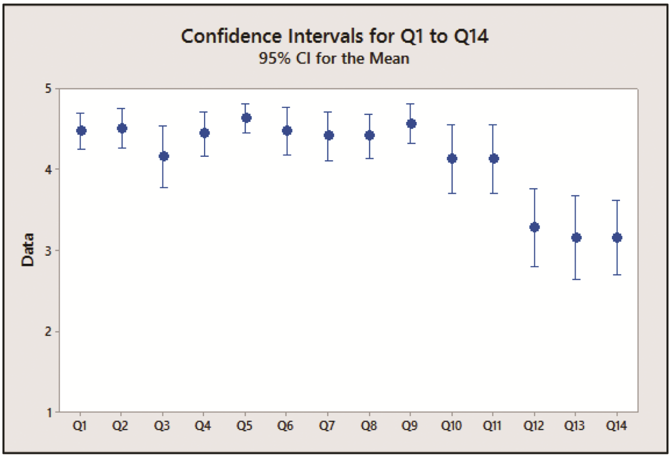

Fig. 5. Confidence Intervals for each set of answers to the questionnaire.

In view of the reliable reproduction of the results obtained from the questionnaire mentioned above, at the end of these assessments users responses were submitted to the calculation of Cronbach's alpha coefficient. The alpha value obtained was 0.85, which as George and Mallery [18] stated it can be classified as a scientifically accepted results, indicating that the analysis of the profile of the responses estimated a reliable degree of confidence on the questionnaire scale.

Aiming to create a captivating environment and able to promote learning, the design of the laboratories used pleasant sceneries (buildings with architectural details). Inside the buildings were installed laboratories and supporting resources (e.g. posters, presentations, videos and tutorials) to provide support and concepts anchors. These resources were highly appreciated by users as shown in answers to Q1, Q4, Q7 and Q8. Comments like "Very cool, this made me have the feeling of being in a laboratory due to the format and appearance" - subject 5; "… the experience of immersion in the virtual world was very interesting and I intend to participate in other experiences of this type…" - subject 6; "I found the lab pleasant and interesting…" - subject 12 were made by the interviewee.

The mobile learning added to AVATAR through use of smartphones and tablets for presenting video and animations were also praised. In this aspect, QR-Codes were included in all laboratories so that users could access via their mobile device the contents multimedia related to the experiments. Participants approved the use of QR-Codes: "I found the use of QR-codes cool because I can access from my own cell phone." - subject 9; "QR-codes work normally." - subject 19.

Conversational agents were also included in the environment in order to provide advices to users and answer questions about related topics. At this point of the project development, agent's knowledge base is still not extensively populated being very limited in fact and answers to questions Q12, Q13 and Q14 have shown that, despite appreciating the presence of agents, users did not felt them helped too much. Even so, subject 10 observed: "… I realized that security guard and the teacher provided me with some guidelines…", which demonstrates that this strategy has the potential to be used.

On the other hand, users pointed out in the comments some suggestions that would like to view the agents, e.g. "… the agents should interact more, following the avatar and adding information as if they were talking" from subject 5, in order to provide explanations and statements when necessary, or even provide clarifications on how the user should interact with a particular experiment.

In order to provide a guidance to user in the virtual world, marked trails indicating a way to go where placed and users tend to follow that path. In situations where this resource was not available, the evaluators expressed in their comments that they felt lost in some moments. The assessment shows that for users to enjoy of an intuitive navigation (Q3), implementations are required to guide the directions that users should follow, especially when it comes to laboratories focused education, in which it is indicated that firstly the users interact with anchor contents related to the experiments, so that later, they can advance and interact with more complex contents, to the extent that they are to completing their interactions.

When the students were asked about the resources of the laboratories that were intended to promote learning (Q5), most indicated to agree with such elements, as well as believe that their knowledge had been expanded after activity in the virtual world (Q6). In this respect, it is observed that the users were favorable to the use of immersive environments combined with educational activities (Q9), which is best explored, according to the report of the users in the comments, when coupled with the fact, it enable interaction with realistic experiments and other multimedia, elements where they indicated that they would like to be able to interact with more three-dimensional simulations. For example, subject 6 reports that "… the experience of immersion in the virtual world was very interesting and I intend to participate in other experiences of this kind".

7 Conclusion

This work presented an approach to provide different learning experiences using a 3D virtual world. The labs were built based on the concepts of experiential learning and active learning, looking for promoting learning through doing, thinking, testing and exploring, by the interaction, interventions and relationships in the 3D immersive environment, without the damages that real-world experiences.

Even without exploring all possibilities of the proposed approach, it is concluded that the laboratory in 3D virtual worlds presents great potential to learning and teaching process, when focused to hands on activities, mainly laboratory practices. It also reduced costs, risks and damages in the laboratories uses, making the education process feasible in the cost and benefit relation.

Analyzing the response forms, it was found that the participants perceived the proposed environment as pleasant, highlighting the "sense of being here" within the laboratory and the intuitive aspect of the environment and the experiences developed. Another finding is the participants' assertion that the resources present in the virtual 3D world are useful for learning, although there is no complete implementation of them. Other discovery was the potential use of conversational agent, once many subjects reported that they interacted with agents in labs and said enjoyed the experience.

Some contributions of this work are: (1) improve the virtual laboratory design in virtual worlds 3D promoting use of environments intuitive and pleasant; (2) arouse attention to immersive environment and their potential use to education; (3) provide a tool to science learning and teaching; (4) approximate science lessons to young students by games environment; (5) identify the need of a conversational agent to support student's actions in the virtual laboratories.

As future a work, it is necessary refine the laboratories and experiences to answer the subjects suggestions. Other research points are to define a measure the engagement and motivations of students in laboratories and identify how and when learning happens in the labs developed in 3D virtual worlds.

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Immersive Learning as an Opportunity to Upgrade Learning Outcomes and Improving Skills in Political and Social Sciences

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Abstract. In recent years, new models and methods of learning and teaching have made their way into social sciences curricula, moving beyond STEM education in higher learning institutions. They can be considered as a complement to the classes. An interesting case is presented here for political science. Starting from the analysis of context and several experiments of immersive learning in the domain of political and social sciences, the authors report their own experience as teachers of the subject matter of "Elites and social movements" with BA students. This research corroborates conclusions from earlier studies and presents proposals that allow reflecting about the adequacy of new methods of teaching and learning to contexts of high exigency and training for new elite's members.

Keywords: Political and social sciences · Elites · Pedagogical innovation · Immersive learning · Higher education · Teaching

1 Introduction

Several international and national institutions related somehow to education consider that students' participation in learning processes is crucial for their social and cognitive development (Ananiadou and Claro 2009; OECD 2016; Schleicher 2012). This understanding is valid for all levels of education and follows from the fact of perceiving that the world is changing faster than programs of the disciplines (OECD 2016; Thomas and Brown 2011) and this has implications in our lives and the lives of other people.

The idea that the university's role is not limited to the transmission of knowledge but to introduce people to work, that was defended by the European Union, with the so-called Bologna reform, which established a common system of credits and recognition of academic diplomas in Europe, is revolutionary, but already dated. Indeed, it is foreseeable that a lot of professions change considerably or even disappear in the future due to the development of automation systems and artificial intelligence. For example, IBM created ROSS, the first lawyer of the artificial intelligence world. The legal

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opinions of ROSS are more accurate (90%) than human beings (70%) (Dondero 2016; see also the site of ROSS at http://www.rossintelligence.com). In medicine as well, systems of artificial intelligence are more reliable in the diagnostic of diseases than qualified doctors are. It is debatable if we have to prepare students for the practice of a profession, because it is more likely that they exercise during their lifetime several roles.

These data suggest that we should look differently at the role of education, and this, in fact, is already happening. Several recent studies indicate that more important than the student acquiring necessary knowledge for the exercise of a profession it is the acquisition, throughout the training process, of transversal competencies or skills (EC 2012), in areas such as communication, definition of priorities, creativity, critical thinking, emotional intelligence, teamwork, complex problem solving, etc.

The perception of the profound transformations occurring currently in the job markets is not new, but it presupposes a change of attitude, behavior and structures in the field of education, and in particular in higher education (Janta et al. 2015). This perception is backed by political scientists that argue for changes in the teaching and learning processes (Payerhin 2003).

This present document tries to contribute to the complex social problem of training students of political and social sciences relating pedagogical innovation through the use of pedagogies and immersive technologies with the transformation of the students' profile, aiming at a more efficient performance in their activities. Consequently, we expose our pedagogical experience as professors of the discipline of "Elites and social movements", a subject for undergraduate students taught in a regime of distance education.

Beyond the issue of change in teaching and the challenge ahead, we have tried to give a description of our experience insisting on the context of political science and the peculiarities of this disciplinary tradition to allow some bridges of interpretation for readers of other traditions such as computer science, gamification and experts in experiments in virtual reality.

2 Challenges of the Study

For Schleicher (2012), director of the Department of Education and Skills of the OECD, the systems characterized by higher educational performance have common characteristics: they give much importance to the training and selection of teachers; give more importance to the quality of the teaching staff than the size of the classes; substitute the bureaucratic control and the accountancy by the professionalization of the organization of the work. These systems encourage teachers to innovate in pedagogy, to improve their performance and the one of their colleagues and to thrive for professional development. The most advanced systems search on top of all that to provide a high level of quality for the service given, so that all students could benefit from excellence in teaching.

Schleicher refers to primary and secondary education, but his words are valid for higher education in which the success of students (Payerhin 2003; Schaap 2005) depends on their own behavior and the behavior of the rest of the agents, as well as on the characteristics of the education system.

According to a report from OECD (2012), the excellence of the system of education consists of the professionalization of professor, the creation of a coherent and collaborative network of schools and the valorization of the choices made by the students, and they matter more than the hereditary factors. Professors are invited to develop experiments for learning applied with the participation of students for their acquisition of new skills required in the job markets.

Camacho and Lagare (2016: p. 155) in their review of the literature on competence based education (CBE) and personalized learning (PL) conclude that “Twenty-first century employers prefer to recruit employees who have demonstrated mastery of competencies in the related field, and who are ready to perform the skills and tasks necessary in the workplace”. According to Blackburn (2017), “With the development of new digital tools [“microlearning” or personalized learning], as a different form of knowledge acquisition, is becoming an important facet of learner motivation and learning outcomes”.

These authors highlight the importance of informal learning, based on relationships that allow agents of the educative processes to Exchange experiences, giving examples such as digital games and simulations used for building experiences approximating real situations.

In line with the European Union, several European governments bet on the development of science and higher education to promote citizenship and inclusion, employability, specialization and a production of new knowledge. With the initiative “Digital competencies e.2030 (*Competências Digitais e.2030*) Proposal for an integrated program in digital skills, for Portugal, 2017–2030” (Portugal 2017), the Portuguese government aims specifically at the training of students in digital skills in order to enable them to be produce new knowledge in international interaction.

This challenge has an obvious political, social and cultural dimension with implications in the teaching of the political disciplines (EC 2016), which justifies the present work.

3 The Immersive Dimension in the Case of Political Science Teaching

At this juncture, it is worth trying to clarify what we mean by immersive practices and what do they serve, in the context of the teaching of the curricular unit of Elites and Social Movements, for undergraduate students in political science.

In the curricular unit of Elites and Social Movements we study the observable behavior of people in real social life. Specifically, we study behavior of people who stand out for their individual positions in society (elites), but also for collective behavior (social movements).

In a disruptive pedagogical exercise, we ask the students to place themselves in the role of the people and groups they study, trying to transform the knowledge acquired in the curricular unit into behaviors that are observable and measurable.

As a way to develop their behavioral skills, such as communication or leadership, we help each student understand how he or she can operationalize what he or she has learned in order to change his or her behavior and improve performance.

In addition to being an excellent tool to support the acquisition of knowledge, immersive learning approaches and techniques have the advantage of promoting the capacity of students to become involved in learning processes.

But what, after all, are immersive techniques in this context?

The immersion is understood as an experiential training technique that consists of transforming the learning processes into stories carried out by the students who are invited to live stimulating experiences and parallel those to their daily life.

Students' tasks are performed in cooperation or interaction with other students and people and are recorded.

An immersive experience is a real-life situation in which the student engages in an unexpected and disruptive context that produces, among other things, a set of emotions that work as key to understanding how to use the knowledge transmitted in the learning process.

In curricular activities, we promote the development of what we call "real life games" where each student puts into practice specific actions with peers and others to achieve results (e.g., the elaboration of a rule or regulation, the passing a law, the creation of a civic movement or political party, etc.).

The ability to take specific actions gives students rights such as the right to publish an article, take a study trip, or undertake an internship. In this way, students become aware of aspects of reality that they normally do not pay attention to, and their behaviors become more dynamic in order to achieve the desired rights and recognition.

As professors responsible for the curricular unit we have a great concern with the design of the training activities, with the evaluation of student satisfaction and also, though not exclusively or mainly, with the evaluation of student learning.

What we expect from students is what employers normally expect from their workers: a behavioral change. In practice, there is an initiation of students to work, with anticipation of problems and reactions typical of employers, which is a powerful learning factor for students.

Throughout the years in which we taught the curricular unit of Elites and Social Movements, we realized the benefits of experiential learning which have improved the techniques used.

Our experience is based on similar experiences that occur in face-to-face teaching, which work as a complement to traditional pedagogical approaches, although in our case, the experience is reinforced by the fact that we use a virtual pedagogical model that is already the result of the application of Innovative and disruptive principles.

By comparing the results between the more conservative approaches and the immersive methods to teaching this curricular unit, we notice the greater impact of the latter approaches in terms of students' motivation to learn, learning outcomes and student belief in their ability to do things properly. It is, in fact, a change in the mindset that is taking place.

It is our goal to apply in the future these immersive methods to the organization where we work by imagining ourselves as participants in real-life experiences with the objective to move that organization to a higher and more effective level of performance.

4 The Context of Pedagogical Practice in Political Science, International Relations and Related Disciplines

The specialized literature reports a significant number of innovative pedagogical experiences in political science and international relations (Asal and Blake 2006; Brock and Cameron 1999; Cairney 2012; Dorn 1989; Fox and Ronkowski 1997; Frederking 2005; Omelicheva and Avdeyeva 2008; Smith and Boyer 1996) involving the use of participatory and immersive technologies. The political nature of the disciplines favors this experimentation (Nield 2008; Payerhin 2003; Schaap 2005).

The study of elites and social movements is part of political science and politics. Specifically, elites are groups of people who, by their characteristics and qualities, are at the top of society (Michels 2001 [1915]; Mosca 1939; Pareto 1991 [1901]). The systems of political representation in the modernity developed themselves in the sense of articulating the political elite (Pareto 1991) with the aim of democracy of the masses supposedly represented by the same elite. In this context, the formal education system was seen by national governments as a factor of democratization in the access of the masses to higher education (Dahl 2000). However, the history of democracy has shown how problematic it is, difficult to do and sometimes insurmountable.

The formation of social elites is related to the use of advanced pedagogies and technologies (Dirckinck-Holmfeld et al. 2012), but to what extent can participative and immersive pedagogies and technologies be appropriate for the formation of elites?

Our pedagogical experience covers undergraduate students in a distance education system and obeys the same pedagogical principles of the experiences reported to in face-to-face teaching, i.e., flexibility of educational processes, interaction between agents, introduction of students to work and research activities.

At the same time we analyze the usefulness of the recourse to immersive tools by undergraduate students in virtual environment and try to know if they fit the formation of elites.

According to classical political sociology (Pareto 1991 [1901]; Mosca 1939 [1896]; Michels 2001 [1915]), elites are those at the top of the social pyramid, regardless of the reasons why individuals occupy these positions: hereditary factors, intelligence, social relationship capacity, etc. Nowadays, the study of elites is essential for understanding social change, social inequality and democracy. If social change is not accompanied by adequate social policies and practices, it tends to be unpredictable and inequitable (Turner 2011). Paradoxically, the democratization of education in recent decades has been accompanied by an increase in social inequalities (Jones et al. 2008); (Turner 2011). Paradoxically, the democratization of education in recent decades has been accompanied by an increase in social inequalities (Jones et al. 2008).

The digital society, characterized by widespread use of computers and telecommunications in all spheres of life, implies a renewal of practices and models (Friedrich-Ebert-Stiftung 2016).

In Shanghai, teachers use a digital platform to share lessons. Their reputation increases in function of the number of lessons that are ‘downloaded’ and commented. At the end of each year, the school director asks the teachers if they have taught the students well and also what was their contribution to improving the education system

(Schleicher 2017). By stimulating crowdsourcing of educational practices, Shanghai has created a community of practice of teachers that allows the sharing of creative experiences, fueled by the desire to contribute and be recognized for it. This example shows that the success of changes in educational processes depends on the behavior of agents, aiming not only at individual but also at collective goals, and at the teaching structures.

The old dispute of the social theory of knowing what is most important – human structure or action – does not make much sense today, because both are important (Archer 1995; 2000; 2013; Elias 2001; Sayer 2010; Sayer 2011).

The students of the Elites and Social Movements course, belonging to several bachelor's degrees, are getting prepared to be elites, giving their best in their various activities (*e.g.,* studies, volunteering) and helping to improve the performance of others with those with who they relate.

In the preparation of the learning activities of this curricular unit or class we have taken into account the reports of experiences with participatory technologies in classes of political science and international relations (Dacombe and Morrow 2017).

By participatory Technologies, in the field of education, we understand the technologies that allow students to intervene in the construction and dynamics of the teaching and learning processes.

Students' participation, in the learning processes, as active citizens, tends to be valued as an explanatory factor of democracy itself (Bonavides 2004) existing different forms of student participation (from simple to complex) with a focus on social and cognitive development (Duarte 2009: 10 e s.).

Students' participation in the educational process is seen as valuable because it strengthens their personality and contributes to their formation as responsible citizens (Laver 1997; Fox and Ronkowski 1997; Damron and Mott 2005).

If, on the one hand, individuality is relevant in social processes, on the other hand, in the most developed societies teamwork and collective values are favored.

Given the evolution of societies, several authors note the scarce variety and effectiveness of the "conventional" means of teaching political science (Omelicheva and Avdeyeva 2008). The complexity and abstraction of the subjects implies learning problems (Loasby 1999) and students' lack of interest (Cairney 2012).

In constructing the activities of this curricular unit, we defined as objectives (aims) the most effective involvement of students and the development of their cognitive capacities and knowledge appropriation. For this purpose, we took into account the proposals of the use of simulations and construction of alternative scenarios by the students (Dacombe and Morrow 2017, p. 209; Dorn 1989).

Learning activities and outcomes were rigorously defined and timed for a period of four months (between March and June) in the school year 2014–2015. We selected 59 students from a total of 111 who chose the modality of continuous assessment, which implies the performance of regular practical activities. The students were accompanied by the teachers and two tutors, who are PhD students in political science.

One activity focused on the students' analysis of the life paths of personalities, real or imaginary, of the country and city of their residence, partly identified by themselves. The students working on these tasks were free to define the model of people's evaluation and to change the rules of social recognition, and their positions had to be explicitly substantiated.

In another activity, the students were asked to pronounce themselves on a model of evaluation of performance of the professors of a university; they were allowed to change it, at the same time justifying their choice in a reasoned way.

The students were also asked to analyze, in a reasoned and grounded manner, the scientific and pedagogical rules applicable at the university.

Finally, students were invited to write various opinion articles and to vote the best one on European political elites and/or social protest movements in the European Union.

The students had access to all the learning resources available on the university portal and also the possibility to access, upon a reasoned request, to other documents that they considered necessary.

The evaluation process was defined by the teachers, with a hearing of the students. The students' participation was weighted at 40% of the final classification, according to the university's virtual teaching model, with a similar degree of requirements as for those with just the final exams (those not included in the modality of continuous evaluation).

5 Discussion of Learning Processes

After our experience, Dacombe and Morrow (2017: p. 209) reported on their own experiences in the use of immersive techniques, which they called immersive theater, for the teaching of political science in the classroom. Their experiences were developed with undergraduate students, as in our case, using simulations inspired by the principles of immersive theater. These authors conclude that the principles of immersive theater, which are similar to the principles we apply, have the potential to develop teaching techniques that strongly engage students in the discussion of theoretical problems while developing their negotiation, communication and working skills in group. The authors attribute the success of their experiments to the development and planning of the simulations, as well as to a structured reflection period after the sessions.

It is important to note that the development of the Dacombe and Morrow simulation experiments was done in collaboration with Coney, the theater company specializing in immersive performances. In our case, we listened to psychologists from organizations studies, social scientists and politicians, and we organized a dedicated panel at a political psychology conference that we organized in Lisbon in early 2017.

Our experience has much in common with the experiences reported in the literature but at the same time allows us to complement some conclusions of the studies in this area. Like all other experiences, our experience focused on students and aimed to increase their learning potential. The results were presented on the moodle electronic platform, although most of the work was developed by participants outside the platform.

We will now turn to the discussion of the conclusions we have reached.

In the first place, the idea that the use of flexible and interactive pedagogical tools allows to cross the frontiers of political science and politics is proven. Students have skills that because of the closeness to the teacher and to peers that they are able to reveal.

Nibbelink (2012) speaks of a radical intimacy propitiated by the use of immersive pedagogies and technologies that meets the emancipated spectator and that gives them the ability to perceive the big issues. Our students have used means and resources beyond what we have suggested, which has opened the door to new research topics. There were real experiences of initiation not only to the work but also to the investigation by the students. We also note that the classifications of the learners in the course have improved because of the students' participation in the applied activities.

Secondly, we prove Laver's (1997) thesis that politics is also played and constructed. Several students have gained motivation for the exercise of civic and political functions, previously or in the meantime initiated.

Third, it is proven that the preparation and development of activities are very important for the success of immersive practices. The learning styles count (Damron and Mott 2005) as already proven with students of Political Science (Fox and Ronkowski 1997). For several years, we had class experience in which only a small number (less than 15%) of students had good, very good or excellent grades. In order not to have a very high rate of disapproval, there was a tendency to lower some of the requirements. Our experience demonstrates that it is possible in an introductory course to discuss important issues and get appropriate responses from students as long as they become active. In more than 80% of cases, students were able to use the technologies to access useful digital resources. It also increased the volume of resources used, confirming Nield's (2008) perspective of the student's emergence as an actor/author of the educational process.

Fourthly, discussion about what is most important or effective in fostering good learning - the classical class, the debate, or the new active learning methods, has been hampered, because, in different ways, all have been used.

Fifth, it is highlighted the pertinence to do this experiment with undergraduate students. In a 2009 study, Julie Loggins discusses the success of the experience of simulating the decision-making process in international relations with undergraduate students (Loggins 2009). The idea of the infantilization or lack of autonomy of undergraduate students, now so fashionable, may be partially true, but must be rebutted with active pedagogies that motivate students to learn.

The idea that we have to do things differently is very strong (Payerhin 2003). Learning political science through games (Schaap 2005) is indeed possible. The design of simulations in a virtual classroom is one of the most remarkable facts that we observe in the relationship between teachers and students and between students themselves.

The idea that democracy can be perfected and that, in addition to political parties, we can have the direct and responsible participation of citizens is no longer utopian. However, pedagogical activities should be tested and evaluated in order to guarantee high standards of learning and achievements.

In the last activity of the Elites and Social Movements course, we left a question for students to think and answer, individually or in groups: can we reinvent politics through human creativity and imagination?

The reflections of the students, along with their works, were published at the end of the semester in electronic format. The response rate for the last request was 94.5% (52 students out of a total of 55 students).

6 Conclusion and Future Work

Understanding what tools are most appropriate for a teaching and learning process that generates students capable of contributing actively to their personal development and to the development of the country and the world in which they live is a task that concerns us as teachers of the discipline of Elites and Social Movements.

We started with the assumption that innovative teachers seek to respond to students' learning needs outside the conventional classroom model. To that end, we have taken the recommendations of international and national institutions and the work of various authors in the field of social and political sciences. Laver successfully used games to demonstrate the complexity of political interactions. Smith (2012) used games to teach undergraduate students to learn the concepts developed by Maurice Duverger. Woodcock (2006) used the Simpsons series to get students to discuss political theory and democracy. These initiatives have in common the perspective that learning should not be a passive but an active process and that the students should feel free to collaborate with each other and discuss the meaning of their own learning and what they want to learn.

We are talking about pedagogical experiences that may be in conflict with the norms of a classroom of a conventional university. The point is whether it is possible to vary the form and methods of teaching in a university and to what extent. Immersive practices are not the panacea for solving all the problems of the students in our time but they are an important element, along other ones, if the standards of exigency are high.

In his book Playing Politics, Laver (1997) *Playing Politics*, Laver (1997) discusses the need to develop ways of teaching that make it possible to understand political concepts by large audiences. This is the greatest challenge to the use of immersive pedagogies and technologies. More and more digital resources are being used to enable collaboration among students around the world, but it is not yet clear who the beneficiaries of these practices are.

Immersive practices allow not only for improved evaluation, but above all for better or more active participation. And perhaps it is this participation or implication that is reflected in the results of the students and leads the universities of reference to use them. It is necessary, however, to think more carefully about the role of the teacher. Countries where institutions collaborate, students and teachers perform better, so attention should also be paid to the work of teachers.

In future work, it will be interesting to investigate what a good student is and what a good teacher is and how they relate in virtual environments or immersive approaches; namely knowing how to make decisions and who takes them. Thus, we will know if these new practices effectively contribute to the creation of old-fashioned elites or new elites, with this or another name. A crucial aspect to take into account is the internal recognition (e.g., publications and other joint work) and the external forms of collaboration (e.g., visibility).

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A Virtual Museum Installation for Time Travel

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Abstract. This work discusses the methodology for the design, development and deployment of a virtual 19th-century Fish Curing Yard as an immersive museum installation. The museum building now occupies the same space where the curing yard was over 100 years prior, hence the deployment of a virtual reconstruction of the curing yard in a game engine enables the museum visitors to explore the virtual world from equivalent vantage points in the real world. The project methodology achieves the goal of maximising user experience for visitors while minimising cost for the museum, and focus group evaluations of the system revealed the success of the interaction-free design with snackable content. A major implication of the findings is that museums can provide compelling and informative experiences that enable visitors to travel back in time with minimal interaction and relatively low cost systems.

Keywords: Virtual reality · Virtual museum · Immersion · 3D reconstruction

1 Introduction

A museum installation for exploring the past has been designed, implemented and evaluated in this work. The system features immersive, yet inexpensive technology which allows museum visitors to facilitate a comparison of the past and present from equivalent vantage points. Museum visitors can walk up to the installation in the foyer, pick up a virtual reality headset and look into the past to explore a 19th-century curing yard which occupied the space that the museum building occupies today.

The requirement to explore the past from fixed locations around the museum building has informed the decision to deploy the exhibit as high-fidelity photospheres (360° panoramic images) instead of a resource-intensive 3D model powered by a game engine. Hence the use of immersive, yet inexpensive technology to

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facilitate a comparison of the past and present from equivalent vantage points in a museum setting is the major contribution of this work. Furthermore, an interaction-free design which provides snackable content to visitors thus enabling a group of people (a coach tour for example) to explore the past and share their experiences with one another, offers a contribution in the design of immersive virtual museum installations. An iterative methodology has been adopted for the design and implementation of the system, and evaluation has been conducted which demonstrates the success of the system for exploring the past as well as the acceptance of the interaction-free design. The findings of the evaluation also reveal insights into how visitors interact with virtual museum installations as well as the considerations that (staff and administrators of) museums face when managing such installations.

The remainder of the paper is organized as follows. Section 2 provides a background discussion on virtual museums and the partnership (and previous work) that led to the conception of the project. Section 3 discusses work done on the use of 3D technologies for museum installations and heritage visualisation. Section 4 provides an overview of the methodology adopted for the project, and Sect. 5 discusses the design and implementation of the system, highlighting the reconstruction process and the exhibit installation. The results of the system evaluation are provided in Sect. 6 and Sect. 7 concludes the work.

Fig. 1. Visitors with VR headsets

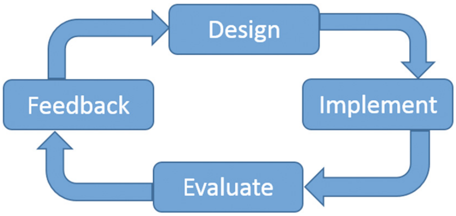

Fig. 2. Research methodology

2 Background – Virtual Musems and 3D Media

The term "Virtual Museum" refers to either (1) the recreation of a physical museum, like-for-like which enables visitors to remotely simulate a virtual visit of the museum or (2) the creation of artifacts, items or experiences for users' consumption. This could be done remotely (on the Internet) or on-site (in a physical museum) [1]. The second definition is of pertinence to this work, as it introduces the design, deployment and evaluation of an immersive museum installation aimed at providing an educational resource on local history.

Virtual museums have gained popularity in recent decades [2], and projects that leverage computer graphics to re-enact historical scenes date back the early 1980s [3]. Like recent interest in using 3D computer imagery and graphics to deliver engaging experiences to users, previous generations leveraged the techniques at their disposal in order to enhance immersive experiences [4]. The use of

Panoramas (and similar film-based techniques such as Cineorama, Diorama, Georama and Stereorama) for cultural heritage applications date back to the 18^{th}-century. These systems and their concomitant technologies were leveraged due to their ability to "involve" audiences and place them at the centre of the scene. However, due to content and cost limitations, the popularity of these technologies declined as people sought alternatives [5]. The use of panoramas as part of a general body of spherical and 3D media has seen a resurgence in recent years. This trend can be attributed (in part) to advances in photography, computer graphics, mobile and digital technologies. This, coupled with the desire to visualise the past and explore geographically-distant landscapes [5], provides new opportunities and facilitate the development of systems that enable us to bridge time (historic) and space (geographic) barriers.

Timespan museum and arts centre is a cultural organisation located in Helmsdale, a small town on the north-east coast of Scotland. Timespan previously collaborated with the Open Virtual Worlds (OVW) research group at the University of St Andrews to mark the 200^{th} anniversary of the Scottish Highland Clearances by producing a Clearances Trail App and an immersive CAEN Township installation [6]. The Clearances Trail App is a mobile app (available on Android and iOS) that enables users to take part in a guided tour of the Strath of Kildonan, which was central to the Highland Clearances in the 19^{th}-century. The tour combines text, audio narratives, images and a location-aware map to educate users on the history of the Highland Clearances. The CAEN Township installation is an immersive exhibit which features a Microsoft Kinect and three large screens, situated in a "story-telling room", that enables visitors to visualise and explore a 3D model of CAEN, a pre-clearances settlement in the Scottish Highlands. Users can move around the model, enter longhouses, trigger informative pop-ups, listen to stories and watch animated movies, all of which are designed to educate the audience and provide them with a sense of the Highlands before the Clearances.

The building which Timespan now occupies was a fish curing yard around the late 19^{th} and early 20^{th}-century. Fishing was a major source of income and livelihood for the inhabitants of 19^{th}-century Helmsdale, hence the curing yard played an important role in the village's economy as it was a space where the herring and salmon caught by fishermen were gutted, cured and packaged for transportation. The ability to re-live and explore the curing yard as it stood in the 19^{th}-century thus serves as a great resource for preserving and disseminating the heritage for the locals, and provides a medium for tourists to learn and engage with local history. This is the motivation of this work.

As part of Timespan's 30^{th} anniversary a project was conceived to celebrate local history. The aim of the project was to produce an immersive museum installation that would serve as an educational resource for the village locals as well as offer novel, interactive experiences to the museum visitors, some of whom are foreign travellers passing through the Highlands, and the ongoing collaboration with the OVW research group and the success of previous projects provided a good platform to execute the project.

3 Related Work

The use of 3D technologies to recreate and visualise history has been documented extensively in literature. The reconstruction of an important but now derelict cathedral as it stood in the 14th-century is documented in [7]. The work describes the reconstruction process including interdisciplinary research, building the landscape based on Ordinance Survey data, establishing the architecture, and embedding sound and scripted Non-Player Characters (NPC) such as canons and historical figures. The resulting model and associated content have been deployed in learning contexts such as schools (for primary and secondary education), festivals (for community engagement), and on the web (accessible remotely through a browser). A framework for building interactive virtual museum content and exhibitions is proposed in [8]. The system leverages a popular game engine in addition to web frameworks to provide a distributed service (based on data pulled from popular online repositories) that enables users to easily create, manage and share virtual exhibits which are not limited to a specific application domain, but rather support a broad range of applications. A system for visualising 3D models of Mediterranean sculptures, optimised for both small (mobile) and large (desktop) screens is presented in [9]. The system is capable of streaming content over a network and displaying content at multiple resolution levels so as to improve performance and facilitate the inspection of the model in high levels of detail. In contrast to [9], which combines a mobile-based and desktop-based approach, [10] adopts a purely mobile-based approach to heritage visualisation. The system, which features cross-platform support (made possible by web technologies), enables users to visualise a 3D model of a mediaeval town with minimal resources. The impact of 3D technologies in the domain of cultural heritage is investigated in [11], and the findings affirm the case for using digital capture approaches such as photogrammetry and laser scanning to foster community engagement with cultural heritage, as well as the use of immersive technologies such as virtual reality headsets to provide compelling experiences thus increasing users' engagement with heritage content. These work demonstrate different ways in which 3D technologies can be used to recreate and visualise the past. The reconstruction process described in [7], the user-centric approach adopted in [8], the multi-platform approach adopted in [9,10], and the findings of [11] have been given due consideration in the actualisation of this project.

Furthermore, remote virtual museum visits in older adults result in a positive experience and high usability when an interaction-free design is adopted [12], such that users can consume content with little or no active interaction. This provides rationale for the interaction-free design adopted in this work. It is worth noting that the virtual museum presented in [12] facilitates a remote visit, contrary to the system designed in this work which allows visitors to explore the past on-site. Nonetheless, the design principles remain relevant because the primary objective is to present "snackable" content to visitors thus providing an informative and engaging experience in little time.

Technological advances, the proliferation of smart devices and 3D media, and the corresponding reduction in cost have contributed to the popularity of virtual museums in recent decades. These technologies enable the development of virtual exhibits that mitigate the risk of damage to artefacts and require little or no real estate [2]. The concept of the "Museum of Pure Form", proposed in [13], involves the use of virtual reality devices to provide immersive experiences to visitors. It overcomes a limitation of traditional museums (in which visitors cannot go close to or touch exhibits) by providing haptic feedback to simulate the sense of touch while interacting with digital replicas of the exhibits, usually coupled with stereoscopic visual display of the digital replica for immersion. In addition to bodily-immersive technologies, spatially-immersive technologies have also been deployed in museum contexts. The use of a panoramic stereo screen to present artwork to museum visitors is presented in [14], which documents a high degree of interaction with, and immersion in the virtual environment. In a similar vein, [6] reports on the recreation of a 19^{th}-century township and its deployment in a museum, which enables visitors to explore the township through body gestures. The installation uses the Microsoft Kinect for motion detection and three large projection screens arranged as a semi-hexagon to produce a 150° field of view. The common denominator of the aforementioned work – and what makes them relevant to this work – is their use of technologies in museum contexts, either to replicate museum exhibits which can be accessed off-site, or to create virtual environments which can be deployed on-site. This demonstrates the maturity of virtual museums and the versatility of immersive technologies; for instance, body-based devices are used in [13] while space-based devices are used in [6,14], all with the common goal of giving users a sense of presence in a virtual world. It is worth noting that the system proposed in this work uses neither haptic (as in [13]) nor spatially-immersive (as in [6,14]) technologies owing to cost and space constraints respectively, but rather features a head-mounted display and a screen (slotted into a false wall) to deliver an immersive experience in while minimising cost and space requirements.

In summary, computer graphics and 3D technologies have facilitated the recreation of historical scenes and artefacts, which have been used in the development of exhibits that offer interactive and immersive experiences to museum visitors. These developments have been leveraged in this work, with the contribution of enabling museum visitors to compare a recreated historical scene and its present day counterpart from an equivalent vantage point.

4 Methodology

The methodology for this work was one of a practice-based research. During an initial research phase, heritage experts at the museum consulted archival documents from the local and neighbouring museums. Two of the primary sources used for research include [15], which sets out the plan for the first curing yards in Helmsdale and [16], the annual reports of the British Fisheries Society – the industry regulator. Based on these sources, as well as maps and plans of the area, a preliminary 3D model was created using Unreal Engine 4 [17]. This model then served as the basis for eliciting feedback from the heritage experts

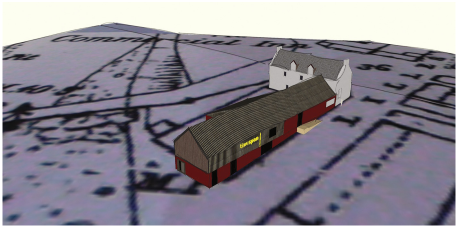

Fig. 3. Preliminary model in Sketchup

Fig. 4. Equirectangular image of the yard

and locals, which provided further input for refining the model. An iterative design-implement-feedback cycle (see Fig. 2) led to the development of a model that was deployed and evaluated with the visitors and heritage experts at the museum.

A prototype of the system was trailed at the Helmsdale Highland Games in the summer of 2016, where members of the general public were invited to explore the reconstruction using virtual reality headsets and xbox controllers, and provide feedback in form of Likert-scale questionnaires and interviews. The first access point (a location of interest in the museum for which data was gathered from the equivalent vantage point in the virtual environment) was installed in the fall of 2016 and museum visitors were invited to interact with the system during an open day event (Fig. 1). This access point was evaluated with focus groups in the spring of 2017 and the findings are discussed in Sect. 6.

5 Design and Implementation

Design decisions were made on interaction – using fixed-view access points, content – using spherical images, and platform – using virtual reality headsets, after which the system was implemented, beginning with research, followed by 3D modelling, content extraction and system deployment.

5.1 Reconstruction Process

The reconstruction process began with gathering visual evidence and culminated with the deployment of stereo equirectangular images which were extracted from an Unreal Engine 3D model.

Historical Research: Historical research entailed gathering scale plans of the building and historical images of the local community. The scale plans represented the footprint of the curing yard which has undergone minimal changes in the lifespan of the building. In addition, a map of the village Helmsdale was obtained and this served as the basis for the development of a building plan.

3D Modelling: The modelling process began in Sketchup [18] using the plan and footprint uncovered by the research phase, to ensure that the building was modelled to scale. The Sketchup 3D model (early stages shown in Fig. 3), which represented the frame of the building, was then exported as a Collada mesh and imported into Unreal Engine. The model was then populated with objects that would have been found in a 19th curing yard (as uncovered by the research), and textured with appropriate patterns to improve the photo-realism. The output of this process was a photo-realistic 3D model of the curing yard as it stood around 1890. This model – which featured troughs, barrels and buildings, as well as the surrounding landscape and river (see Fig. 7) – served as the basis for content extraction and deployment.

Content Extraction: Stereo equirectangular images, formatted in a top-bottom manner (see Fig. 4) were extracted from the 3D model using Unreal Engine's *"Stereo Panoramic Movie Capture"* plugin. This plugin provides options to change input parameters so as to control the quality of the resulting captures. These parameters include the horizontal (and vertical) angular increment (i.e. the number of slices captured horizontally and vertically as factors of 360° and 180° respectively), horizontal field of view (i.e. how much of the spherical environment can be viewed at any one time), and eye separation (i.e. the distance between the stereo cameras, to mirror the Interpupilary Distance [IPD]).

Deployment: The equirectangular images extracted from the model were used to make photosphere tours of the different vantage points around the curing yard. The photosphere tours were deployed as a mobile app (on Android, enabled using the OpenGL environment) which can be viewed using a mobile VR headset (such as the Google Cardboard [19]) in stereoscopic mode and without a VR headset in wide mode, and as a web-based photosphere tour for both online use (as deployed on Roundme [20]) and offline use (enabled using krpano framework [21]) which can be navigated using an Xbox controller or with a standard keyboard and mouse. The considerations that influenced these modes of deployment are discussed in Sects. 5.2 and 5.3. Historical images (see Fig. 5) and text snippets were embedded into the virtual environment to provide context, draw attention to the equivalence of the real and virtual vantage points, and provide heritage interpretation. This was achieved by blending the flat, historical image onto an equirectangular, virtual image such that the historical image appeared to be superimposed on the spherical environment represented by the virtual image (see Fig. 6).

5.2 Design Decisions

Content: A fully-immersive environment was adopted to satisfy the requirements for an engaging on-site installation. This could have been achieved by either deploying the full 3D model or deploying photospheres of vantage points. The use of the 3D model allows users to explore the 3D model of the curing yard in first-person view while photospheres restrict users to exploring the system from distinct vantage points. On the other hand, photospheres enable the

Fig. 5. Workers in a 19th-cent. curing yard

Fig. 6. View of the virtual curing yard

Fig. 7. Bridge & river in Virtual Hemlsdale

Fig. 8. Exhibit installed in the foyer

deployment of spherical environments with minimal resources on a low-end workstation or smartphone, while a 3D model requires high-end computing power and graphical resources for optimal performance. In addition to the high level of engagement, an interaction-free design for exploring fixed-view points was required, hence the photosphere approach was adopted over the model approach. The restriction of users to spherical, view points also resulted in an accurate mapping of the past (virtual world view) to the present (real world view).

Hardware Platform: Mobile (smartphone with an enclosing virtual reality headset) and Desktop (PC with a tethered virtual reality headset) platforms were considered for the hardware. Although the mobile platform had relatively lower space (real estate) requirements, the Desktop platform was chosen owing to its increased computing power and lower head-tracking latency which results in a higher fidelity experience. This also gives the installation a more permanent feel than could be obtained from the use of mobile phones and headsets. The Oculus Rift [22] and the HTC Vive [23] virtual reality headsets were considered for deployment because they represent the newest generation of high-fidelity, consumer-grade headsets. The Oculus Rift was chosen as it has smaller physical space requirements as compared to the HTC Vive.

5.3 Exhibit Installation

As discussed in Sect. 5.2, a PC with a tethered virtual reality headset was chosen for the installation. The spherical environment was designed as a web-based virtual tour using krpano [21], which retrieves content from a web server running on the PC. To provide input feed into the Oculus Rift headset from the virtual tour, WebVR – an experimental JavaScript API that facilitates consumption of web-based content via virtual reality headsets – was used [24]. At the time of developing the installation, the two WebVR-compatible browsers for desktop were Chromium (an open source version of Google Chrome) and Nightly (a version of Mozilla Firefox). Chromium was chosen (over Nightly) for the installation because it exhibited greater compatibility with the system features when both browsers were tested.

A false wall was built in the museum to accommodate the computer, with a slot for the screen to fit into, outlets for cables and a protruded base for the headset to sit on as shown in Fig. 8. A decision was made to keep the installation interaction-free and easy-to-use. For this reason, interaction was limited to exploring the immediate surroundings of the virtual environment that correspond with each access point. In addition, the exhibit space was stripped of extraneous devices that did not contribute towards exploring the point of interest, thus there were no traditional computer peripherals (keyboard, mouse) or virtual reality controllers (Xbox controller, Oculus touch). This contributed towards the usability of the system, such that the installation sent a clear message to visitors: "*put on the headset and look around*".

Alongside the ease-of-use requirement was the ease-of-management requirement, i.e. the system should run seamlessly and require little or no input from the museum staff. This includes turning on and shutting down automatically at the start and close of business respectively. Automatic startup was achieved by changing the system BIOS setting, and automatic shutdown was achieved using the Task Scheduler feature of the Windows 7 Operating System. In addition to automatically starting up the computer, the spherical environment was automatically launched shortly afterwards. This was done through the use of a batch script that contained the commands to be executed in sequence. A link to this script was placed in the "Startup" programs folder of the computer so that it is launched after the computer boots up.

A challenge was encountered when attempting to launch the virtual reality component of the installation automatically. This resulted from an inherent security feature of web browsers which require user input (such as a mouse click or key press) in order to activate the fullscreen mode, and since the WebVR requires the environment to be in fullscreen mode, any attempts to automatically launch it failed due to a lack of user input. The solution to this problem was to simulate a mouse click at the centre of the screen using a Java program, and to attach an "onclick" event to the web environment, whose action is to launch the virtual reality component. The "Startup" batch script was then modified to launch the "clicker" program shortly after launching the web-based spherical environment, thus user interaction was successfully simulated.

Table 1. Questionnaire items

Questionnaire Entry
I think that this system is easy to use
I would recommend this system for learning history
This system has changed how I think about Helmsdale
I am not more interested in learning about local history
I felt like I was there in the virtual environment

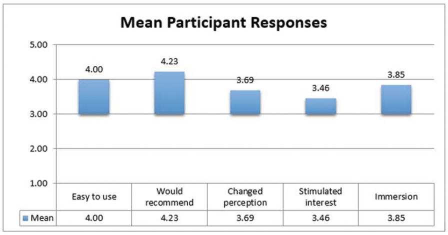

Fig. 9. Mean responses to items

6 System Evaluation

The system has been evaluated with emphasis on *usability* from a user's perspective and *value* from a heritage expert's perspective. *Usability* is defined in terms of user engagement with the technology; this is investigated using Likert-scale questionnaires, semi-structured interviews and focus groups. *Value* is defined in terms of the contributions that the system makes towards actualising the heritage organisation's goals as perceived by the heritage experts.

A user study was conducted at the Helmsdale Highland Games that took place on the 20th of August 2016, where attendees were invited to trial the systems. Feedback was gathered from thirteen (13) participants and the feedback was positive overall. Participants found the system very engaging and interesting, and expressed that it gives viewers an insight into the past through a captivating visual experience. The ability to explore the virtual environment at one's pace, the ability to focus on areas of interest and the superimposition of archival images on virtual content were cited as positives. One participant expressed the desire to dynamically explore the virtual environment and another mentioned a mild feeling of dizziness while using the headset. Overall, the qualitative feedback suggest that the system is suited for exploring the past in an engaging manner.

Participants also filled in a custom 5-point Likert scale (where 1 represents "strongly disagree" and 5 represents "strongly agree"). The custom questionnaire (shown in Table 1) was used instead of a standardised industry questionnaire to ensure a quick turnaround time and to directly elicit quantitative feedback on five aspects of the system: ease of use, recommendation potential, ability to change perception, ability to stimulate interest and level of immersion. The results (summarised in Fig. 9) show that participant responses were all positive (i.e. well above the neutral score of 3), hence participants found the system easy to use, participants would recommend the system for learning history, participants' perceptions of Helmsdale were changed by the system, participants became more interested in learning about local history and participants felt immersed in the virtual environment.

In addition to the user evaluation, an expert evaluation – in the form of pre- and post-deployment interviews – was conducted with heritage experts at the Timespan museum and art centre. This took the form of interviews conducted before the system was deployed so as to gauge expectations, and interviews conducted after deployment to review outcomes and elicit feedback on level of satisfaction. An interview with Anna Vermehren, the Director of Timespan revealed that the museum hoped to offer novel, interactive experiences to visitors, through an installation that is informative, easy-to-use, and leaves a long-lasting impression. When asked about her views on the project output, she said:

> *"...the final product is definitely beyond the expectations that I've had in the beginning both visually and also in terms of the research...I really love the integration of archival material (images) because it demonstrates the research conducted".*

An interview was also conducted with Dr Jo Clemens, Timespan's Archive Development Manager and the project lead. When asked about how the installation will add value to visitors, she stated that the system offers a unique experience to visitors by bridging time and space barriers, in the sense that it enables to visitors compare their current location (i.e. where they are currently standing and using the system) to what it was like in the past, thus fostering a comparison of past and present and enabling them to see how it has evolved. The context of location (i.e. comparing the past and present from an equivalent vantage point) is important in achieving this, as context turns the virtual environment into something that is more than just interesting images, thus making the experience more meaningful. In addition to educating visitors, the installation will pique visitors' interests in local history and direct them to the museum archive where they can learn more.

The curing yard was evaluated with a focus group consisting of nine (9) persons (six female) at the 2017 Timespan Conference. The evaluation took the form of an open-ended discussions which lasted for approximately one (1) hour, in which participants gathered around the curing yard installation and took turns standing in front of the screen and using the virtual reality headset. A discussion ensued during which an observer took notes of the comments and participant behaviour. The notes are categorised based on the aspects of usability, content and technology as discussed below.

Usability: A discussion ensued about the ease of use of the system, as one participant remarked about how "straight-forward" the installation was. A participant stated that the position of the installation (in the museum foyer next to the Front of House desk) worked really well, as it made it easily noticeable to new museum visitors and it made a clear statement to visitors to simply "walk up and use" the system. Furthermore, the lack of interaction was cited as particularly beneficial to older-aged visitors, as users simply had to put on a headset and look around. Participants all agreed that the absence of peripherals (besides the headset and the screen) made the installation less intimidating and more inviting to users.

Content: Participants expressed curiosity about the single-view nature of installation, as one participant asked why there were not multiple locations that could be accessed in the virtual environment. A museum staff who was part of the discussion mentioned that the installation serves as the first in a series of three access points around the museum, where each access point provides a single, 360° view of what the 19^{th}-century curing yard would have looked like at that vantage point. This explanation seemed to "sit well" with participants. However, a participant stated that this decision made the resulting installation seem so "basic", suggesting that a more dynamic environment could have been deployed with the technology used for the installation. Also on the aspect of content, participants seemed to appreciate the blending of an archival image into the virtual environment, together with informative text snippets which fade in and out when an area of interest is looked at. Participants also suggested the addition of audio to provide more information and context about the 19^{th}-century curing yard. One participant suggested including ambient sound in form of historical songs that were often sung by herring girls while gutting fish, and another suggested the use of audio narratives instead of (or at least together with) the text snippets for the benefit of children (who may be unable to read) and adults (who may be unwilling to browse around for the snippets).

Technology: As participants explored the curing yard, a participant asked why an Augmented Reality (AR) approach – as opposed to a Virtual Reality (VR) approach – had not been adopted for the installation. The participant suggested that a system where visitors could hold up a device in a direction in the museum foyer and be presented with a synthetic environment with informative text, may have worked better than the current installation. Another participant chimed in to state that such a system would require the use of mobile devices, which would either require purchasing multiple devices or requiring museum visitors to have capable devices with the application downloaded and installed. This would be less practical than the current installation as suggested by the participant. Furthermore, yet another participant made an argument for the use of VR instead of AR by stating that the use of VR instead of AR enables users to immerse themselves in the virtual environment (which represents the past) and compare the experience with the real environment (which represents the same space in present day). Such a comparison of experiences would be lost if a mixed (augmented) reality approach was adopted.

An evaluation also was conducted with a focus group consisting of 3 (female) participants, aged 50–70, who are all members of the Timespan Heritage Group. This exercise was particularly valuable because the participants were all experienced heritage practitioners who represent the target demographic, hence they were able to provide valuable insights. Overall, the participants stated that they were satisfied with the experience. Participants were pleased with the level of detail in the Curing yard, and they consider the system as a very informative resource and a good way to learn about heritage. The findings of the exercise are discussed in terms of user experience, technology and content.

User Experience: When asked about the user experience, a participant stated that they were pleased. One participant stated that they found the experience *"very smooth"* and another commented *"you're really there, wow, all round you"*.

A participant stated that *"the use of old pictures blended into the virtual environment brings the exhibit to life"*. Conversely, another participant was displeased with the embedded historical image because *"it comes in and obscures what is behind it (i.e. the virtual environment) too quickly"*. A participant suggested that a chair might be useful so that when users wish to make a full 360° turn, it can be done safely while seated as opposed to while standing. This might mitigate the risk of falling or getting entangled by the headset wires when turning. At this point, another participant suggested that wireless headsets may improve the user experience.

Technology and Content: Participants expressed preference for the use of engaging, virtual reality technology as a means of interpretation over storytelling. In addition, participants thought that the use of virtual reality made the exhibit more exciting, and makes them excited to try new means of heritage interpretation. In terms of content, one participant suggested that the use of audio narratives would be beneficial, while another expressed preference for ambient sound (in form of voices in the background) instead of a narrative. Overall, participants expressed acceptance of the proposed addition of audio to the exhibit.

6.1 Challenges and Limitations

A major challenge was in determining how to maximise user experience with minimum cost. As discussed in Sect. 5.2, to create an immersive, spherical environment, a 3D model approach was pitted against a photosphere approach and the latter was adopted due to its relatively-lower resource requirements. A decision was then made on how best to deploy the spherical environment, at which point mobile-based virtual reality systems were pitted against desktop-based virtual reality systems. An immersive, desktop-based approach was chosen as it represented the ideal trade-offs between cost and user experience, i.e. it was found to deliver the best experience per price unit as compared to a mobile-based, photosphere approach or a desktop-based, 3D model approach. Table 2 shows the trade-offs between cost and user experience for the system configurations considered.

Another challenge manifested in form of a trade-off between ease of use (from the perspective of the museum visitors) and convenience of management (from the perspective of the museum staff). For convenience, the exhibit should be

Table 2. Comparison of developed mobile and desktop VR systems

System	Cost	User Experience
Mobile VR (Photospheres)	Low	Medium
Desktop VR (Photospheres)	Medium	High
Desktop VR (3D Model)	High	High

relatively easy to turn on/off and debug when issues arise, and for ease of use, the system should be relatively straight-forward to use with minimal (or no) instructions. To this end, the system was configured to automatically boot-up and shut-down on a schedule to minimise the burden on museum staff, and the interaction was made as interaction-free as possible so that visitors know how to engage with the system without being told what to do.

6.2 Future Work

The next stage of the project involves deploying the model in more access points around the museum so that visitors can explore the curing yard from multiple vantage points. The new access points as well as the existing one will incorporate curing yard related sound tracks as well as audio narratives to improve on the immersive experience, and further evaluation will be conducted to evaluate whether the site-specific nature of the installation becomes more obvious to users once there are more access points, evaluate whether the target demographic (over 65s) will interact with the technology, and the extent to which the novelty of the technology contributes to the interaction, and evaluate how site-specific, virtual reality exhibits which are distributed across a museum can function as an educative tool.

7 Conclusion

The motivation, methodology and implementation of a 19th curing yard virtual reconstruction have been discussed in this work. The curing yard has been deployed as an on-site museum installation that visitors can interact with to explore local heritage and compare the past and present from equivalent vantage points. The content of the museum installation has also been deployed as a mobile app for Android smartphones and as a virtual tour which is accessible via a web browser. Emphasis has been placed on an interaction-free design which delivers "snackable" content to ensure that the system easy to use, the experience is informative and engaging, and the resources required are kept to a minimum. The system evaluation has revealed positive feedback, as users at a community event who interacted with the system prototype expressed views on the value of the system in providing a means to visualise local history. Evaluation was also conducted with heritage experts to investigate the potential value of the system from the perspective of heritage organisations. The feedback was positive, with experts stating how the mix between archival images and generated computer graphics brings the past to life. In addition to these, focus group evaluations have revealed that the system is ease of use, features informative content and offers an engaging experience for group exploration. These findings suggest that museums and heritage organisations can provide compelling and informative experiences that enable visitors to travel back in time with minimal interaction and relatively low cost systems.

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Correction to: A Virtual Museum Installation for Time Travel

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In the original version of this paper, the name of the 7th author was misspelled. This has now been rectified as "Jo Clements".

The updated version of this chapter can be found at
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