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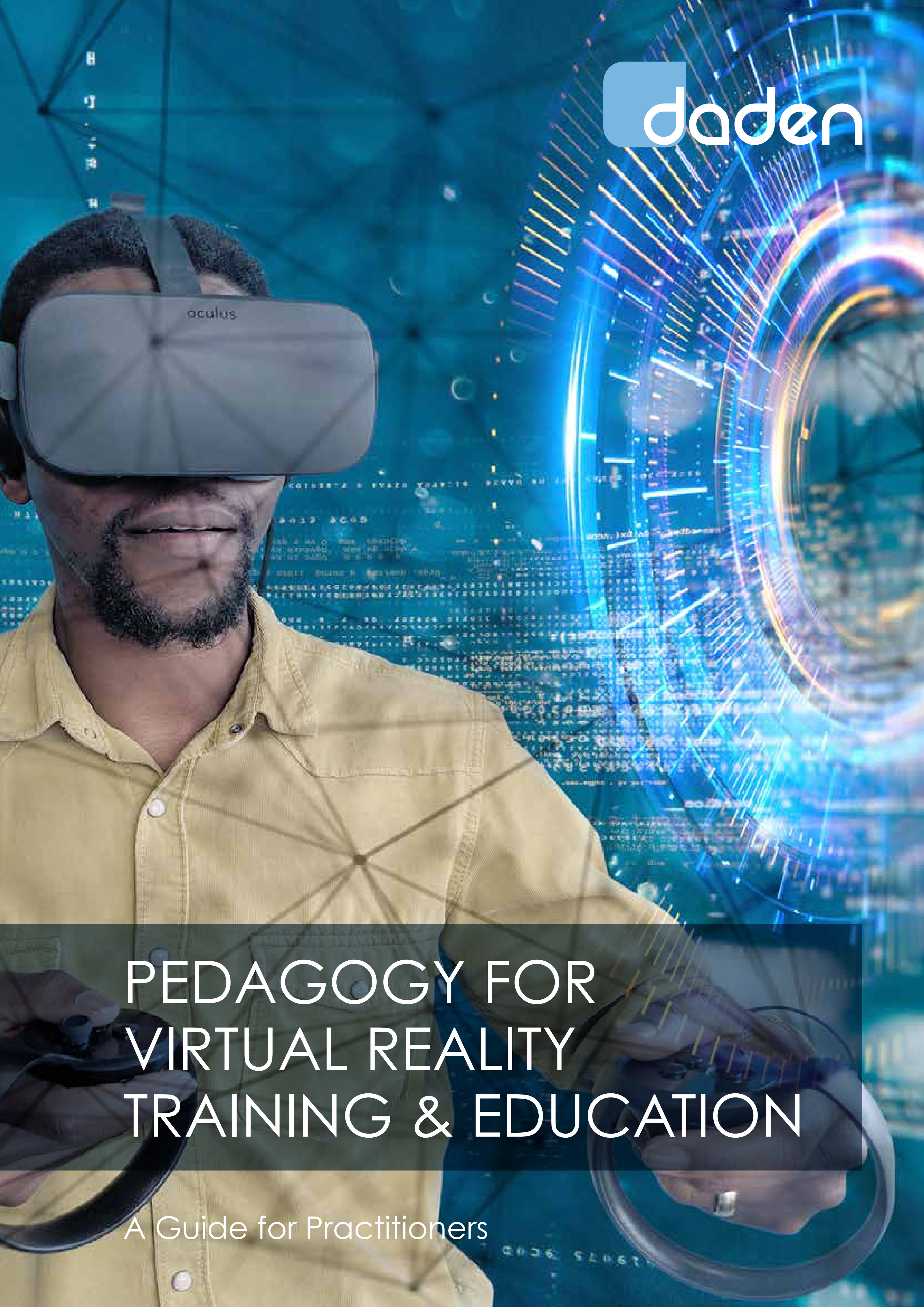

PEDAGOGY FOR VIRTUAL REALITY TRAINING & EDUCATION

A Guide for Practitioners

This document is a derivative of the document "Evidenced Based Models for VR Training", produced by Daden Limited for the UK Ministry of Defence and Defence Science and Technology Laboratory (Dstl) and made available under a CC BY 4.0 Licence.

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PEDAGOGY FOR VIRTUAL REALITY TRAINING & EDUCATION

A Guide for Practitioners

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Contents

Foreword

Virtual Reality (VR) seems finally to be coming of age. Consumer devices and user-friendly content creation platforms are beginning to put VR into the hands of anyone who wants or needs it.

Virtual Reality has been through several evolutions over the last few decades. In the 1990s it was about big cumbersome Virtuality headsets, then in the 2000s the focus was on DesktopVR, with Social Virtual World platforms such as Second Life and Open Sim giving us a first taste of what the Metaverse could be like. With the launch of the Oculus Rift DK1 in 2013 the attention swung back to Head-Mounted Display VR (HMD-VR), and in the years since there's been a danger of losing sight of all the good work done during the virtual world years, whilst grappling with the unique challenges and experiences offered by HMD-VR. This eBook is an attempt to bring together the best of the learnings from all forms of VR over the past two decades or more.

In my own work in VR (a space I've been active in since 1996) two things have always been important to me. First, it is the user that should have the choice about whether they use HMD-VR or DesktopVR – and it's a choice they should be able to make every time they use an experience. HMD-VR is wonderful – but it's just not practicable to use it in a café, on the sofa half-watching TV or on a train. Let the user choose. Second, it's about democratisation. Democracy of access (so it should run on cheap, i.e. mobile, hardware if necessary) and democracy of content creation (so anyone with reasonable IT skills should be able to create good looking and interactive content). It's this last element, democratic interactivity, that seems to be a current challenge, and ironic given how well Second Life dealt with it almost two decades ago!

We could of course have called this book "Pedagogy for the Metaverse" and maybe shifted a few more copies, but we believe in keeping our feet on firm (if virtual) ground – presenting tried and tested evidence-based approaches that tutors and trainers can use with the systems that are available now. I hope that you find this eBook of use, and if you do I'd love to hear from you.

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The support of the UK Ministry of Defence in creating this eBook is acknowledged. The original document, Evidence Based Models for Virtual Reality Training, of which this is a civilianised version, was produced as part of the Defence Science and Technology Laboratory's SERAPIS SSE programme which brings together the best of government and industry to develop new battle winning capabilities in Simulation and Synthetic Environments for the benefit of the UK's Defence and Security.

Introduction

VR is being increasingly used throughout public and private sector organisations to teach and train people at all levels, from teaching history, geography and STEAM subjects in schools and colleges to maintaining equipment, dealing with customers, delivering hospital care, and visualising and experiencing new environments and even new datasets.

This eBook is focused on the application of VR to training and learning, although the information may usefully inform other VR use cases. It aims to make the evidence base for VR readily available to tutors and trainers involved in learning and training projects and activities, improving engagement with VR in ways that both support staff and result in better learning and training for students and trainees. It has been developed from a literature review of pedagogically-driven research into VR and immersive 3D education and training, supported by focus groups and academic consultations. We have sought to identify clear and effective pedagogic frameworks that can be applied by tutors and trainers to VR projects, and to make the important information available in a readily-digestible form.

VR is evolving rapidly. If organisations are to make good use of this technology, particularly for learning and training, then they must understand how best to employ it, informed by the evidence from previous commercial, academic and even military uses of both VR and related 3D immersive learning and eLearning technologies.

The eBook considers the underlying approaches to learning which are being leveraged by VR, the key elements of the VR experience (including immersion, agency, embodiment and presence) and how HMD-VR and Desktop VR differ (and it's about mutual strengths, not either-or), before looking at some tried and proven models to help you think through each stage of the VR curriculum and experience design, development and evaluation process. The eBook ends with pointers to a range of technical and non-technical considerations, a glimpse at what the future might bring, and finally some links to further reading.

Whilst this eBook focuses on Virtual Reality many of the models are just as applicable to Augmented Reality and Mixed Reality experiences. This eBook also considers both Desktop and Head-Mounted Display approaches to VR. Don't worry there are definitions of all of these in the next few pages!

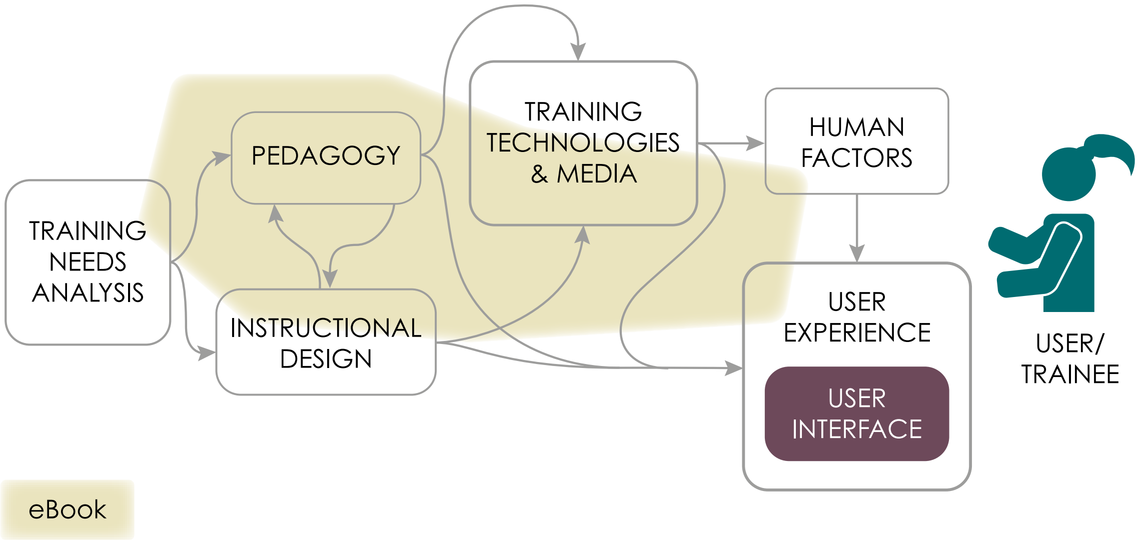
We have done our best to provide hyperlinked footnotes to all the key research, papers and ideas that have informed this eBook. Just click on the links in the footnotes to read the original research.

We should perhaps make it clear what this eBook is not.

It is not intended as a guide to the detailed design of a VR User Interface (UI) or even User Experience (UX), nor a guide to the Human Factors issues of VR, or a Training Needs Analysis manual. Rather it is concerned with the bigger picture of understanding why and how VR works, the different ways of approaching the design of VR training, and how students can learn best from VR. It is also not a guide to the technology (which is changing so fast even an eBook would struggle to stay current), nor a guide to why VR is worth using – which has been covered by other studies. It is intended to help you understand why VR is different (and indeed when it is not), and as guidance on how to use VR effectively as part of a blended and integrated approach to training, underpinned by sound academic theory and evidence.

Our Scope

In using VR to support training and education you will have the maximum chance of success if you build on evidence-based best practice, leveraging the techniques and approaches which have already been proven, and deploying them in a way that takes advantage of the key characteristics of VR.



In particular pedagogy, human factors, instructional design, and related domains such as Training Needs Analysis, User Experience and User Interface/Man-Machine Interface design all need to work together to deliver a successful training system. The choice of training media, of which VR is just one, may have a significant impact on each of these, and may be driven by some, and in any realistic training scenario VR will almost always be just one part of a mix of training media.

Training Needs Analysis is understanding what skills and knowledge people need in order to be able to do the job, what their current levels of performance and ability are, and then specifying the training that will make a difference. Goldstein and Ford's *Training in Organizations: Needs Assessment, Development, and Evaluation*[1] provides the classic introduction.

Pedagogy is the art and the science of teaching and learning, it is understanding how people learn, and as a result how best to design instruction so that people do learn.

[1] Goldstein, I. L., & Ford, K. J. (1993). Training in Organizations: Needs Assessment, Development, and Evaluation . Pacific Grove, CA: Brooks.

Instructional Design is having clear instructional goals, breaking down the required learning into appropriate chunks, choosing how each is going to be used for training, having a clearly defined process of how to create and deliver the training, and then measuring its success. It should say, rightly, little about how the training is delivered – that is where pedagogy comes in. Approaches to Instructional Design include methodologies such as the UK MOD JSP822's DSAT, Analyse-Design-Develop-Implement-Evaluate[2] (ADDIE), the Successive Approximation Model[3] (SAM) and Four-Component Instructional Design[4] (4C/ID). These are just as applicable to VR as to any other learning technology.

Training Technologies and Media refers to the form in which the training is being delivered, whether classroom, discussion, role-play, eLearning, field exercises, book-based, VR, video, audio or any other means.

Human Factors is about considering what happens when a person actually tries to use the system. Whilst traditionally focused on physiological issues (can they use the controls, does it fit, is it too heavy/hot) it increasingly embraces the psychological (and emotional) impacts of use.

User Experience (UX) is about thinking of the (training) experience from the point of view of the student, what will it feel like to them, and how it can be designed so that it all just flows. It is closely allied to Human Factors, but typically takes a more user and individual-centric viewpoint.

User Interface/Human Machine Interface (UI/HMI) Design is more about the minutiae of what a particular interface looks like and how it works, and is just one part of the User Experience.

[2] https://educationaltechnology.net/the-addie-model-instructional-design/
[3] https://www.alleninteractions.com/services/custom-learning/sam/elearning-development [4] https://www.4cid.org/publications/

What is Virtual Reality?

The term Virtual Reality has been applied to many different technical approaches to visualisation over the decades, and matters have not been helped by the introduction of terms like Extended Reality (XR), and even a confusion between VR and Augmented Reality (AR). So here are a few definitions to help make sure that you understand how we've defined things.

EXTENDED REALITY (XR)

Extended Reality is the umbrella term used for all the technologies that create immersive experiences in which users interact with digital content which augment or replace the physical world.

VIRTUAL REALITY (VR)

Virtual Reality is the form of XR where the user primarily interacts with the digital experience rather than the physical world, and through being immersed, typically in a 3D virtual environment, feels like they are somewhere else.

HEAD-MOUNTED DISPLAY VR (HMD-VR)

HMD-VR is VR explicitly delivered through a head-mounted display which completely covers the user's field of view, completely blocking out the physical world, and which offers 3 or 6 degrees of freedom (3DOF/6DOF) and usually hand controllers or gesture control. This is sometimes referred to as "Immersive Virtual Reality" but that term can be misleading and is best avoided.

DESKTOPVR

DesktopVR refers to VR experiences delivered using a conventional 2D computer screen (desktop, laptop, tablet or mobile), in either first or third person where the user can navigate and interact with a rich virtual environment, such as in Fortnite, Minecraft, Second Life or the UK MOD's Defence Virtual Simulation (DVS).

CAVES

Caves are VR delivered by a walk-in environment where typically 3 walls are full screen displays and whose view may change as the users moves their position in 3D space.

PHOTOSPHERES

Photospheres are also referred to as 180 or 360 degree images or video. The users is placed at the centre of an image or video with a 360/720° solid angle and can look around in all directions (360°) or just anywhere in the forward arc (180°).

AUGMENTED REALITY (AR)

Augmented Reality overlays digital information onto a viewscreen (typically a smartphone, but possibly a heads-up-display) and supplements reality rather than replacing it.

MIXED REALITY (MR)

Mixed Reality overlays digital information onto a head-mounted see-through screen, where the digital information is 'aware' of the physical geometry of the world and the user's movement in it and responds to it.

Simulation, Games and Serious Games

There has been significant work over recent decades on the use of games technology and game-based approaches in learning and training, whether implemented by paper and card, eLearning or VR.

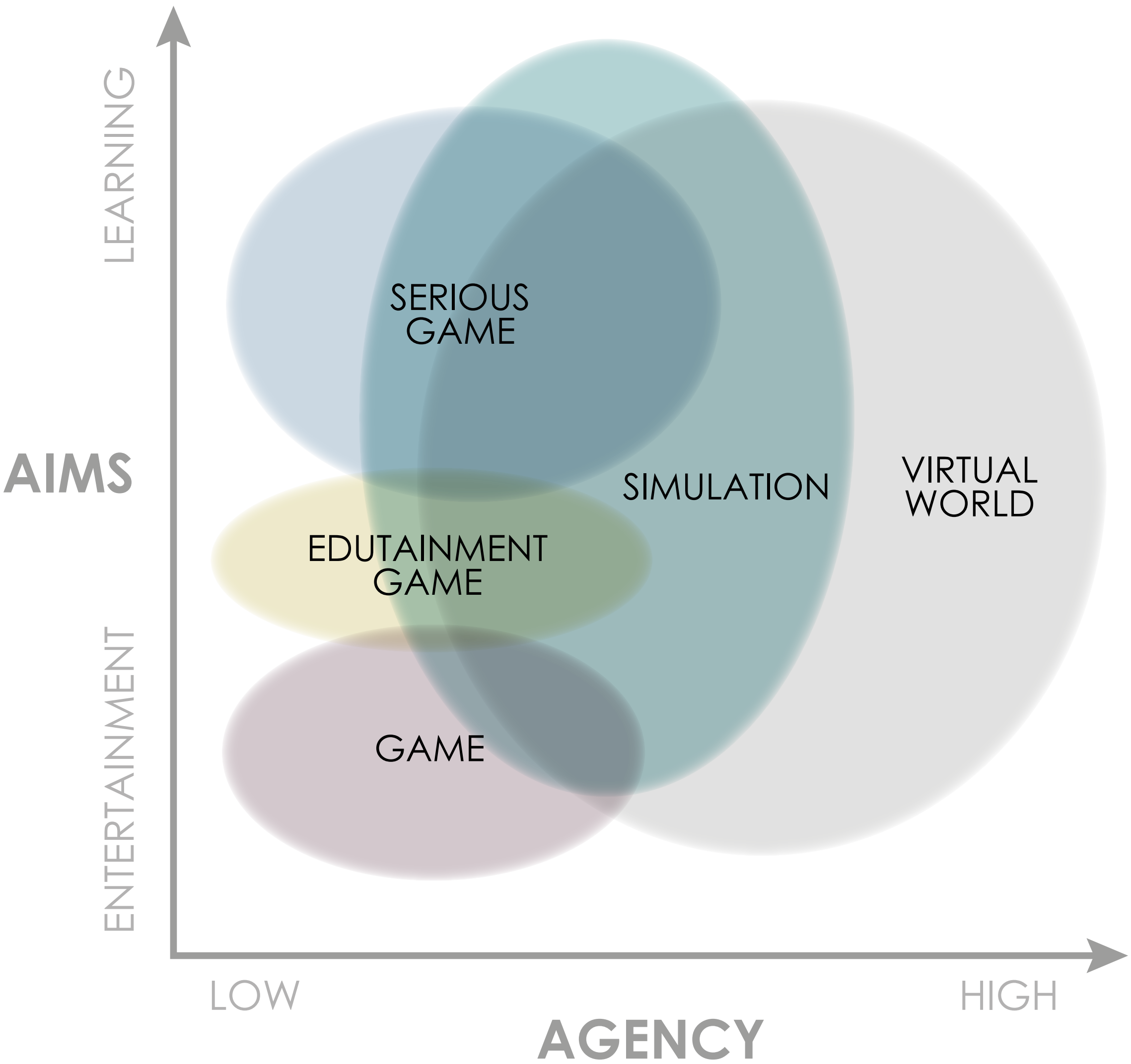
Simulation (modelling a process) and Serious Games (games used for serious purposes, such as training and learning) are two areas that this work has impacted, each potentially providing a different perspective on the same subject.

Virtual Worlds (from Second Life to Fortnite) can also have aspects of simulation, games and serious games. Aldrich[5] (a leading researcher in this field) sees virtual worlds, games, and simulations (when considered as digital experiences) as highly interactive virtual environments, all with their own affordances and purposes – although visually all three could look identical.

[5] Aldrich, C. (2009). Virtual Worlds, Simulations, and Games for Education: A Unifying View. Innovate: Journal of Online Education 5, (5).

Aldrich identifies the key differences as being that:

- **Educational simulations** use rigorously structured scenarios with a highly refined set of rules, challenges, and strategies which are carefully designed to develop specific competencies that can be directly transferred into the real world.
- **Games** are fun, engaging, activities with structure and rules and whilst usually used purely for entertainment, may also allow people to gain exposure to a particular set of tools, notions, or ideas.
- **Virtual worlds** are multiplayer (and often massively multiplayer) 3D persistent social environments, but without the focus on a particular goal, such as advancing to the next level or successfully navigating a scenario.



Approaches to Learning

Pedagogy is the method, and practice, of teaching. It encompasses teaching styles and theory, as well as feedback and assessment.

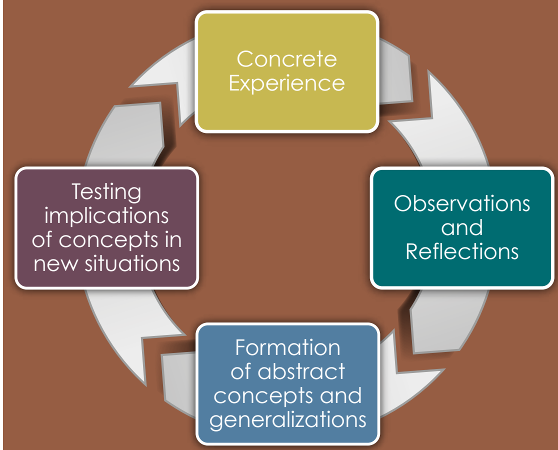
The study of pedagogy seeks to understand the learning process in order to optimise learning, by taking account of the personal, situational and contextual factors that impact on learning and the different teaching methods available. These theories can be applied across a wide variety of different contexts and training technologies, including VR.

In this section we look at some of the key foundational approaches to pedagogy, three key psychological factors being leveraged by VR training, and some practical approaches to pedagogically based learning and training design.

FOUNDATIONAL APPROACHES

These approaches to pedagogy have a relatively long history and lay the foundations for much of the more practical approaches described later. Of particular note is how most of these have the student, rather than the topic, tutor or technology, at their core.

Kolb's Learning Cycle



Kolb's seminal Learning Cycle[6] is focused on the importance of reflection. It incorporates both goal-directed and behaviour learning theories to account for the way learners learn.

Following an experience (concrete experience), learners reflect on and evaluate their experience (reflective observation). This enables learners to engage in abstract conceptualisation where they reflect on how this learning relates to their prior knowledge and experience. Learners then apply and test the learning in new situations. VR potentially enables faster iteration around this cycle, with learners being able to put new learning into virtual practice more often than they can physically.

[6] Kolb, D.A. (1984). Experiential learning: Experience as the source of learning and development. Prentice Hall.

Constructivism

According to constructivists, knowledge is not an absolute, but is rather constructed by the learner based on their previous knowledge and overall view of the world.

Proponents of this approach believe that learners construct knowledge and are predisposed towards learning. For effective learning to take place, the learner must be actively engaged in selecting and interpreting information from their environment. Understanding therefore comes from interacting with the environment, resolving cognitive conflict, negotiating social situations, and evaluating individual understanding. VR allows for a far richer learning environment than many more traditional forms of eLearning and so should aid a constructivist approach.

Experiential Learning

Experiential learning was popularised in the 1930s by Dewey[7] who emphasised the human capacity to reconstruct experience and thus make meaning of it. Dewey believed that education was a process of continuous reconstruction and growth. The role of the tutor was to organise learning activities that built on the previous experiences of the students and direct them to new experiences that furthered their growth. To foster this continual growth, the curriculum should be closely tied to the students' experiences and be developmentally appropriate. VR is ideally suited to create such flexible and accessible learning experiences without many of costs of physical world training. Dewey opposed theories that considered knowledge to be specialised and independent of its role in problem-solving inquiry.

Actor Network Theory

Actor network theory[8] is one of the most recent approaches to pedagogy and is a means of exploring the relational ties within a network – such as that linking the student, colleagues, the tutor, the topic, the learning technology, their prior experience and other contextual factors. It is perhaps more of a method than a theory because it describes an approach rather than providing explanations for observations. What is central to this approach is that actors may be both human and non-human, thus for example weapons, vehicles and digital devices are seen as actors that have influence. Clearly, VR headsets could also be seen as actors if viewed through this lens. Actor network theory focuses on exploring networks, and in the impact between networks and actors, and the controversies inherent in these.

[7] Dewey, J. (1938) Experience and Education, Collier and Kappa Delta Pi.
[8] Latour, B. (1987) Science in Action: How to Follow Scientists and Engineers Through Society, Open University Press.

PSYCHOLOGICAL PERSPECTIVES

Whilst the specific features of VR will be considered later, there are three important psychological perspectives on learning which are especially relevant to VR training: **information processing, cognitive load theory** and **situated cognition**.

Information Processing

According to information processing models, memory can be episodic or semantic. Episodic memory involves recalling events in detail and sequence. Semantic memory involves the encoding, storage and retrieval of factual information. Information processing involves registering input or sensory information, short-term memory processing and rehearsal, and long-term memory storage.

Considering this approach, a number of factors can affect rote learning, including meaningfulness, placement of an item within a list, practice or rehearsal, transfer or interference of prior learning, organisation (chunking or categorising), encoding, context and mnemonics. Several factors also affect meaningful learning, such as abstraction (i.e. getting the gist), perceived importance, and patterns of thought or behaviour from previous learning. VR can enable the creation of both semantic and episodic memory, with the VR user ideally having the same type of episodic memory of a virtual experience as of a physical one.

Cognitive Load Theory

Cognitive Load Theory is built on the premise that since the brain can only do so many things at once, learning should be defined and focused.

It is based on cognitive studies which show that processing new information results in 'cognitive load' on working memory before being committed to long-term memory which can affect learning outcomes.

As a result, learning experiences should be designed to reduce working memory 'load' in order to promote long-term acquisition. The ability of VR to show things as they are, minimising the need for the student to mentally translate a 2D drawing to a 3D model, or to animate a process from a set of arrows, should mean that the student has less mental work to do, and so can focus on the real learning.

Situated Cognition

Situated cognition is where learners are immersed in activities and content that mirrors the situation they are trying to learn about, exactly how VR is typically used.

It also echoes situated learning theory which postulates that the context of learning (i.e. situation and place) is critical to what is learnt[9].

A specific example of this is the concept of 'encoding specificity' which states that the transfer of learning is maximised when the conditions at retrieval (i.e. on the job) match those present at encoding (i.e. during learning).

VR is perhaps ideally suited to leverage situated cognition and encoding specificit by placing students into a virtual copy of the ultimate physical environment to create these cues in order to encourage later recall.

[9] Greeno, J.G. et al. (1993). Transfer of situated learning. In Transfer on trial: Intelligence, cognition, and instruction. Ablex Publishing.

PRACTICAL APPROACHES TO PEDAGOGY

Building on the foundational approaches a wide variety of different practical methodologies to learning and training have been developed, taking pedagogically sound approaches to learning design.

Problem-solving, project-based and problem-solving are more traditional approaches, whereas problem-based and inquiry-based/problem-orientated are more recent pedagogies and more student focused.

Problem-solving Learning

After some formal instruction students are given questions or tasks to complete and are expected to develop the solutions using the information they've been given.

The focus is on the training required to achieve particular competencies, and exploration is not encouraged. A part-task training experience in VR would be an example of this.

Scenario-based Learning

Often used as a catch-all for various active forms of learning. In eLearning (including VR) a problem scenario is presented and the student makes choices to reach a satisfactory outcome. Much of military VR training is along these lines, particularly in collective training.

Scenario-based learning builds on the concept of situated cognition described above, and tends to focus on performance improvement, rather than on students constructing their own knowledge.

Project-based Learning

Project-based learning is predominately task orientated and the project is often set by the tutor with students working individually or in groups. Project-based learning tends to be a technique used in an area of the course rather than an overall training/educational strategy such as problem-based learning. In VR a range of exercises and experiences may be required which the student can select from as the need arises, or VR could be used as the 'project home', collecting material gathered and providing a collaborative working space.

Problem-based Learning

In problem-based learning[10], the focus is on organising the course content around problem scenarios rather than subjects or disciplines. Students work in groups or teams to solve or manage these situations, but they are not expected to acquire a predetermined series of 'right answers'. Instead, they are expected to engage with the complex situation presented to them and decide what information they need to learn and what skills they need to gain in order to manage the situation effectively. The approach is very student-centric and students are offered opportunities to explore a wide range of information, to link the learning with their own needs as learners, construct their own knowledge and to develop independence in inquiry. As with project-based learning, VR might need to offer a wide range of training experiences, and can act as a collaboration platform. Ideally it should also support self-authoring so that students can create their own experiences and simulations to support their investigations.

Inquiry-based Learning

In inquiry-based learning, learners engage with a self-determined process of enquiry. The approach is intended to foster collaborative learning and deep engagement through enquiry, with complex, often fuzzy, problems and issues. This is a type of problem-oriented learning (rather than problem-based learning) and stems from the suggestion that problem-oriented learning allows for the use of open-ended problems i.e. real problems to which solutions are not known. The VR requirements are likely to be similar to those for problem-based learning, but with even more of a focus on collaboration and self-authoring.

[10] Savin-Baden, M. & Howell Major, C. (2004). Foundations of Problem-based Learning. Open University Press.

GAMIFICATION

Games and gamification are approaches to learning that many students engage with and are increasingly used within education and industry.

Gamification is where game mechanics are used to improve a non-game activity (including training) by creating a gameful experience, which helps develop motivation and other behavioural outcomes.

In contrast, serious games (as discussed earlier) are complete games whose main purpose is to educate users.

Given that much of the activity around VR is games related, it should hardly be surprising that the boundary between simulation, training and gamification is somewhat porous, and that many of the gamification techniques listed here have direct applicability to VR training.

You should consider whether introducing some of the gamification techniques listed could help with motivation on a course or set of VR lessons. However not all students have a positive response to gamification so early consultation and piloting is essential.

Many games are also, by their very nature, multi-user, and there is active research on the use of VR within the context of team and collaborative working and training[11].

[11] Balint, B. N. et al. (2020). Exploring the characteristics of immersive technologies for teamwork. In Virtual Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2020..

Some of the game mechanics that are typically used when gamification is taking place include:

- Gaining points
- Leaderboards
- Power-ups
- Levels
- Skills Pathways
- Collectibles
- Unlockables
- Easter Eggs
- Badges
- Rewards
- Puzzles
- Resource Management

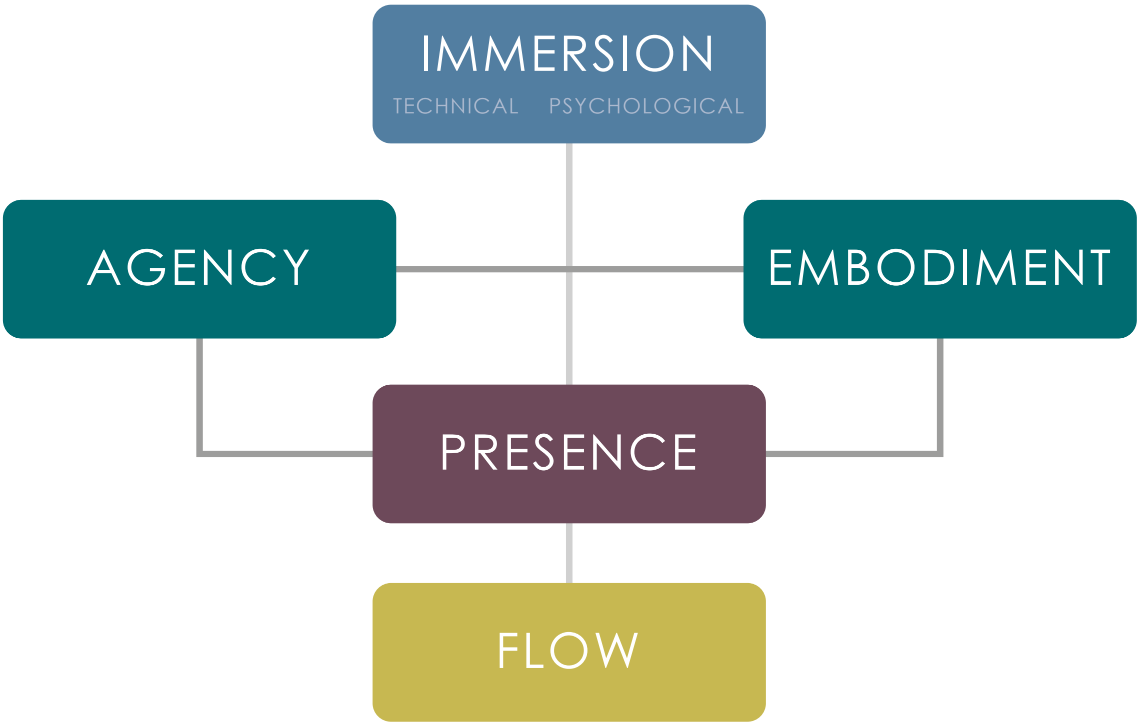
Key Features of VR

What is it that makes the VR experience different from more traditional eLearning?

Researchers have identified five key features which VR delivers in a unique way. Understanding how to leverage each of these is key to taking fullest advantage of what VR has to offer.

Immersion is the foundation for the VR experience, but must be combined with agency and embodiment in order to deliver the sense of presence which is where the true power of VR appears to come from, and which at its best can result in the student entering a flow state. In exploring the use of VR it might be useful to try and design exercises that emphasise singly or in combination the different VR features in order to examine their effect.

Note though that many researchers also see VR as being a highly individual experience, based on context and our own psychology and physiology. Some of the first researchers in the field identified imagination as being one of the most important factors. So be aware that no matter how 'good' a VR experience is, maybe not everyone will get the same things from it.



Immersion

Immersion is the sense of being *'enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences'*[12]. Immersion is increased by having:

- less awareness of your 'real' physical environment (so HMD-VR typically delivers more immersion than DesktopVR)
- natural control over your actions (so fewer menus) and
- the environment responding to your presence.

Several researchers split Immersion down into:

- its technical aspects (e.g. screen resolution and refresh rate) and
- the psychological aspects (e.g. the emotional response and sense of 'being there').

Presence

Presence is a step beyond simple immersion, it is where you feel that you are 'interacting directly, not indirectly or remotely, with the environment. You feel that you are part of that environment'[12]. Slater[13] splits presence down into:

- the place illusion, the sense of being there generated by the technological immersion and visual realism; and
- the plausibility illusion the sense that the perceived events are actually happening – and informed by a sense of credibility, agency and narrative.

True presence is often described as when you have a real feeling of having visited a place when you leave VR.

Co-presence is also a consideration; places usually feel more 'real' when there are other people (represented as avatars) there, even if computer controlled. Some researchers have even found that training effectiveness was increased (e.g. with paramedics) when virtual onlookers were present.

[12] Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. Presence, 7(3), 225-240.
[13] Slater, M. (2009). Place Illusion and Plausibility can lead to realistic behaviour in immersive virtual environments. Philosophical Transactions of the Royal Society of London, 364.

Agency

Agency is the extent to which you feel that you are in control of your own actions and can control, or at least influence, the (virtual) world around you. If you feel a high sense of agency then research suggests that your presence, spatial awareness, and co-presence will be higher, which should lead to better training.

Researchers have found that certain factors assist in generating agency in VR, including:

- viewing the world from a first-person perspective,
- being able to move freely and explore with minimal constraints, and
- being able to do as you want within the virtual environment.

Note however that in DesktopVR some researchers have found that there is more sense of agency and presence from a third, rather than first, person perspective.

Embodiment

Embodiment is the degree to which you feel that your avatar is your own representation of yourself. Kilteni[14] breaks the sense of embodiment into three components:

- the feeling of being located inside the avatar's body,
- the feeling of being in control of the avatar, and
- the feeling of owning the avatar's body.

Embodiment is damaged when there are glitches in the animation (for instance hands moving through the body, or elbows at odd angles), and interestingly there is some debate over whether full body avatars offer more embodiment than partial (e.g. head and hands) avatars.

There also needs to be no match between your physical appearance and your avatar's, and in fact VR provides a powerful opportunity to put yourself in someone else's body and to "walk a mile in someone else's shoes".

[14] Kilteni, K. et al. (2012). The sense of embodiment in virtual reality. Presence: Teleoperators and Virtual Environments, 21(4).

Flow

Flow is defined as *'the state of intense involvement in an activity, an extreme version of immersion, losing self-consciousness, being unaware of fatigue and having a modified sense of time'*[15] and is linked to immersion and presence.

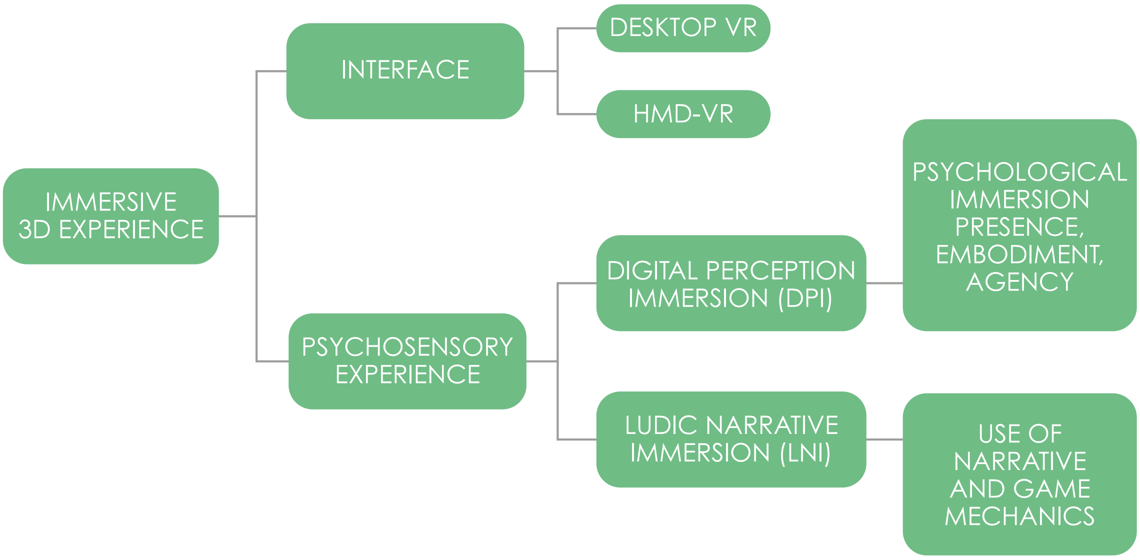
Students are believed to perform at their best when in a flow state, when the level of challenge of the activity is appropriate to their skill level. A flow state is where we want to get students to during training. In VR anything that jars with the experience, or where they consciously have to think about how to use the environment, will immediately drop them out of the flow state and should be avoided.

[15] Csikszentmihalyi, M. (1990). Flow: The psychology of optimal experience. Harper & Row.

HMD-VR vs DesktopVR

Whilst much of the recent media attention has been on Head-Mounted Display VR (HMD-VR) researchers are undecided as to whether it provides 'better' outcomes in training and learning than DesktopVR.

A key analysis by Rudea[16] clearly shows the distinction between how users are accessing the virtual environment and the experience which they are having once connected – see also the USE model presented later. This is reminiscent of the earlier distinctions between technical and psychological immersion, and between the place illusion and the presence illusion. The fact that Rudea applies equal prominence to the narrative and ludic (game) elements in creating the experience as to the more perceptual elements is also notable.



Analysis of the Virtual Reality experience (Adapted from Rudea[16])

In comparing HMD-VR with DesktopVR and other training media, researchers have typically found that whilst greater immersion (i.e. HMD-VR) has increased enjoyment and motivation (which is useful in its own right) it is not typically linked to increased performance. What seems to correlate better with performance is presence – which seems to be as achievable with DesktopVR as with HMD-VR. Issues with cumbersome VR controls and safe movement can detract from that sense of presence, and hence impact training, so good Human-Machine Interface (HMI) design is essential. Students are also likely to be able to spend longer in DesktopVR sessions than they can in HMD-VR.

[16] Rueda, C. et al. (2018). Categorizing the Educational Affordances of 3 Dimensional Immersive Digital Environments. Journal of Information Technology Education: Innovations in Practice, 17(1).

Cyber Sickness

A key issue in the use of VR is that of cyber-sickness (CS), prevalent in HMD-VR but not typically in DesktopVR. One recent review (although based on pre-2019 headsets) found that *'60–95% of participants experience some level of CS during exposure to a virtual environment, whereas 6–12.9% of the participants prematurely end their exposure'*[17]. There are signs that continuing improvements in resolution, refresh rates, and latency may be reducing the incidence of CS.

Having a DesktopVR alternative to any HMD-VR experience would though still seem a sensible option, particularly since DesktopVR can also be experienced on mobile and tablet devices, and so can be more location (and time) independent.

[17] Caserman, P. at al. (2021). Cybersickness in current-generation virtual reality head-mounted displays: systematic review and outlook. Virtual Reality, 1-18.

Applied Models for VR Training

Given that computer systems have been used to deliver learning and training for over 50 years there is much that can be learnt from the research into eLearning systems and teaching in 3D Virtual Worlds which is directly applicable to training in VR – in addition to those models which have been developed for learning and training specifically using HMD-VR.

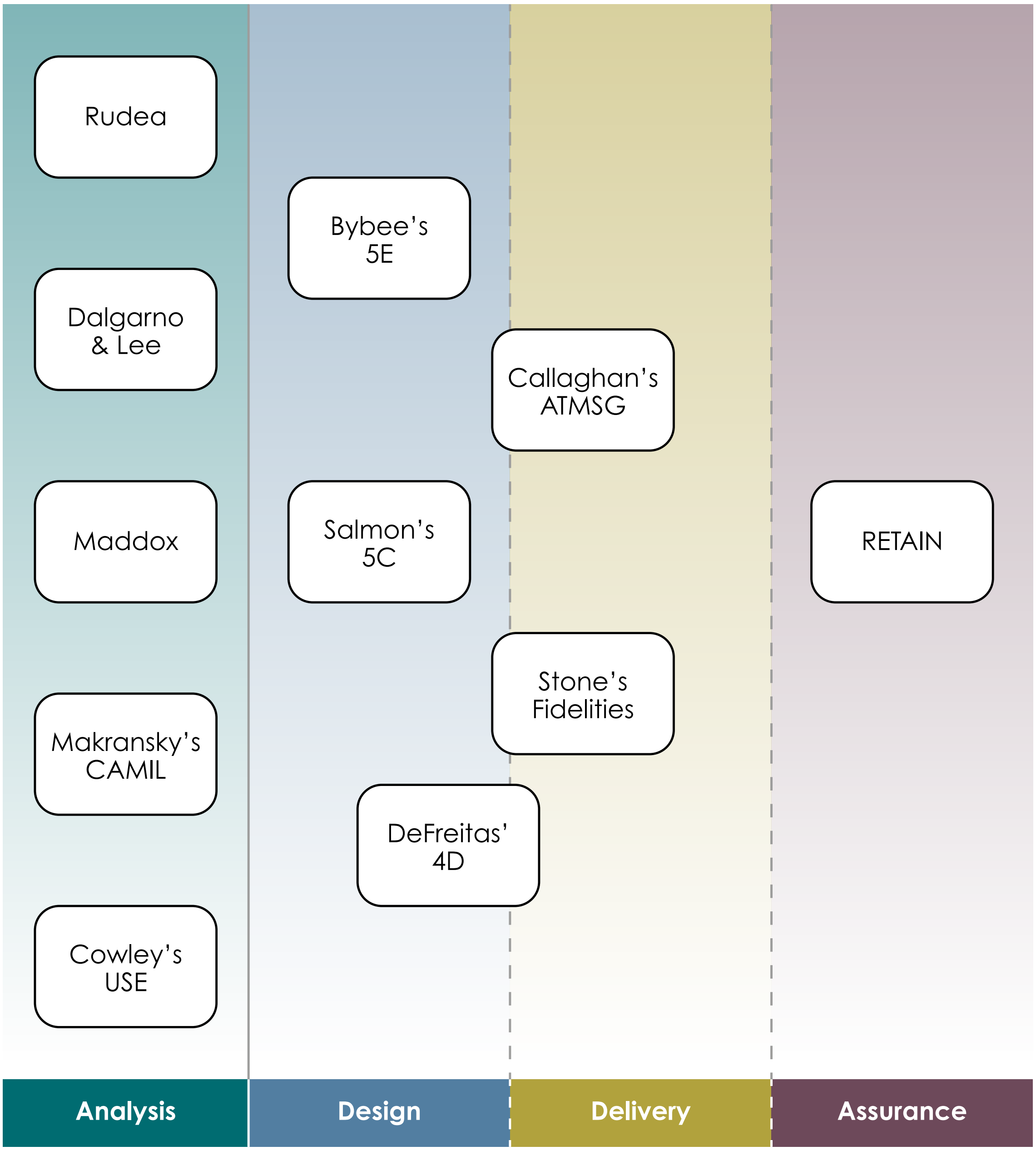
The adaptability and specificity of these theories and models may prove to be key to understanding how far they go to explain and support the VR learning environments. For example, newer models created to embrace and explain the way new technologies can be applied to learning will be particularly useful if they contain more detailed explanations of how the psychological and cognitive processes involved lead to deeper learning, whilst older models elucidated prior to the use of this technology may prove helpful if the general principles transcend the particularities of the new approaches.

Note though that VR will almost never be the only medium of instruction involved, different parts of a course, or even lesson, should be using the most appropriate media for the training (influenced by subject and student). Even in VR orientated sessions other media and methods may be used to brief, support and debrief/evaluate the students (and training) afterwards.

In this section we'll look at actionable models drawn from over two decades of work on eLearning, DesktopVR and HMD-VR that can help you to think about how VR should be used in training and how the design of a VR experience should be approached in order to maximise its training impact. The models are ordered from the higher-level more holistic ones, to those that support specific aspects of VR training design and evaluation, roughly reflecting the ADDIE model.

The diagram shows which models are most applicable to each stage of the process. At the Analysis stage each of the 5 models offers a different perspective on the affordances of VR, and you should be consider all of them in order to appreciate the different potential roles and impacts of VR. Bybee and Salmon then offer some guidance for the phasing of the course and learning, again taking slightly different perspectives. The remaining four models have a more specific focus and you should ideally look to use each of them as valuable tools on every VR project.

Through leveraging models which have proven successful over the past decade or so in improving the understanding of the affordances of VR and in creating more effective VR experiences, you should be able to create better exercises, with more engaged students, which should both contribute to better trained staff.



Note: Rudea has been described in the previous section

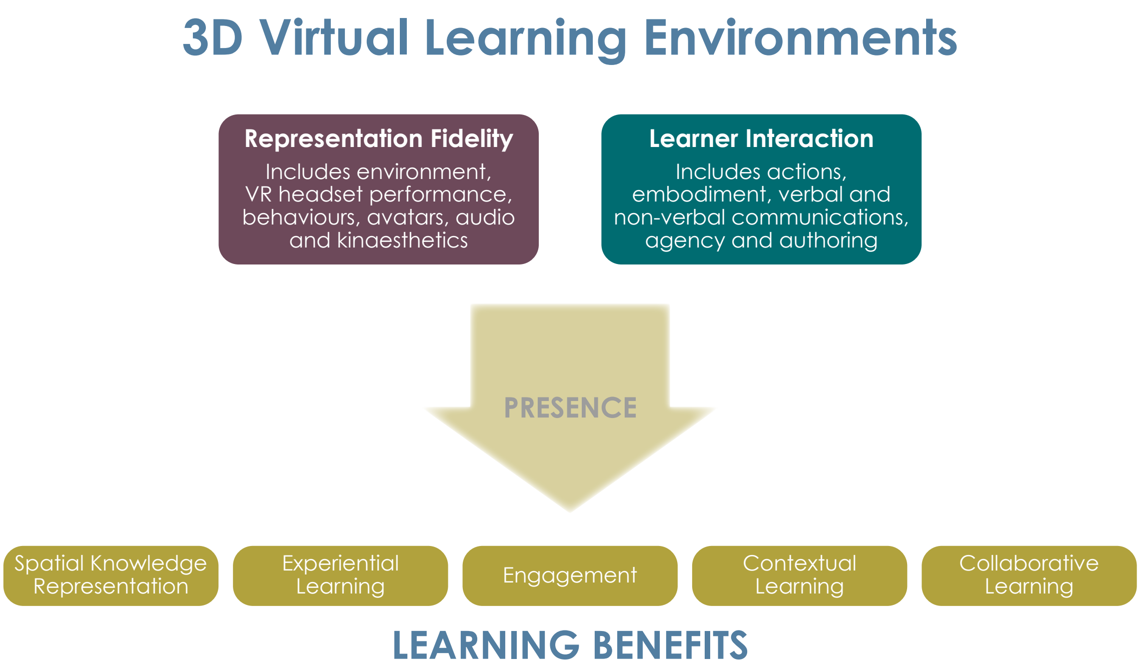
DALGARNO AND LEE

According to a seminal paper by Dalgarno and Lee[18], a 3D virtual environment is characterised by having the illusion of three dimensions, smooth temporal and physical changes, and a high level of interactivity. They identify representational fidelity and learner interaction as being the key characteristics of VR which lead, through the sense of presence, to affordances that enable VR to facilitate training tasks that:

- Lead to the development of enhanced spatial knowledge representation of the explored domain;
- Would be impractical or impossible to undertake in the real world;
- Increase intrinsic motivation and engagement;
- Improve the transfer of knowledge and skills to real situations through contextualisation of learning;
- Lead to richer and/or more effective collaborative learning than is possible with non-VR alternatives.

These tend to be seen as the key reasons for doing VR training as opposed to more traditional eLearning.

The Delgarno and Lee model can help you identify when a VR approach to training may be more appropriate than other means based on the learning benefits which it can best provide.



A simplified version of Dalgarno and Lee's Model

[18] Dalgarno, B., & Lee, M. J. (2010). What are the learning affordances of 3-D virtual environments? British Journal of Educational Technology, 41(1), 10-32.

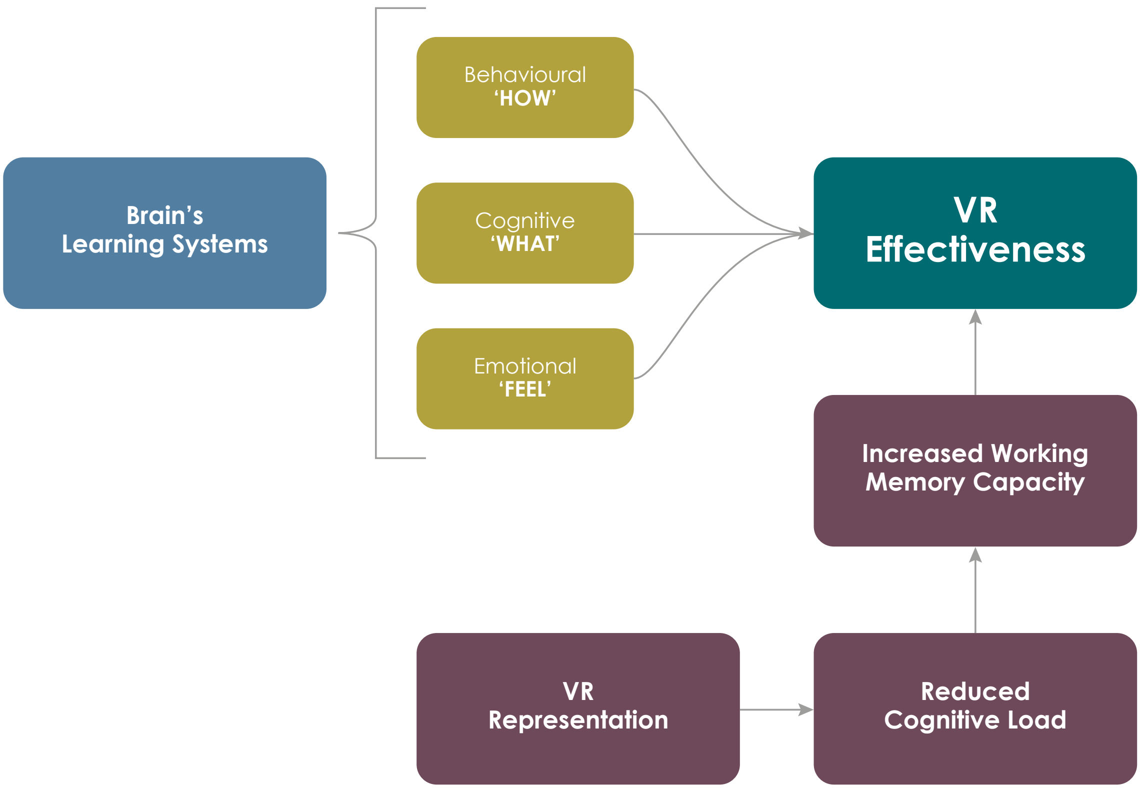
MADDOX'S LEARNING SYSTEM MODEL

Maddox[19] suggests that the effectiveness of XR is due to the engagement of multiple learning systems in the brain:

- the behavioural, the how, which encompasses not just what to do but how to do something;
- the cognitive, the what, which involves acquiring the necessary knowledge and facts; and
- the emotional, the feel, which is about being able to perform under different conditions, anticipating outcomes and enhancing understanding and awareness.

Maddox also points out that, as discussed earlier, since VR is a 3D environment the learner has to do less work than would be needed to convert traditional 2D images into 3D, so the cognitive load should be reduced, and the decrease in work for the learner can lead to an increase in working memory capacity to help learn.

Maddox is helpful in encouraging you to take a more holistic approach to VR training. You should ensure that training is designed to engage all aspects of the student's brains, not just the typical task training (the "how") but also allowing them to explore around a topic rather than being kept within a narrow pathway (the "what"), and ensuring that they are emotionally engaged with the training and beginning to naturalise it (the "feel").



The Learning System Model (Adapted from Maddox[19])

[19] Maddox, T. (2018). The Learning Science of Extended Reality (XR) Technologies in Healthcare: Parts 1, 2, 3, and 4.

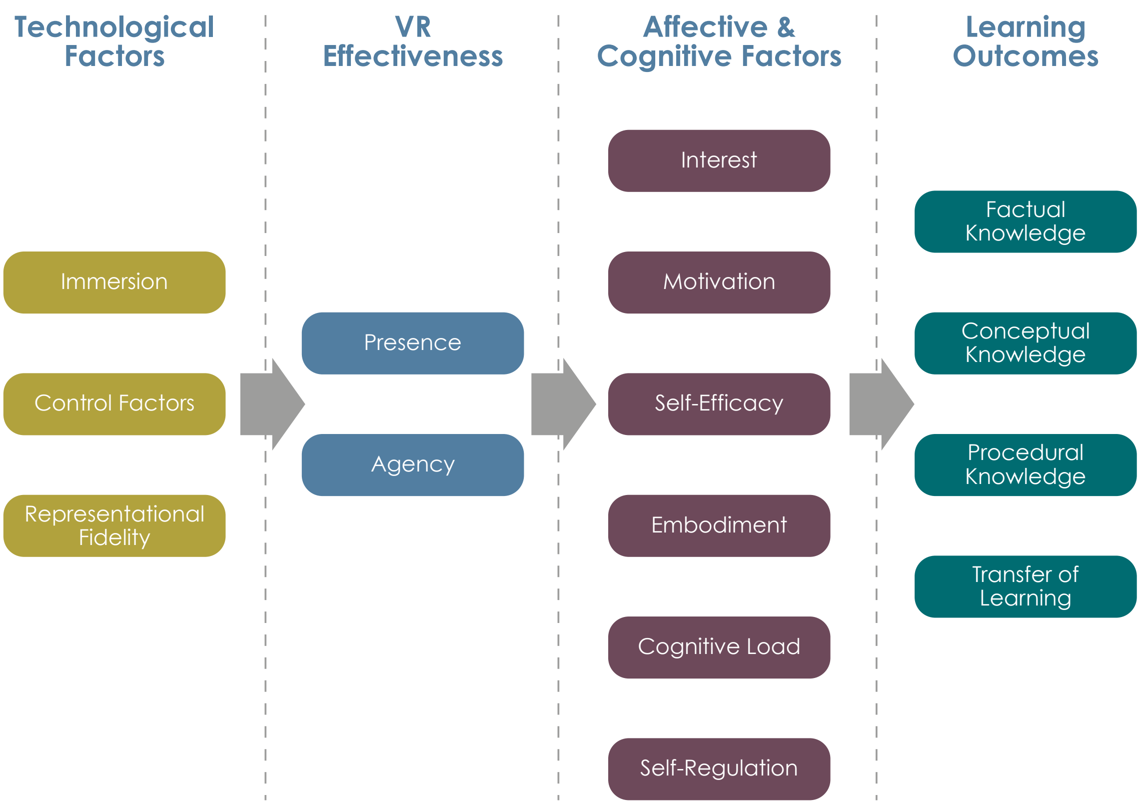
MAKRANSKY'S COGNITIVE AFFECTIVE MODEL OF IMMERSIVE LEARNING (CAMIL)

Makransky[20] (another key researcher in the field) has developed the Cognitive Affective Model of Immersive Learning (CAMIL) as a useful model of learning in VR. The model 'identifies presence and agency as the general psychological affordances of learning in Immersive Virtual Reality (IVR), and describes how immersion, control factors, and representational fidelity facilitate these affordances.'

Aligning it with Dalgarno and Lee spatial knowledge could potentially be added to the Learning Outcomes, or may be seen as an aspect of Procedural, or even Factual knowledge.

This model (as with Dalgarno and Lee) emphasises that in order to get the true benefits of VR training the experience should be designed to maximise the senses of immersion, presence, and agency as described earlier.

CAMIL should help you to move beyond the more obvious aspects of VR (the kit, the visual "wow") and to consider how you can best encourage the development of presence and agency in the experience, as these are then the key to successful learning outcomes.



The Cognitive Affective Model of Immersive Learning (CAMIL) (Adapted from Makransky[20])

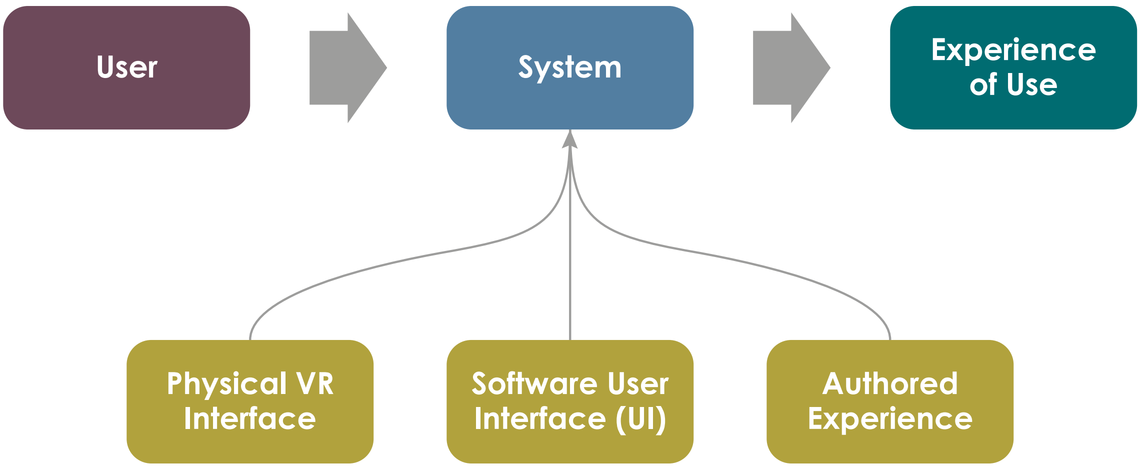
[20] Makransky, G., & Petersen, G. B. (2021). The Cognitive Affective Model of Immersive Learning (CAMIL): a Theoretical Research-Based Model of Learning in Immersive Virtual Reality. Educational Psychology Review, 1-22.

COWLEY'S USER-SYSTEM-EXPERIENCE MODEL

Cowley's User-System-Experience model is useful since it clearly separates out the elements which create the experience (the physical and digital interface and the 'authored' part of experience) from the experience itself, which is focused on the result of the User's interaction with the System – a vital distinction.

One key result of this is that each student is bound to have a different 'Experience of Use' to other students for the same VR training exercise, and that the selection of VR hardware and the authoring of the training experience are only part of the VR effect. Presence and Immersive Tendency Questionnaires exist (see Further Reading) to help better understand the student experience, and the more that tutors can self-author or amend a VR training experience the more chance they have of matching it to different student needs. But remember that students can't necessarily alter the physical world in which they will have to work, and so any 'personalisation' of training should be sensibly managed.

Cowley's model should encourage you to take a more user-centric view of the training experience. In particular it highlights that different students will each have their own unique "experience of use" - no matter how good the hardware, software and authored experience. Early and frequent testing by real students, to the extent that development becomes an iterative and even collaborative task (as codified by the Successive Approximation Model described on p10) is one way that you can ensure that this model is kept front of mind.



The USE Model (Adapted from Cowley[21])

[21] Cowley, B. et al. (2006). User-system-experience model for user centered design in computer games. In International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems. Springer. Full-text available on ResearchGate.

BYBEE'S 5E MODEL

This next pair of models are at a further level of detail, thinking about how sessions should be structured as part of a larger training course. The 5E model[22] is a very general model of approaches to learning and applies to VR as much as to any other form. It identifies five different aims for the learning experience.

Any training course is likely to include a mix of these, but each lesson should probably focus on only one or two, to avoid confusing the student. The table provides some examples of activities in VR which map to each aim.

Bybee is an excellent tool for you to apply at the course level, thinking through how lessons might move from simple engagement and exploration at the beginning, to the core of explanation and elaboration at the middle, until finishing with evaluation. Diving into explanation and elaboration without letting students engage with the topic, identify its links to their prior learning and then explore around it may both reduce motivation and limit the context within which they see the training.

Aim	Description	Activity Example
Engagement	The focus is on activities which simply engage students. Connections are made with what students already know and can do.	A game-based activity to engage students.
Exploration	Equipment and activities are explored, with minimal guidance, through virtual or physical interaction.	An open, unbounded exploration of a location or equipment, possibly collaborative and with some interpretative elements.
Explanation	Students explain their understanding of concepts and processes and new concepts and skills are introduced and taught as required.	Using the VR space for a collaborative show and tell, or a structured learning experience to introduce new skills.
Elaboration	Activities allow students to apply the new training in context and build on or further extend understanding and skill.	A more simulation type VR experience, putting skills into practice, but with some guidance and real-time feedback.
Evaluation	Students assess their knowledge, skills and abilities, and student development and lesson effectiveness is evaluated.	A pure VR simulation, with only natural feedback, supported by an after-action review.

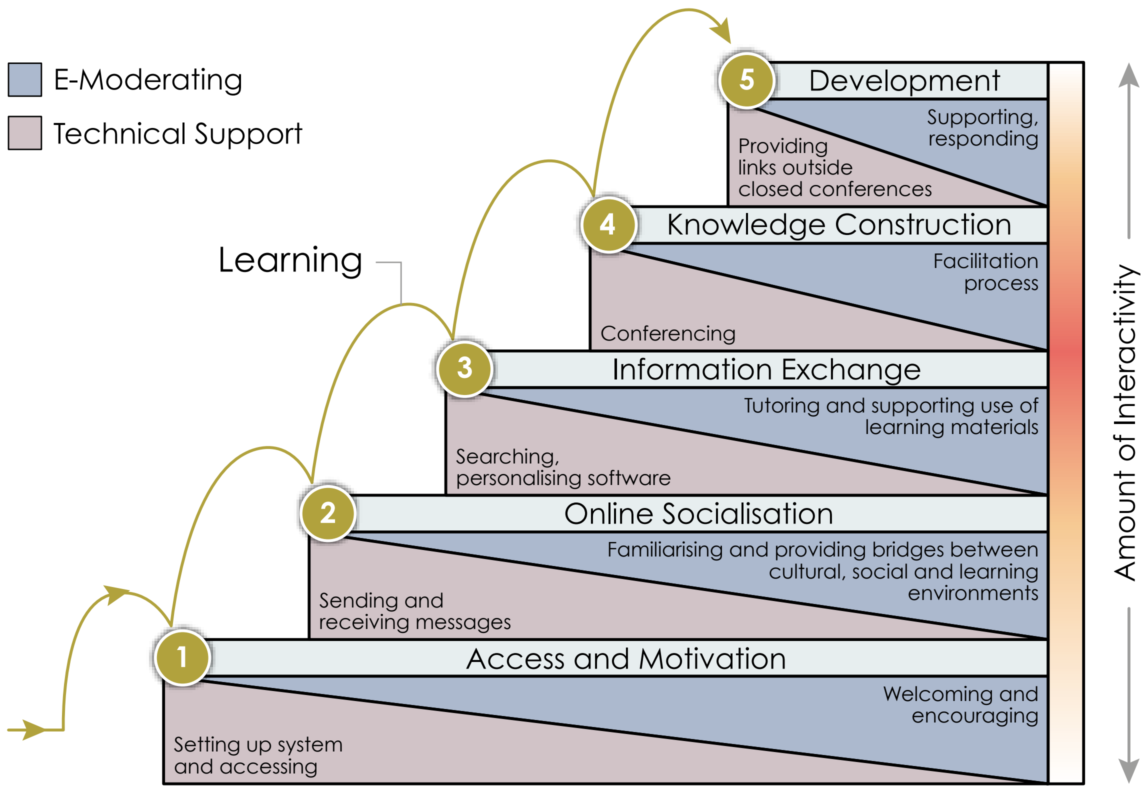
[22] Bybee, R. W. et al. (2006). The BSCS 5E instructional model: Origins and effectiveness. BSCS.

SALMON'S 5C MODEL

Salmon's five stage model[23] was developed to allow remote groups to work and learn together. Each stage provides scaffolding to allow students to become confident and independent. This scaffolding takes the form of a structured process paired with appropriate support or e-moderation. It begins with access and motivation, and moves on to online socialisation, information exchange, knowledge construction and finally development.

Such a pedagogical approach is relevant to VR because such training does not occur in a vacuum but requires support and collaboration with other media, students and tutors.

Salmon's model is particularly useful when you are delivering training remotely as it identifies the likely stages on the student's journey. Typically they first have to access a course (which VR may make more problematic) and may then want to get to know other students before actively engaging with the learning - which may be as much from other students as from the tutors. As the model shows you will need to think about the different resources, media and methods which will be required to support the student at each stage - and where the use of VR might provided added requirements, as well as added opportunities (e.g. virtual common rooms and games rooms to increase socialisation).



Salmon's 5C Model[24]

[22] Salmon G. (2003) E-moderating (2nd edn). Routledge Falmer. [24] Gilly Salmon. Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) Licence. https://www.gillysalmon.com/five-stage-model.html

DE FREITAS'S 4-DIMENSIONAL FRAMEWORK

Stepping down another level the 4-Dimensional Framework[25] helps you to think about the context of the learning before diving into the more detailed VR design decisions. The model comprises four areas (or dimensions): **Learner Specifics, Context, Representation** and **Pedagogy**.

Learner Specifics

This dimension considers the training from the perspective of the student. The types of questions to ask yourself (and ideally confirm by survey of potential students) are:

- What existing domain knowledge do they have?
- What are their IT skills like?
- Do they have previous experience of training in VR, or of playing 3D/VR games?
- How much time do they have to give to the training? Is it structured or ad-hoc? What are the other pressures on their time?

Context

This dimension considers the context in which the training will take place. This includes technical and process concerns such as:

- What devices will students use to access the training (HMD-VR, DesktopVR, Mobiles)?
- What access will they have/do they need to broadband and wifi?
- Will they be training in a training room, at home, in a coffee shop or on deployment?
- What pre-training might they need – in the domain or in VR equipment?
- What supporting materials will they need – hand-outs, quick reference guides, videos etc?

[25] de Freitas, S. et al. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. British Journal of Educational Technology. 41.1.

Representation

This dimension considers how the immersive environment reflects and represents the physical (and human and emotional) world.

Not all simulations need a high-level of fidelity, and too high a level of fidelity can cause problems both with running the application and with students just losing themselves in the detail!

A good model to consider representation issues through is Stone's 4 Fidelities model in the following pages.

Pedagogy

Well that's what most of this eBook is about!

There are multiple ways to approach the design of a VR training session depending on what you want to achieve, informed by the Learner Specifics and Context.

The pedagogic models and approaches presented earlier in this eBook will hopefully help you think through the pedagogic design in greater detail.

STONE'S 4 FIDELITIES

Bob Stone's Fidelities[26] provide a useful approach to flesh out the Representation element of the 4-Dimensional Framework.

Stone's model identifies four different aspects of fidelity, three are related to what is represented (environment/context, task, interaction) and the fourth is related to considering hypo and hyper-fidelity, i.e. are we showing too little or too much?

Whilst not explicitly covered by Stone it is also worth ensuring that the psychological, ergonomic and affective (emotional) fidelities of the task are also considered.

Context/Environment

This aspect considers how well the detail of the environment within which the task takes place is modelled. Considerations include:

- The level of geometric detail, but more detail implies more memory and more graphical power in the viewing device
- Texturing of surfaces, including natural variability and lighting – especially shadows
- Natural movement in trees etc
- Non-player character (NPC) avatars moving around the environment to make it seem lived in (and to give a sense of pattern of life and of consequences) – see the earlier discussion on co-presence.

Task

This aspect considers the task being trained itself, and the appropriate sensory and behavioural features that need to be modelled to support the delivery of the desired training. Key considerations are:

- What is the appropriate level of task detail?
- Where is the divide between task and interaction?
- What elements can/should be covered by other media before/after the VR session?
- How are conversational aspects of the task being modelled?

[26] Stone, R. (2008). Human Factors Guidelines for Interactive 3D and Games-Based Training Systems Design. Human Factors Integration Defence Technology Centre Publication. Ministry of Defence, London.

Interaction

This aspect considers how closely real-life interactions need to be modelled.

- If training on equipment this may well include consideration of the use of custom controllers and even the use of haptics and force feedback. The downside of haptic approaches is (currently) an increase in cost and a dependence on additional pieces of training equipment (and potentially locations).
- For interpersonal interactions within the training, how are the non-verbal elements (e.g. expression, gesture) being modelled, as well as any student-NPC dialogue?

Hypo and Hyper Fidelity

Stone's fourth class is hypo and hyper-fidelity - a measure set against the other three and characterised by the inclusion of too little, too much or inappropriate detail.

There is no assumption that all of the measures need to be at the same level of fidelity, and as the consideration of hypo- and hyper- fidelity show the levels of fidelity should be such to support the training, and are not an end in themselves.

CALLAGHAN'S AUGMENTED ACTIVITY THEORY MODEL

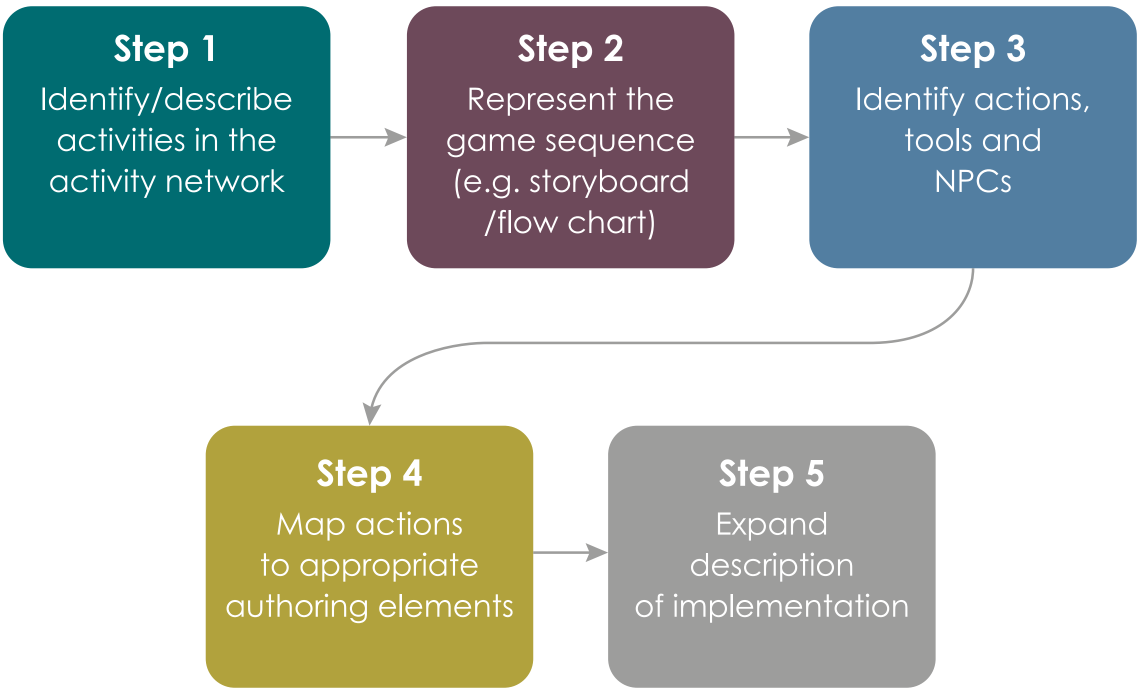
Whereas Bybee and Salmon are more concerned with how different lessons form part of a greater whole, Callaghan's Augmented Activity Theory-based Model of Serious Games (ATMSG)[27] is more about the design process for a single lesson – and how to cope with the challenges of designing for VR.

The framework asks you to map the lesson/task as an activity network, and from this to storyboard or flowchart the main activity sequence. You then use this to identify the specific objects, non-player characters (NPCs), and actions and interactions needed within the scenario. These actions are then linked to authoring elements (e.g. game states, variables, triggers) and finally the implementation is documented in detail ready for building/authoring. Much of the current authors work in VR has followed a very similar development model.

Callaghan first demonstrated ATMSG in a serious VR game called Circuit Warz (sic) to teach electronics.

Callaghan notes the differences between intrinsic and extrinsic instruction (e.g. obvious by form vs. a notice), and between elements which promote gaming/engagement behaviour and those which contribute to the learning.

Experience has shown that this ATMSG approach of breaking the lesson/task down into component activities, and then identifying students' likely paths through those activities is a good way to draw out all of the 3D assets, interactions and NPCs that will be needed for an exercise before the focus switches to exercise authoring.



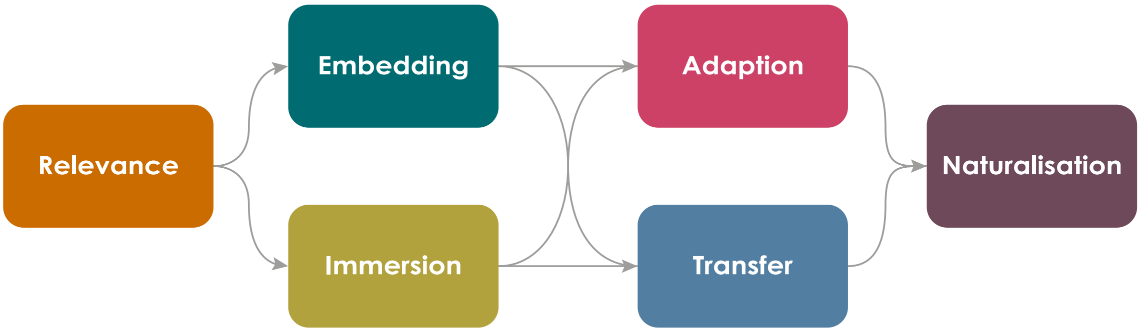
The ATMSG approach (Adapted from Callaghan)

[27] Callaghan, M.J. et al. (2018). Extending the Activity Theory Based Model for Serious Games Design in Engineering to Integrate Analytics. International Journal of Engineering Pedagogy (iJEP), 8(1).

RETAIN

Futurelab's RETAIN model[28] identifies Relevance, Embedding, Transfer, Adaption, Immersion and Naturalisation (RETAIN) as key measures of a serious game, and its scoring methodology based on these measures is a useful approach to evaluating a VR experience.

- **Relevance**
  Is the training relevant to students and building on previous work?
- **Embedding**
  How well does the training fit with the VR experience, especially any narrative or ludic/game elements?
- **Transfer**
  Can the student apply knowledge from/to other areas?
- **Adaption**
  Does the student change their behaviour as a result of the training?
- **Immersion**
  Is the student engaged and immersed in the training?
- **Naturalisation**
  Does the training become habitual in the long term?



Each element is scored from 0 (low) to 3 (high). These scores are then weighted for each element as follows: Relevance (1), Immersion (2), Embedding (3), Adaption (4), Transfer (5) and Naturalisation (6).

The model is based on three existing theories: Keller's Attention, Relevance, Confidence/Challenge, and Satisfaction/Success (ARCS) model, Gagne's Events of Instruction that are applied against Bloom's taxonomy of knowledge acquisition, and Piaget's ideas on schema.

[28] Ulicsak, M. (2010). Games in Education: Serious Games. Futurelab. Bristol, UK.

Technical Considerations

Beyond the five primary factors considered earlier (Immersion, Agency, Embodiment, Presence, Flow) there are numerous considerations and factors at work when using VR. Some of those most relevant to training and which are a direct function of the VR system and experience are discussed below.

Perceptions of Time

When people are in VR they often report a disconnect to the passage of time in the physical world—sometimes referred to as the time-dilation effect. The more flow they experience, the more they lose the sense of time. This could have an effect on training since participants might think they can do a task more quickly than they can in the physical world—or miss physical world deadlines whilst engaged in the VR training!

Perceptions of Space

Researchers have found that people's perceptions of space can be different in VR, and there are indications that having a full-body avatar (e.g. one with legs) can help in spatial estimation. One particularly interesting area is that of proxemics, the amount of space that people feel is necessary to have between themselves and others – also called social distance. Researchers have found that broadly users treat social space in VR in a similar way to the real world, and the more realistic the other avatar is the more realistically they treat it.

Synchronous vs Asynchronous Experiences

A useful concept in considering the design of VR training experiences (and other training) is that of synchronous versus asynchronous. In a synchronous experience tutor and students are present in the environment at the same time, whereas with asynchronous experiences students undertake the experience when the tutor (and potentially other students) are not present. Typically, the asynchronous version requires more scaffolding as the tutor is not there to guide students through or to answer questions.

It should be noted that the terms can also be used within the context of remote collaboration – where synchronous is more like a conventional meeting, but asynchronous is like a persistent project or documentation room, with people reviewing and adding post-its, documents and annotations as it suits them.

Designing Feedback

Dunwell[29] provides a four-dimensional consideration of feedback in serious games, linking it to both flow and Kolb's experiential learning model, and which is just as applicable to VR training experiences. Dunwell's four dimensions are:

- Type (e.g. evaluative, interpretative, supportive, probing, understanding, evolutionary);
- Format (e.g. text, audio, video, simulated outcome);
- Frequency/Timing (e.g. immediate, delayed, dynamic);
- Content.

Another way of considering VR feedback is in terms of whether it is what you get in the physical world (e.g. an ill person looks ill) or something artificial (e.g. coloured 'health bar'), and, as with Dunwell, whether it is delivered within the simulation or after the training concludes.

Sound Design

Several studies have found that sound can be an important part of any immersive experience. One researcher found indications that audio had a more implicit (rather than explicit) influence on the player experience in HMD-VR compared to DesktopVR, due to the impact of the overall sensory experience. Adding multiple sound types/sources were though found to detract from, rather than add to, the experience – suggesting that sound should be used, but sparingly.

Eye Tracking

Rappa et al[30] provide a useful summary of eye tracking technology as it applies to VR and MR. They identify 6 areas in which eye-tracking technology has been used to support learning and performance in VR and MR environments, including measuring and enhancing visual attention, cognition, emotional response (affect), usability, immersion, and supporting overall assessment.

[29] Dunwell, I. et al. (2011). Four-dimensional consideration of feedback in serious games. In Digital games and learning (pp. 42-62). Continuum Publishing. [30] Rappa, N. A., Ledger, S., Teo, T., Wai Wong, K., Power, B., & Hilliard, B. (2019). The use of eye tracking technology to explore learning and performance within virtual reality and mixed reality settings: a scoping review. *Interactive Learning Environments*, 1-13.

Non-Technical Considerations

As well as the technical considerations there are a number of non-technical issues that need to be considered when using VR as part of a training course.

In particular, the more visceral nature of VR can make some of these a greater issue than in less immersive forms of eLearning. This section is intended to highlight the issues and further reading is encouraged – some suggestions can be found in the Further Reading page towards the end of this eBook.

Ethics

HMD-VR can be a very visceral experience, and students can feel more intimidated than in DesktopVR spaces as it's not so easy to just look away. You need to think about the situations you put students in and what choices you give them in order to ensure that the training is being ethically (and morally) delivered. A key concern is that VR can lead to unintended behaviour change back in the real world (so-called negative training).

Gender and Bias

Linked to the issue of ethics it is very easy to make a gender biased or mis-representative VR experience. First-person experiences in particular need to consider whether they need male and female student options, and whether that has any implications for the rest of the exercise design.

Racial and other biases offer a wider challenge, avoiding the stereotyping of NPCs and ensuring that the first-person experience reflects the lived experience of the student.

There can also be issues with HMD-VR equipment design that can make them sub-optimal for female users[31], although it should be noted that some researchers have found that females typically feel more presence and can perform better in VR tasks than males.

[31] Stanney, K. et al. (2020). Virtual reality is sexist: but it does not have to be. Frontiers in Robotics and AI, 7, 4.

Privacy

HMD-VR allows an unprecedented level of student tracking. One concern is that tracking data could not only allow a student to be finger-printed by interaction behaviour, but also have their physical and emotional triggers identified. There is also the linked phenomenon known as 'anonymous intimacy' where a user may reveal more in a conversation with an NPC in a virtual environment than they would do to a person in real life.

Health and Safety

Since HMD-VR users have minimal awareness of their physical environment (although in-built safety features are improving) you need to ensure that students are in a safe space, and typically being watched by a safety chaperone. A key consideration is how long an HMD-VR session can last, and some research has suggested a maximum of 55-70 minutes, depending on the quality of the experience design[32].

[32] Kourtesis, P. et al. (2019). Validation of the virtual reality neuroscience questionnaire: maximum duration of immersive virtual reality sessions without the presence of pertinent adverse symptomatology. Frontiers in human neuroscience, 13, 417.

Virtual Characters

Whilst much of the initial use of VR was for visualising and training on 'things' it is becoming more and more apparent that for training to be truly life-like the simulations also need to contain people, not just the students but virtual characters (also called NPCs), with whom the student can potentially interact.

A useful model for virtual characters is a movie based one, as described by Van Velsen[33]. Characters are split into three groups: foreground characters (stars), medium-level characters (minor roles) and background characters (extras). This approach can help you to spend any budget wisely, investing the most in the Stars and the least in the Extras.

Stars

The Stars are the NPCs that the students will primarily interact with. They are likely to have a more developed conversational ability (although probably still limited to the training domain), and a wider range of emotional expression and gesture responses.

Minor Roles

These are NPCs with whom the student may briefly interact – typically to give an instruction to, to ask a question, or be provided with information. These will have some limited conversational ability and may have some facial expression control.

Extras

These are the NPCs that the student sees but doesn't interact with. They are there to make the place look busy and realistic. They may though react to what the students (or others) do (e.g. if shooting starts), and their presence or absence may have useful information about pattern-of-life.

[33] Van Velsen, M. et al. (2009). Table-top gaming narratology for digital interactive storytelling. In Joint International Conference on Interactive Digital Storytelling (pp. 109-120). Springer, Berlin, Heidelberg.

Another useful distinction is between NPCs that are acting as part of a scenario and those which are actually playing a training role – although these may overlap. The latter are sometimes referred to as Pedagogic Agents. Baylor and Kim[34] have developed a typology of Pedagogical Agents based on three instructional roles: The Expert, The Motivator and The Mentor. They suggest that each agent has an appearance (e.g. age, dress code, style of speech) that maximises the student perception of their role.

The Expert

Provides succinct and accurate information to the student in a formal and objective way.

The Motivator

Doesn't operate as an authority on the subject (and in fact has a level of knowledge similar to the student) but works as a partner that suggests ideas, encourages the student to continue the tasks, and promotes reflection.

The Mentor

Less formal than the Expert, but more so than the Motivator, the mentor integrates the characteristics of both to act as a collaborative guide who provides accurate information. However, this is delivered in a more confident tone than the motivator and encourages the student to think more deeply and reflexively about a task and their performance.

Straddling the divide between student avatars and NPCs is the use of VR for role-play, where tutors or other students control some or all of the avatars that the student interacts with. Evidence suggests that although the student may hear the voice of a tutor or colleague the visual difference of the avatar, and the setting and immersion itself, can help in the suspension of disbelief which can be so hard in physical role-play.

One point to note is that whilst speech-recognition is still error-prone it limits the ability to have a natural conversation with an NPC when in HMD-VR (as opposed to DesktopVR, where typed chat is far more usable and common). This can currently reduce the immersion and presence felt when interacting with an NPC in HMD-VR and role-play is one way of addressing this.

[34] Baylor, A. L., & Kim, Y. (2006). Simulating instructional roles through pedagogical agents. International Journal of Artificial Intelligence in Education, 15 (1) 95-115.

Considerations in Commissioning

The considerations presented in this eBook apply as much to the purchasing of VR/simulation training systems and content as they do to the design and development of in-house courses and exercises delivered through existing VR capability.

In particular, any VR system should ideally have the capability to deliver exercises based on almost the whole range of models and approaches described here. The experience of VR is primarily about what you see and how you interact – it is how you then use those elements that creates the presence and flow needed for an effective training exercise. Any new system or content should offer the flexibility to create a range of experiences.

It is also important to note that any VR system should ideally integrate with any Learning Management System (LMS) in use, so that course and student assignments can be centrally managed, and learning analytics captured for storage and analysis back on the LMS. Existing standards such as Shareable Content Object Reference Model (SCORM)[35] and Learning Tools Interoperability (LTI)[36] and emerging standards such as The Experience API (xAPI)[37] are intended to aid in this process.

Within a military context there may also be the need for VR systems, particularly when used for collective training, to integrate with other VR and simulation systems within some form of Live-Virtual-Constructive training environment (see the MOD's DMaSC Modelling and Simulation Standards Profile[38]). Again, standards such as High Level Architecture (HLA)[39] and WebLVC[40] exist to support this – although typically not adopted within the commercial and academic sectors.

Portability of 3D assets between systems in order to maximise re-use of any investment is also a key consideration. Emerging 3D model standards such as glTF/glTB[41] are bringing a new level of portability in commercial and game systems. The portability of experience logic seems a lot further off, although some of the approaches used in medical Virtual Patients offer some promise.

Also note the complementary nature of HMD-VR and DesktopVR. Whilst HMD-VR may offer more motivation and fun, DesktopVR is often more practical, and avoids any issues with cyber-sickness. VR is a highly personal experience, and the choice between VR modes should ideally be one of student and context choice, the evidence suggesting that it is not the mode of VR which is important in terms of training impact, but rather the sense of presence. As a result, any new system or course should ideally offer both HMD-VR and DesktopVR access to every training experience.

[35] https://scorm.com/ [36] http://www.imsglobal.org/activity/learning-tools-interoperability [37] https://xapi.com/overview/ [38] https://www.gov.uk/government/publications/modelling-and-simulation-standards-profile/dmasc-modelling-simulation-ms-standards-profile-dmsp [39] https://standards.ieee.org/standard/1516-2010.html [40] https://www.sisostds.org/StandardsActivities/DevelopmentGroups/WebLVCPDG.aspx [41] https://www.khronos.org/gltf/

Working Flexibly

In practice we recognise that many of you will only have access to one sort of VR platform, and that any ability to implement some of the ideas in this eBook is limited by the capabilities of those platforms.

However as suggested in the previous section the models described in this eBook are as much about how you connect things together as they are about the specific technologies or systems. So many of the approaches presented here should be readily available to you. You just need to think creatively and flexibly. Here are a few ideas to get you started.

PEDAGOGY

- Use the Kolb's experiential-learning cycle to design a VR training course.
- Consider how your current or future VR training leverages the concepts of situated cognition and cognitive load theory. Can you reduce the cognitive load in order to increase training effectiveness?
- Consider what a problem-based learning approach to your training might look like.

APPLIED MODELS

- Use Dalgarno and Lee or Makransky's models to really try and break apart an existing VR training experience and identify what elements are contributing to, or distracting from immersion, presence or agency.
- Can you create exercises which emphasise different degrees of Agency, Embodiment and Presence and compare the results?
- Apply de Frietas' 4D model and Stone's 4 Fidelities to your next training session design task. And what about emotional fidelity?

VIRTUAL CHARACTERS

- Try creating exercises with NPCs in specific Expert, Mentor and Motivator roles.
- Create a VR role-play exercise.
- Try adding more Background characters and Minor Roles into a scenario – and remember the research that suggested that paramedics learnt more when they were being watched by virtual bystanders.

OTHER CONSIDERATIONS

- Can you use Dunwell's model to try different configurations for feedback?
- Watch how students treat social distance – what happens if an avatar gets "in their face"?
- Ask students to report how long they think they spent in a VR session, and compare it to clock time.
- Try running students through a Presence or Immersive Tendencies Questionnaire (links in Further Reading).

The Future?

Whilst this eBook is not about the technology *per se* it's worth saying a few words on how VR (and indeed XR) might evolve over the next few years or so.

Particular areas of development we are seeing that could impact VR training are highlighted here.

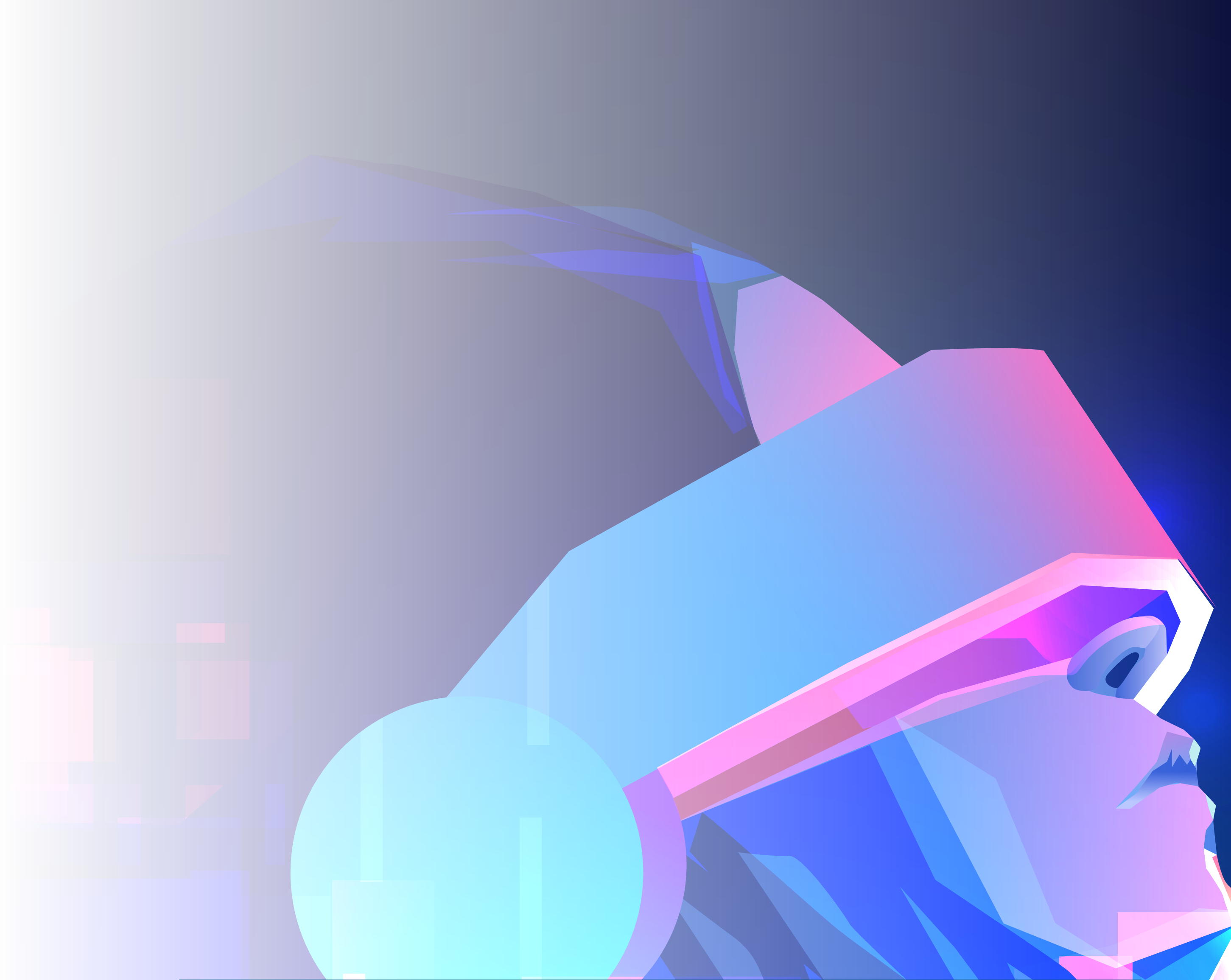
Away from the hardware the most interesting trend in VR may be the continued growth in Social VR – virtual worlds where VR users can meet, socialise, collaborate and ideally build things, and how this might morph into the so-called Metaverse. This is exactly how the Second Life virtual world works. In the Metaverse training exercises are potentially more readily built by instructors as they need them, within a protected area of a larger virtual world (just like a physical training establishment really!).

Increasing use of standalone 6DOF headsets (no separate PC and track lateral as well as rotational movement) rather than tethered headsets (i.e those connected to a separate PC) or 3DOF headsets (those that only track head turning) – making it a lot easier to deploy realistic VR training.

The move from separate hand-controllers to hands-as-controllers and gesture control

Increasing use of controllers that reflect the device you are actually using in VR – the hoist controller or power tool etc – inert but instrumented to work in VR. This helps to increase immersion by making the VR system itself 'disappear'.

Body suits (e.g. the Teslasuit[42]) which both track your whole-body movement and provide haptic feedback though currently very expensive are likely to get cheaper and have a role in specialist training. Strap-on sensors to track your limbs are a cheaper alternative. As well as increasing the sense of embodiment they will also help in the communication of gestures and non-verbal cues.



Better voice recognition, enabling us to talk verbally with NPCs rather than having to use pick-list dialogues. And more realistic avatars for students and NPCs alike.

The development and adoption of standards like WebGL and WebXR[43] which allow fully 3D VR experiences to be delivered directly in the browser (on the Desktop or HMD) so that no downloads are required (e.g. https://hubs.mozilla.com/) – potentially serving VR experiences in the same way as any other eLearning content. Standards for lesson logic itself seem more distant.

Locomotion is still a challenge. All sorts of options have been tried from 360° treadmills to slippy shoes and impact sensors but they come at a cost, and using a joystick to move is an instant way to inhibit flow in VR. This is one that may have to wait for some form of neural interface[44].

[42] https://teslasuit.io/ [43] https://www.w3.org/TR/webxr/ [44] King, C.E. et al. (2013). Operation of a brain-computer interface walking simulator for individuals with spinal cord injury. J NeuroEngineering Rehabil 10, 77

Conclusions

Virtual Reality offers important and exciting opportunities for training, which can sit comfortably alongside more traditional e-learning as part of a blended approach.

Embracing the technology involves an engagement with the pertinent pedagogical issues that best promote training in VR.

Each of the models and frameworks presented here typically provides a different perspective onto different phases of the training planning, design and development process. You may find that different models suit you better (although it should be the needs of the student which are paramount), and all can contribute to the creation of better VR exercises. Likewise, the different pedagogic approaches map to different contexts and you should have at least a basic appreciation of all of the options available and then be able to choose the appropriate approach at the appropriate time. VR is not one thing, and can be used in different ways to blend with different types of training and student.

Whilst the main focus of this eBook is on HMD-VR it has also shown that DesktopVR is also a valid approach and that both can deliver good training effects. Given the prevalence of cyber-sickness amongst many potential HMD-VR users it would seem good practice to always have a DesktopVR version available, particularly since it removes many of the time, place and safety constraints of HMD-VR training.

Running through many of the models is an enhanced appreciation for the importance of the student in the training, and the ideal of structuring the training around them as much as possible. This is particularly important with VR since the key differences between VR and other media are to do with immersion, presence, agency, embodiment and flow – all very individual factors. VR training exercises should play to these affordances, but should not neglect some of the important issues around bias, ethics and privacy that any VR experience should also consider.

Finally, the role of ludic (game) and narrative elements within VR experience design should not be forgotten, particularly for developing immersion and motivation, and remembering that the virtual reality is fundamentally in the user experience, not the technology.

Further Reading

If you would like to explore some of the concepts and models presented in this eBook in more detail then we suggest the following books, papers, articles and websites.

BOOKS

- A Practical Guide to Problem-based Learning Online.
  Savin-Baden, M. Routledge. 2007.
- Simulations and the Future of Learning.
  Aldrich, C. Pfeiffer. 2004.
- Virtual Humans: Today and Tomorrow.
  Burden, D.J.H.
  and Savin-Baden, M. Taylor & Francis. 2019.
- Virtual Reality in Curriculum and Pedagogy.
  Southgate, E. Routledge. 2020.
- Virtual Reality Technology.
  Burdea, G and Coiffet,
  P. John Wiley & Sons. 1994
  (3rd Edition in 2021).

WEBSITES AND PODCASTS

- https://immersivelrn.org/
  - The Immersive Learning Research Network (iLRN) – runs an excellent annual conference.
- https://voicesofvr.com/
  - Voices of VR is an excellent podcast regularly interviewing leading practitioners in the field.

UX AND UI

- Design Practices in Virtual Reality.
  Ravasz, J. 2016.
- Locomotion Vault.
  Di Luca, M. et al. 2021.
- There Are No Wimps in the Metaverse
  Lazzaro, N. 2022.
- User Experience Guidelines for Designing HMD Extended Reality Applications.
  In INTERACT 2019.
  Vi, S., da Silva, T.S. and Maurer, F. 2019.
- UX + VR:14 Guidelines for Creating Great First Experiences.
  Jaime, S. 2017.
- Virtual Reality Design & User Experience.
  Adobe Inc.
- VR Interface Design Pre-Visualisation Methods.
  Alger, M. 2015 (video).
- XR Association's Developers Guide, Chapter Three. Accessibility & Inclusive Design in Immersive Experiences.
  XR Association. 2021.

HEALTH AND SAFETY

- Oculus Safety Centre
  and other VR vendor safety pages.
- The safety of domestic virtual reality systems.
  A literature review by the Department for Business, Energy and Industrial Strategy. BEIS. 2020.

ETHICAL, BIAS AND PRIVACY ISSUES

- Reimagining Reality: Human Rights and Immersive Technology. Heller, B. Carr Center for Human Rights Policy. 2020.
- The ethics of representation and action in virtual reality. Brey, P. Ethics and Information technology. 1999.
- Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. Pan, X., and Hamilton, A. British Journal of Psychology. 2018.

QUESTIONNAIRES

Version 2.0 of Witmer and Singer's Presence and Immersive Tendencies Questionnaires are available in Measuring Presence in Virtual Environments: A Presence Questionnaire. Witmer, B and Singer, M. Presence. 1998.

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